



Revitalizing semi-arid extensive farming habitats through the sustainable management of their associated scrub areas

LIVESTOCK MANAGEMENT PROTOCOL FOR BASIC PROTECTION OF THE SCRUB LAYER

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1. INTRODUCTION

The presence of shrubs on extensive livestock farms provides, in addition to supplementary feed at critical times, numerous other advantages, including the availability of shelter for animals, the preservation and promotion of biodiversity for the entire ecosystem, and the protection or shelter for the natural regeneration of trees. This report details the various functions of shrublands within livestock ecosystems, indicating some forage species (palatable to livestock) and other nurse species (difficult for livestock to graze) to favour tree regeneration. In addition, different strategies for the management of shrubs are presented, ranging from their use as shrub pastures to their protection in order to create islands of biodiversity, with special attention to shrub species typical of the dehesa or susceptible to being introduced with adequate control.

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1.1. Concept of shrubland and presence of shrubs/scrubs on livestock farms

The term "shrubland" commonly encompasses a diverse set of more or less dense shrubby woody plant communities. These communities may be a stage in the natural succession to forest or may constitute the climax vegetation in some environments, although more often they are a consequence of the management of the vegetation: fire, forestry, cultivation, or due to livestock grazing. Depending on the dominant species in each community, these communities are commonly referred to as *chaparral*, kermes oak groves, wild olive groves, mastic groves, garrigue, *maquis*, arbutus groves, rockroses, gorse groves, broom groves, thyme groves, lavender groves, juniper groves, palmetto groves, etc. These designations correspond to phytosociological communities typified according to their floristic composition, relationships, origin, natural evolution, uses, etc. (Bermejo-Bermejo et al., 2009; San Miguel Ayanz, 2001) which have been mapped and studied in detail, although with limitations due to their lack of a more precise definition (Cabello et al., 2009).

In some cases, the presence of shrubs on extensive livestock farms has been considered as a negative or undesirable element, as it detracts from the size of grassland and poses a fire risk. This is the case of the Pasture Eligibility Coefficient (CAP), currently called Pasture Subsidiability Coefficient (CSP) (Ministry of Agriculture, 2023), which subtracts the area of shrubland from the eligible area of permanent pasture for the application of Pillar I of the Community Agricultural Policy (CAP). However, a controlled presence of these species, in addition to offering a greater variety of food resources throughout the year, provides numerous other advantages which make it highly desirable to have a varied grid or mosaic of plots, both in terms of species and plant communities.

Herbaceous communities are usually considered to be the basis of any extensive livestock feeding, offering high quality pasture and forage as long as minimum moisture conditions are maintained in the topsoil. However, if these areas are wooded, they can also provide twigs and pruning waste at certain times of the year, as well as forest fruits (acorns, chestnuts, carobs and others). The added presence of shrubs offers new

opportunities for browsing, both for growing shoots, leaves and in some cases flowers and fruits with different nutritional value and with interesting nutraceutical properties (Rodríguez-Hernández et al., 2023). Steeper slopes should be covered mainly by woody species that hold and create soil; this would also be the case in areas with very little soil or very stony ground. In addition, the presence of stands or patches of scrub in different areas of the farms (hedgerows, understory, copses, etc.) provides valuable islands of fertility and biodiversity (Moncayo-Riascos & Gálvez-Cerón, 2018) that would give greater stability and resilience to the entire livestock ecosystem.



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Figure 1. Example of reticulation in livestock landscapes. Herbaceous pastures surrounded and dotted with trees and shrubs. La Janda region (Cádiz).

Author: Ildefonso Caballero.

Sowing, planting or maintaining hedges of shrub and tree vegetation on the edges of enclosures, with a great diversity of species, provides leaves, branches and fruits to feed livestock during periods of grass shortage, as well as providing shelter and protection from heat, wind or cold. But in addition to hedges between boundaries, it is also important to conserve shrub and tree formations around watercourses, which help to prevent soil erosion, purify water, conserve biodiversity and supplement the food supply of herbaceous vegetation. The presence of these shrubs and the pruning of these trees can provide green fodder of great interest during the summer.



Figure 2. Hedge between herbaceous pasture boundaries.

Author: Ildefonso Caballero.



Figure 3. Soto in the course of a stream.

Author: Ildefonso Caballero.

Finally, "scrubbing", or increasing the cover, density and biomass of native shrubs, is a tool to encourage the regeneration of hedgerows and woodland in dehesas. The scrub protects tree seeds and seedlings, recycles nutrients, defends against grazing, provides mycorrhizae, etc.



Figure 4. Controlled scrubbing in the dehesa allows for natural regeneration.

Author: Ildefonso Caballero.

1.2. Services provided by woody species

When talking in general about plants of interest in livestock farming, only their food supply is taken into account. However, within the ecosystem of an extensive livestock farm, it is interesting to have other plants that act as islands of biodiversity (Moncayo-Riascos & Gálvez-Cerón, 2018) and that offer other uses and services (Salas et al., 2018), such as, for example:

- Shade and protection against cold, rain or wind.
- Water and soil retention in case of heavy rainfall (erosion control).
- Pumping of water and nutrients from deep soil layers to the surface layers.
- Microclimate in and around the interior that favours the establishment of other species and herbaceous communities, as well as the growth of tree species.
- Shelter for auxiliary fauna for biological control of pests and diseases of livestock, crops and trees.
- Nutraceutical and medicinal substances.
- Food for pollinators, which are essential for the multiplication of grassland species.
- Forest fruits for insectivorous birds during autumn and winter.
- Carbon fixation and transfer of nitrogen and other nutrients (depending on species) to the soil.
- Increased resilience to climate change.

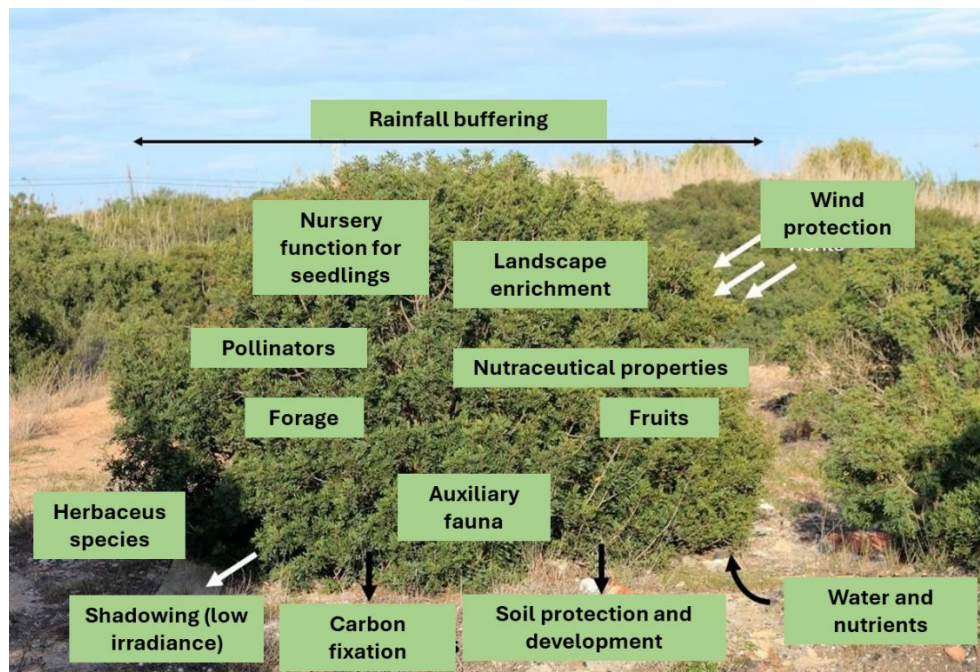


Figure 5. In grasslands, woody species behave as islands of biodiversity providing various ecosystem services.

In this respect, both trees and shrubs can play a very important role. In the case of pasture systems, the trees (mainly *Quercus sp.*) also provide valuable foodstuffs (twigs, acorns), requiring the occasional presence of shrubs to protect the new specimens from grazing in order to guarantee the natural renewal of these trees. In arable plots, as in the countryside, the presence of a few large trees provides shelter or natural protection for the animals, which is essential for making use of the stubble fields during the summer in optimal conditions of well-being. This role can be supplemented or replaced by stands of shrubs or hedges between the boundaries.



Figure 6. The tree provides shade and shelter.

Author: Ildefonso Caballero.



Figure 7. Livestock farming on pasture and cropland with scattered shrubs, hedges and stands of bushes.

Author: Ildefonso Caballero.

The forage production capacity of woody species is difficult to determine, as their utilisation depends very much on their accessibility to livestock and their nutritional quality will depend very much on the time at which they are utilised. To calculate the potential forage production of shrub vegetation, Rutherford (1978) indicates that in Mediterranean climate areas the forage utilisation is between 1/12 and 1/3 (8.3% to 33.3%) of the consumable dry matter. The minimum can be applied to predominantly shrub areas and the maximum to areas of well-developed Mediterranean scrub (Díaz-Gaona et al., 2014). In case of dehesas, Medina-Blanco (1956) calculates the production of holm oak twigs at 0.6 +/- 0.38 kg/tree per thinning, and 3.75 +/- 1.4 kg/tree per pruning.

Another service provided by shrub species that is becoming increasingly important is their nutraceutical and medicinal properties (Rodríguez-Hernández et al., 2023). Thus, animals instinctively selectively graze certain species that can help them to reduce their parasite load, relieve indigestion or improve their respiratory function, as explained below.

1.3. Fodder shrubs

Fodder shrubs are species that have a certain regrowth capacity after grazing and whose twigs and leaves have good palatability and nutritional value. The existence or planting of forage shrubs provides a strategic food resource for animals. These species can be interspersed between hedges and stands of natural shrub vegetation, or they can form cleared copses. If they develop into trees, pruning would be necessary for their consumption.

The ideal characteristics of a forage shrub and/or tree are as follows:

- Easy reproduction (by seed or cuttings) but low invasiveness.
- Easy establishment or establishment on pasture land.
- High leaf, twig or fruit production.
- No toxicity and good nutritional quality.
- Livestock desirability.
- Resistance to pruning and browsing by animals.
- Easy regrowth capacity.
- With characteristics that allow grasses to grow at their base and canopy projection.

Logically, when choosing the species to be planted in an area, it is important to ensure that they are adapted to the local climate and soil conditions. Thus, among the fodder shrubs of interest in Mediterranean climate zones some species stand out, the most outstanding characteristics of which are summarised below (Castroviejo, 1986; López González, 2006):

Acebuche (*Olea europaea* L. Var. *Sylvestris*).

Short description	Wild variety of the olive tree. Shrub or tree that can reach 10 m in height. The trunk is twisted and curved, with smooth, greyish-brown bark. Evergreen, leathery leaves, the upper side is greyish-green and the underside silvery, and their shape varies from narrow and elongated to elliptical and tiny. The flowers are grouped in panicles or clusters and are whitish-yellowish in colour. The fruit (<i>acebuchina</i>) is drupe-like, green at first and blackish when ripe. Flowering in May/June and fruit ripening in Autumn.  Figure 8. <i>Olea europaea</i> L. var. <i>Sylvestris</i>. Author: Ildefonso Caballero.
Habitat	Adapted to the Mediterranean climate, with not very cold winters, dry and hot summers, affected by frost. It is indifferent to the type of soil and grows from sea level to 1500 m in the south, always on sunny exposures.
Other uses	Oil from wild olive has antihypertensive benefits, as it has a higher content of sterols, tocopherols, triterpenes and secoiridoids.

Tree lucerne (*Medicago arborea*).

Short description	Perennial shrub reaching 2 m in height. Trifoliate leaves with obovate, elongated leaflets, toothed at the ends. The flowers are orangey-yellow in colour and are grouped in a dense inflorescence of clusters. Flowering lasts from March to June. The fruit is a curved legume in the shape of a circle or short spiral.  Figure 9. <i>Medicago arborea</i>. Author: Ildefonso Caballero
Habitat	Semi-arid Mediterranean climate, with rainfall between 200 and 400 mm, strong summer drought and warm temperatures exceeding 22°C in summer. Very resistant to drought, but not to frost. Indifferent to soil type (chalky or siliceous). Can live in shallow soils poor in nutrients and organic matter.
Other uses	Of great interest as a fodder crop. It is also cultivated as an ornamental because of its showy yellow flowers. It is planted in orchards and seedbeds as a windbreak, due to the hardness of its wood, which is used in handicrafts.

Tagasaste (*Cytisus proliferus*).

Short description	Evergreen shrub, with an average height of 2.5 m and a maximum height of 6 m, with a tendency to form an arboreal habit. Dense crown, up to 6 m in diameter. Trifoliate, bluish-green leaves. Creamy white flowers. The legume is tight, hairy, with 8 to 16 seeds in each pod, black when ripe.  Figure 10. <i>Cytisus proliferus</i>. Author: Ildefonso Caballero.
Habitat	It prefers light, well-drained sandy soils and acid soils, although it tolerates alkaline soils up to a pH of 8.5. It does not tolerate saline soils. Grows easily on volcanic soils. Very drought resistant, can survive with 200 mm per year, but usually needs a minimum of 600 mm for good production. It is grown between 1,000-2,000 m altitude and tolerates frosts down to -9 °C.
Other uses	Used as a forage shrub, mainly for browsing. Great fodder interest in the Canary Islands to maintain livestock in dry summers, with a similar composition to alfalfa. Forage rich in protein (20-28%), without toxicity and very palatable.

Tiple (*Atriplex mummularia*).

Short description	Evergreen shrub, ashen-coloured (white branches), reaching 1-3 m in height, columnar in appearance, although some specimens often have hanging, very brittle branches. Leaves 2-7 cm long and 1-4 cm wide, alternate, oval-deltoid or rounded. Male inflorescence spiciform in panicles branching towards the apices of the branches. Female inflorescence in dense, thick branched panicles.  Figure 11. <i>Atriplex mummularia</i>. Author: Ildefonso Caballero.
Habitat	Adapted to aridity and semi-aridity. Native to the arid and semi-arid Mediterranean zone of Australia, with annual rainfall of 250-600 mm. Very resistant to high temperatures, with requirements of 30-35°C as optimum photosynthesis temperature, although it can also withstand low temperatures.
Other uses	Forage crop, well accepted by goats. It has 52-67% digestibility and 14% crude protein. The charcoal is of very good quality, with a yield of 25%, as the wood density is quite high.

Sosera or orgaza (*Atriplex halimus*).

Short description	Perennial shrub 2 to 3 m high. Whitish, wrinkled leaves, alternate arrangement. Flowers monoecious, yellowish-greenish, inconspicuous and grouped in dense spike-like clusters. It flowers in summer. It has monospermous, achene-type fruits, with a whitish-pink membranous wing.  Figure 12. <i>Atriplex halimus</i>. Author: Ildefonso Caballero.
Habitat	Preference for areas with high solar radiation and sandy soils. Ability to adapt to very arid climates, saline and marginal soils. Withstands continuous exposure to wind, being frequent on the coasts. Resistant to frosts down to -10°C and rainfall between 75-375 mm, although it can be found in areas with higher rainfall.
Other uses	In addition to its forage interest, it is a plant of gastronomic interest, with some parts being eaten raw (in salads) and helping to reduce flatulence and gas. It is also an ornamental in arid areas due to its low water consumption and is very invasive if the climate is optimal.

Moringa (*Moringa oleifera*).

Short description	Rapid growth, about 3 m in its first year, reaching 10 to 12 m maximum height as an adult. Hanging, brittle branches, light green, compound leaves, 30 to 60 cm long, with many small leaflets 1.3 to 2 cm long by 0.6 to 0.3 cm wide. Flowers seven months after planting. Fragrant, white or creamy white flowers, 2.5 cm in diameter. Produces brown, triangular, hanging pods, 30-120 cm long by 1.8 cm wide, divided lengthwise into 3 parts when dry, each containing about twenty dark brown seeds.
	 Figure 13. <i>Moringa oleifera</i>. Author: Ildefonso Caballero.
Habitat	It tolerates a wide range of climatic and soil conditions, with rainfall from 250 mm to 3,000 mm of rain. It grows in warm lowlands, but also in sunny soils up to 2,000 m above sea level (msnn). The soil must be well drained, as it does not tolerate waterlogging.
Other uses	In addition to its interest in fodder, in gastronomy, its flavour is pleasant, being consumed raw, both leaves and flowers, or cooked in stews. The pod-shaped fruit can also be cooked or roasted. The roots are also edible. In addition, the oil from the seeds is used in food or as fuel. The pods and seeds are also used in water purification and have medicinal properties (diuretic, antihypertensive, etc.).

Mulberry (*Morus spp.*).

Short description	Tree up to 18 m high, branched, with a wide crown and smooth, grey bark when young, but thick, very cracked and brown or grey as it ages. Deciduous, simple, alternate leaves, 3 to 22 cm long and less wide, very variable in shape, but always toothed at the margin. Multiple fruit, 2-3 cm long. White mulberries (<i>Morus alba</i>) start whitish green and ripen to white with pink edges. Black mulberries (<i>Morus nigra</i>) start red and ripen dark purple to black.  Figure 14. <i>Morus spp.</i> Author: Ildefonso Caballero.
Habitat	Indifferent to soil type, although they prefer deep, fertile soils and avoid very acidic ones. They are found from 0 to 2,500 m above sea level, with temperatures from 18 to 38 °C, rainfall from 600 to 2,500 mm, photoperiod from 9 to 13 h and humidity 65 to 80%.
Other uses	Good fodder for livestock. It is also used to feed silkworms (<i>Bombyx mori</i>) for commercial purposes (sericulture). Its wood is of good quality, withstanding changes in humidity without deforming, and is used in lathe work, wheelwrighting, joinery and for making small parts such as tool handles.

Basil (*Anthyllis cytisoides*).

Short description	Shrub with more or less erect branches, whitish or greyish in appearance. Height 80-110 cm and width 80-110 cm. Flowers grouped along the branches arranged in spikes of up to 20 cm, pale yellow in colour, abundant flowering. The fruit is an indehiscent, monospermous legume, small, ovoid, with longitudinal red spots and the seed is yellow to greenish yellow, kidney-shaped.  Figure 15. <i>Anthyllis cytisoides</i>. Author: Ildefonso Caballero.
Habitat	It inhabits a wide variety of substrates: chalky, limestone, schist and even coastal sandbanks, and can be found from sea level to 1300 m above sea level. It has a preference for draining soils and does not tolerate intense frosts.
Other uses	An important forage plant, especially for goats. It attracts bees, being appreciated for its melliferous interest. It is also used for ornamental purposes due to its beauty and hardiness. In ethnobotany it is used medicinally as a stomachic, anti-asthmatic and anti-catarrhal.

Argan (*Argania spinosa*).

Short description	Tree 3 m high, can reach 8-10 m and lives for 150-200 years. Compact crown, woody and thorny, intricate stems. Leaves alternate, entire, narrower at the base, generally no longer than 3 cm. Flared flowers, pentamerous symmetry, small, yellowish or slightly greenish in colour. The fruit is drupe-like, ovoid, up to 2.5 x 5 cm, yellow when ripe, with a fleshy outer part covering 2 or 3 oil-rich seeds. The fruit takes a year to ripen.  <i>Figure 16. Argania spinosa.</i> Author: Ildefonso Caballero.
Habitat	Mediterranean climate with rainfall between 100-400 mm and up to 1,000 m altitude. Very resistant to prolonged drought and high temperatures, but does not tolerate heavy frosts.
Other uses	In addition to its interest as fodder for livestock (mainly goats), the oil is used for cooking, like olive oil, or as a cosmetic, with multiple benefits for skin and hair.

Carob (*Ceratonia siliqua*).

Short description	It is dioecious and has evergreen foliage. It has dark green paripinnate leaves between 10 and 20 cm long. The flowers are small, apetalous, with radial symmetry, yellowish-green in colour and are grouped in caulogenous clusters. The fruit (carob or bean) is a dark brown, leathery pod, 10 to 30 cm long, containing a rubbery pulp with a sweet and pleasant taste that surrounds the seeds. It contains 10 to 16 seeds.  Figure 17. <i>Ceratonia siliqua</i>. Author: Ildefonso Caballero
Habitat	It grows in dry, mild, warm, frost-free climates up to an altitude of 600 m. It is indifferent to the type of soil. It is indifferent to the type of substrate, needs sunny sites and does not mind stony soils or arid ravines.
Other uses	Carob pods and tender leaves are edible and used as fodder. Historically, carob has been used in the production of drinks and sweets, as a natural sweet. The wood is hard, reddish and highly valued in cabinet making, and the bark and leaves have been used as tanning agents and astringents.

1.4. The dehesa/montado system

The dehesa is a livestock ecosystem consisting of wooded pastureland with *Quercus* species (generally *Q. ilex rotundifolia* and/or *Q. suber*), which is maintained and improved through rational grazing of livestock, long agricultural rotations and regular clearing of the woodland. This has its origins in Mediterranean woodland, where a large part of the shrub layer is replaced by herbaceous grassland created and/or maintained by livestock and the tree cover is gradually thinned until an optimum ratio of area covered/uncovered by trees is reached, achieving the maximum amount and availability of pasture throughout the year and a high production of acorns (Box 1). Furthermore, the use of holm oak twigs by livestock is a very widespread traditional use, both from pruning and harvested on purpose, especially during the winter, due to the scarcity of grass due to low temperatures (or even snow), and because of its appetite at that time of year. It is precisely the fodder value of the *Quercus* that hinders its natural regeneration in overgrazed pastures and without the presence of scrub that could act as a nursery or shelter for the new shoots and provide shrub fodder.

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"An area with more or less scattered trees and a well-developed herbaceous layer, in which the shrub layer has been largely eliminated. It is of agricultural origin (land tilled in long rotations) and livestock farming. Its main production is extensive or semi-extensive livestock farming, which usually uses not only herbaceous grasses, but also twigs and the fruits of the trees".

Box 1. Definition of "Dehesa". Spanish Society for the Study of Pastures (2001).



Figure 18. Dehesa harvested and maintained by sustainable cattle grazing, with natural regeneration of the woodland.

Author: Ildefonso Caballero.



Figure 19. Pasture created and maintained by sustainable grazing of Merino sheep.

Author: Ildefonso Caballero.

The dehesa is one of the most environmentally valuable livestock ecosystems, which is why it has been declared Habitat of Community Interest 6310 (Díaz & Pulido, 2009). The principles underpinning the dehesa ecosystem can be applied to other pastures and other tree species, for example wild olive trees. On woody crops, pasture systems can also be developed in olive groves, almond, carob, chestnut and fig trees.

The dehesa is an ecosystem of anthropic origin, the result of the soil it occupies, the climate that affects it, the vegetation that forms it, the livestock that use it and the action by which humans organise its use and management. It is an age-old farming system, an example of rational and sustainable use of the natural resources existing in semi-arid climate zones on poor soils in the Iberian Peninsula, where it occupies approximately 3.5 million ha and 15% of the total Useful Agricultural Area (UAA) in Spain (Olea et al., 2005), plus 1.2 million ha in Portugal (Godinho et al., 2016). The different approaches from which the dehesa can be characterized and Portuguese montados (forestry, livestock, biodiversity, landscape, socio-economic, etc.) may offer slight variations on these figures (Díaz & Pulido, 2009).



Figure 20. Dehesa with acebuches.

Author: Ildefonso Caballero.



Figure 21. Olive grove under pasture.

Author: María del Carmen García.

Many dehesas in Spain have been in a process of fossilisation for decades, due to a gradual loss of density (adult trees per hectare) due to the death of the oldest trees, accompanied by a lack of regeneration of the woodland (Montoya Oliver, 1999; Plieninger, 2007). It is therefore necessary and urgent to take action to

guarantee its future. Among the different possibilities for maintaining the density of adult trees (30 to 40 ft/ha), the most appropriate is natural regeneration based on the recolonisation of shrub vegetation, in a controlled manner, which protects holm oaks, cork oaks and other *Quercus* species from grazing during their initial growth, and which allows the animals' feed to be supplemented with shrub pasture.



Figure 22. Dehesa without natural renewal.

Author: Ildefonso Caballero.



Figure 23. Fossilised dehesa threatened with disappearance.

Author: Ildefonso Caballero.

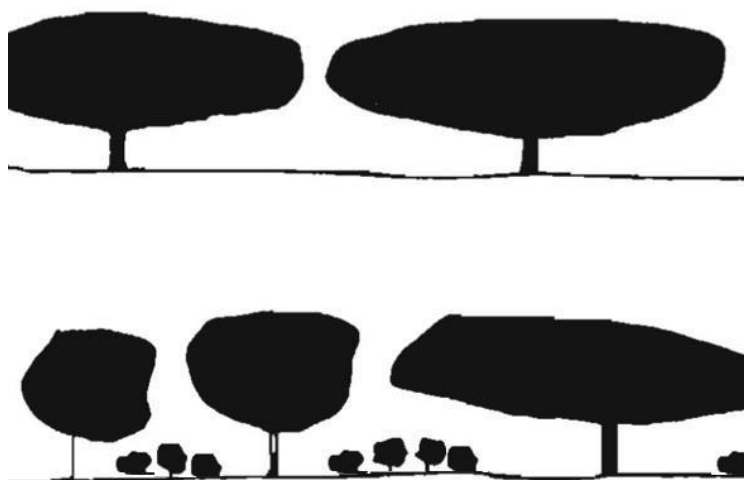


Figure 24. Above: fossil grassland due to its lack of regeneration. Below: pasture with intercalated regeneration that ensures relief and maintenance of the canopy.

Table 1. Comparative summary of different tree regeneration techniques in the dehesa.

Regeneration strategies	Features	Advantages	Disadvantages
Sowing of acorns	Acorns selected from long-lived, high-yielding specimens.	Trees of great quality and longevity from the estate itself.	Very long-term results. Low success rate (many acorns need to be planted).
Planting saplings	Selected 1-2 years old seedlings or hybrids.	Faster results can be achieved. Sometimes subsidised.	From nurseries. High health risk. Low hardiness (many are lost). They need protectors. Great investment.
Natural regeneration	Reserve and/or protection from grazing of enclosures, stands and/or boundaries.	Low investment. High effectiveness.	It can be costly as part of the pasture production is lost for at least the first 5 years. Low acorn-producing trees may grow.

1.5. Riverside vegetation

There are very few permanent watercourses in the territory of the dehesa. However, both in these and in the more or less temporary streams and in the adjacent waterlogged areas, when there are floods, there is a particularly diverse type of vegetation (with some important shrub and tree species due to their fodder value), known as riverside vegetation. The maintenance or re-establishment of this vegetation is of particular interest because it helps to retain the soil and prevent soil loss, as well as serving as a natural water purification system and providing shelter for all types of fauna. These areas should be restricted to grazing to avoid the risk of reinfestation by parasites or the spread of certain diseases such as tuberculosis. In nearby or adjacent areas with cooler, wetter or waterlogged soils, stands of ash, elm, poplar, poplar, hackberry, etc. of great summer interest can be established.

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Figure 25. Riverside vegetation in the course of a stream.

Author: Ildefonso Caballero.



Figure 26. Ash trees and shrubs on fresh pasture land.

Author: Ildefonso Caballero.

1.6. The regeneration of dehesa

A certain controlled scrubbing of pastures allows the natural regeneration of trees and increases the supply of grazing resources. But it also entails certain risks, such as fires or the appearance of wild ungulates that transmit tuberculosis.



Figure 27. A certain level of "scrubbing" of grassland favours the natural regeneration of the dehesa.

Author: Ildefonso Caballero.

The traditional transhumance of extensive livestock in the dehesas favoured the natural regeneration of the woodland, in addition to the low stocking rates and the directed grazing carried out by the traditional shepherds. Nowadays, transhumance has disappeared as a common practice and livestock remain all year round on the dehesa farms, punishing the regeneration of the woodland during the summer and early autumn. Therefore, as a substitute for transhumance, the reserve grazing of some stands or fences is recognised as the most appropriate measure to favour their thickening (Carmona et al., 2013; Plieninger, 2007).

As an alternative or complement, the planting of acorns or seedlings (Montoya Oliver, 1995) can help this natural regeneration. For years, the application of this technique has been covered by subsidies and grants from the administration due to the high investments required and the scarce results obtained. It is natural regeneration that offers safe and viable results in the long term.



Figure 28. Protection of seedlings to prevent them from being damaged by livestock.

Author: Ildefonso Caballero.

1.7. Nurse shrubs

Shrubs are one of the main components of xerophytic plant communities in arid and semi-arid areas with a Mediterranean climate and form part of the transitions (serial vegetation) between forest and grassland, as well as stages of vegetation recovery on abandoned agricultural land. Their morphology produces a microsite beneath them, with a microhabitat that is more benign than the open space for the growth of other species, such as seedlings of other shrub species and even trees. In this way, shrubs act as "nurseries" or protectors

for the species growing in association with them. Therefore, the success of both natural regeneration and reforestation is greater when seedlings grow under shelter or in association with nurse trees than when they grow outside them. In addition to the protection they provide, nurse trees protect from sunlight and encourage vertical growth. In short, a nurse species is one that facilitates the recruitment of another.

There are considered to be seven main mechanisms by which process of nurse tree facilitation occurs (Brooker et al., 2008): shade, soil moisture, nutrients, soil oxygenation, pollination, mycorrhizae and protection from herbivory. In each case, the importance of the different facilitation mechanisms will depend on the factor(s) that most hinder the establishment or regeneration of the species to be promoted.

Thus, in relation to this report, the most important function of nurse shrubs is protection against herbivores, for which they must have a number of characteristics:

- Little or no appetite.
- Have thorny branches or thorns on their stems.
- Reach 1 to 2 m in height.
- Have the ability to grow or spread horizontally to a diameter greater than 1 m.

In addition, if established, nurse plants should be easy to reproduce (by seed or cuttings) but low in invasiveness. The choice of nurse plant or combination of these will depend on the species to be protected and the height to which are to be protected, which in turn will depend on the species of herbivores to be avoided (the most difficult will be goats and cows). In addition, initially, a small plant can be used for the first few years, with the foresight to be replaced or surpassed by a larger nurse plant, which protects a more "defenceless" tree seedling until it escapes browsing due to its height. In the case of *Quercus*, during the first years of life, they grow quite slowly, varying according to different factors (such as soil conditions or the availability of water and nutrients) and it can happen that, without protection, for 3 or 4 years they do not grow more than 10 to 20 cm. On the other hand, there are plants which, like rosemary (*Rosmarinus officinalis*), are not thorny, but are resistant and their aromatic character makes them unappetising, and they can offer some protection in the first years of the new growth of the grove.

Below are several shrub species that can be used as nurseries in the dehesa to protect the seedlings and new saplings of holm oak and cork oak, of which some characteristics are highlighted:

Hawthorn (*Crataegus monogyna*).

Short description	Shrubs or small trees, five to fourteen m high, with a dense crown, thorny branches, deciduous, hairless and serrated leaves. White, fragrant flowers in a corymb. Edible fruit, ovoid in shape, covered with a tender, reddish skin enclosing a sweet pulp and a single seed.  Figure 29. <i>Crataegus monogyna</i>. Author: Ildefonso Caballero
Habitat	It can be found in almost any type of woodland, where it usually forms hedges together with other thorny species (brambles, wild roses, etc.). It is indifferent to the type of soil, as long as there is sufficient humidity, although it has a certain preference for limestone substrates. It tolerates summer droughts poorly. It is found from sea level to 2,200 m altitude. Although it tolerates summer droughts poorly, it is able to grow on a wide range of substrates.
Other uses	Plant of forage importance, its fruits have also been used to feed livestock and it is of melliferous interest. It is fed to livestock as green or dried fodder. Planted as a hedge, it can be used to enclose livestock, thanks to its thorns and branches. In gastronomy, as food, the young leaves are good in salads; and the fruit, being edible, is used to make jams, wine, and to add flavour to brandy. In medicinal use, it is used as an infusion to treat heart and circulatory problems.

Gorse (*Ulex europaeus* and *Genista hirsuta*)

Short description	<i>U. europaeus</i>: growing up to 4 m, forming dense patches, displacing other species around them.  Figure 30. <i>Ulex europaeus</i>. Author: Ildefonso Caballero. <i>G. hirsuta</i>: It is a shrub that can exceed 1 m height, thorny and thickly branched. Simple 7-14 mm leaves, glabrous on the upper side and woolly on the underside. Flowers in conical terminal clusters. Pyriform legume.  Figure 31. <i>Genista hirsuta</i>. Author: Ildefonso Caballero.
Habitat	It inhabits undergrowth of holm oak and cork oak groves. It does not tolerate limestone soils.
Other uses	<i>U. europaeus</i>: In infusion it is used to wash wounds. <i>G. hirsuta</i>: Goats eat its tender shoots.

Rose hips (*Rosa canina*)

Short description	This shrub is up to 2 m tall, with green hanging stems, covered with small, strong, curved spines. The leaves are composed of five to seven oval toothed leaflets. The flowers are pale pink or white and ripen into a deep red ovoid fruit  Figure 32. <i>Rosa canina</i>. Author: Ildefonso Caballero.
Habitat	It has no preference for specific soils, even preferring mountainous or semi-mountainous areas, such as the shrubby undergrowth of deciduous and gall-oak species, but it can also occur in other woods, hedgerows, etc., and even in coastal areas, as it tolerates salinity well. It appreciates well-drained, moist, somewhat fertile soils with a neutral pH (6.1-7.8). Its water requirement is 675-900 mm per year. It can withstand very low temperatures, down to -23 °C.
Other uses	Animals eat its fruits.

Asparagus (Asparagus spp.)

Short description	The genus includes a wide variety of living forms, adapted to habitats from rainforest to semi-desert. Many are climbing plants. Differences in appearance are due to their adaptation to the communities and ecosystems in which they occur.  Figure 33. <i>Asparagus spp.</i> Author: Ildefonso Caballero.
Habitat	They grow mainly in temperate and subtropical regions, being herbaceous perennials or dioecious, climbing and thorny subshrubs.

Sarsaparilla (*Smilax aspera*)

Short description	It is a shrub with slender, voluble stems, one to two metres long and petiolate, spiny, alternate, rough, many-veined, heart-shaped, persistent leaves. The flowers are yellow-cream in axillary clusters, and the fruits are globose berries. It is a thorny climbing plant that needs other plants climb on in order to form a dense, tangled canopy.  Figure 34. <i>Smilax aspera</i>. Author: Ildefonso Caballero.
Habitat	It is always found in the lowlands in many types of woodland, scrub and bramble.
Other uses	Used for the production of highly potent pesticides and poisons. Used for the preparation of the drink sarsaparilla.

Erguen or jerguen (*Calicotome villosa* and *Calicotome intermedia*)

Short description	<i>C. villosa</i>: A highly branched, very thorny shrub up to 2 m high. Both the thorns and the branches are whitish in colour and are longitudinally crossed by green grooves that give it a striated appearance. <i>C. intermedia</i>: This is a shrub up to 1.5 metres high, armed with strong thorns. It is a summer deciduous species which loses its leaves during the summer and regains them as soon as there is sufficient humidity. It flowers between January and March.  Figure 35. <i>Calicotome villosa</i>. Author: Ildelfonso Caballero.
Habitat	<i>C. Villosa</i>: In scrubland with palmetto and undergrowth of cork oak and pine forests. A xerophytic species, it needs mild temperatures. <i>C. intermedia</i>: Its habitat is dry and rocky places and especially those that have been affected by fire.

Jujube (*Ziziphus jujuba*)

Short description	It is a deciduous plant that can reach a height of more than 10 m, although it usually reaches a height of 2.5 m. The trunk is straight with lumps and very wrinkled bark. The flowers are small, inconspicuous, pentamerous, greenish. The fruit is a greenish drupe, firstly greenish and finally black. It flowers between April and August.  Figure 36. <i>Ziziphus jujuba</i> in a pasture. Author: Vicente Rodríguez-Estévez.
Habitat	This species tolerates a wide range of temperatures and rainfall, although it requires hot summers and sufficient water for acceptable fruiting. It tolerates fairly cold winters, surviving temperatures as low as -15 °C.

Black scampi (*Rhamnus lycioides* L. subsp. *Lycioides*)

Short description	Shrub 1-3 m high, intricate and thorny, with greyish branches. Very narrow, drooping leaves, 2-4cm long. Solitary greenish flowers and black drupe fruit. Flowering from March to July and fruiting from August to September.  Figure 37. <i>Rhamnus lycioides</i>. Author: Ildefonso Caballero.
Habitat	Stony, rocky, sandy soils, on various calcareous and siliceous substrates. It is distributed from sea level to about 1000 m (although it does not usually climb that high). Seed stratifies at 4°C until the end of winter. Thermophilic plant in semi-arid-sub-humid environments.
Other uses	Goats eat it very well.

Malandrino (*Rhamnus saxatilis* Jacq)

Short description	1-2 m high thorny shrub with dense branching and reddish twigs with generally opposite thorns. The flowers are yellow or greenish, inconspicuous, and the fruit is a black drupe. Flowers from April to June.  Figure 38. <i>Rhamnus saxatilis</i>. Author: Ildefonso Caballero.
Other uses	Use of the fruit in the dyeing industry (), provides yellow colour.

Blackthorn (*Prunus spinosa* L.)

Short description	Intricate, thorny shrub with grey, criss-cross branches. Simple, greyish, serrate-margined, 5 cm long, single, drooping leaves. Early white flowers before the leaves emerge. The fruit is 1-2 cm in diameter, bluish-blackish when ripe and with a waxy pruina strain. It flowers in March and April and ripens in August-September, the fruit remaining until winter.  Figure 39. <i>Prunus spinosa</i>. Author: Ildefonso Caballero.
Habitat	Very diverse terrain, but generally calcareous. It is distributed from sea level to 1900 m altitude.
Other uses	Its fruit is known for the production of pacharan or sloe liqueur.

Cambronera, escambronera, arto (*Lycium europaeum* L.)

Short description	It is a hedgerow or scrub shrub that grows up to 5 m high. It has thorny branches and elongated, entire, somewhat thick leaves. The pink or violet flowers have a bell-shaped calyx and a five-lobed crown. The fruit is a fleshy globular berry, red or orange in colour.  Figure 40. <i>Lycium europaeum</i>. Author: Ildefonso Caballero Luna.
Habitat	Very diverse terrain with semi-arid to sub-humid environments, it does not frost, so it appears at low altitudes and does not penetrate inland.
Other uses	It is used as a diuretic and hypotensive. Externally it is used to treat ulcers.

Rhamnus infectoria L.

Short description	Shrub 1-2 m high, intricate and thorny with greyish branches. Deciduous. Greenish-yellowish flowers. Greenish drupe fruit, first greenish and finally black. Flowering in April-June and fruiting in August-October.  Figure 41. <i>Rhamnus infectoria</i>. Author: Ildefonso Caballero.
Habitat	It grows in a wide variety of soils, but always calcareous. It does not tolerate drought and needs relatively cool temperatures.

Blackthorn (*Rhamnus oleoides* L.)

Short description	Shrub 3-4 m high, intricate and thorny with greyish branches. Evergreen. Greenish-yellowish flowers. Fruit in greenish drupe at first, acquiring reddish tones when ripe and sometimes black. Flowering in March-May and fruiting in June-September.  Figure 42. <i>Rhamnus oleoides</i>. Author: Ildefonso Caballero.
Habitat	Very diverse terrain, but always calcareous. It climbs very little in altitude, up to 1200 m, and penetrates little inland. It grows in a wide variety of soils, but always calcareous. It climbs very little in altitude, up to 1200 m, and penetrates little inland. It needs warm temperature, it is a thermophilic species.

Prickly pear cactus (*Opuntia* spp.)

Short description	This large genus includes plants of very different sizes and not strictly considered as shrubs, although they can grow to a large size. The segments (cladodes) are characteristic of the genus, with a fleshy leaf-like appearance, flat and generally oval; they have the ability to develop into stems and in turn emit new segments and flowers. The flowers of these plants are large, very open and of colours varying between yellow, orange, red and even purple, appearing at the edges of the segments.  Figure 43. <i>Opuntia</i> spp. Author: Ildefonso Caballero.
Habitat	It inhabits slopes, sunny slopes, roadsides, abandoned crops, degraded scrubland.
Other uses	The animals are fed after the thorns have been removed. There are thornless species within the genus.

2. GRAZING CONDITIONS FOR SHRUB SPECIES

2.1. Livestock grazing and its influence on vegetation

Each herbivore species grazes differently (Voisin, 1960) and as a consequence favours the development of certain plant communities, shaping different landscapes (Montserrat Recoder, 2008). Different factors and variables come into play in the process of selecting the plants consumed by each species. Not only the stage of development and the nutritional value (energy, protein, minerals, toxins...) of the plants in question, but also, for example, the dietary requirements of the animals, which vary according to age and the physiological and environmental conditions at any given time. Therefore, dietary preferences vary throughout the animals lifetime (Manuelian Fusté, 2014; Provenza, 1995).

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Table 2. Grazing characteristics of different livestock species.

Livestock	Mode of grazing	Preferred plant communities	Exceptions
Beef	Low selective and browsing capacity.	Tall herbaceous communities with low diversity.	The Berrenda or Pajuna breeds have a high selective and browsing capacity. The Marismeña breed is very well adapted to the consumption of saline bush pastures.
Sheep	Medium selective and browsing capacity.	Medium-low herbaceous communities with high diversity.	The Merino breed has a low browsing capacity and a great capacity to establish high quality grass pastures (grazing pastures). The Merina Grazalema or Segureña breeds have a great capacity for browsing and grazing in mountainous areas. The Churra Lebrijana breed is very well adapted to the consumption of saline bush pastures.
Goat	High selective and browsing capacity.	Herbaceous and shrub communities with high diversity.	High yielding dairy breeds have lower browsing capacity.
Pigs	The "white" meat breeds have low grazing capacity.	No preferences.	The Iberian pig breed has a great capacity to graze on grass as well as on twigs and fruits.



Figure 44. Cattle generally use tall grass pastures with little selectivity.

Author: Ildefonso Caballero.



Figure 45. Berrenda cattle are very well adapted to grazing on bush pastures in stony mountain terrain. Benaocaz (Cádiz).

Author: Ildefonso Caballero.



Figure 46. Pajuna cows grazing bushes in Sierra Nevada (Granada).

Source: Youtube <https://www.youtube.com/watch?v=lyhvWgZq1HA>



Figure 47. Merino sheep grazing favours the development of low herbaceous pastures of great richness (sheep pastures).

Author: Ildefonso Caballero.



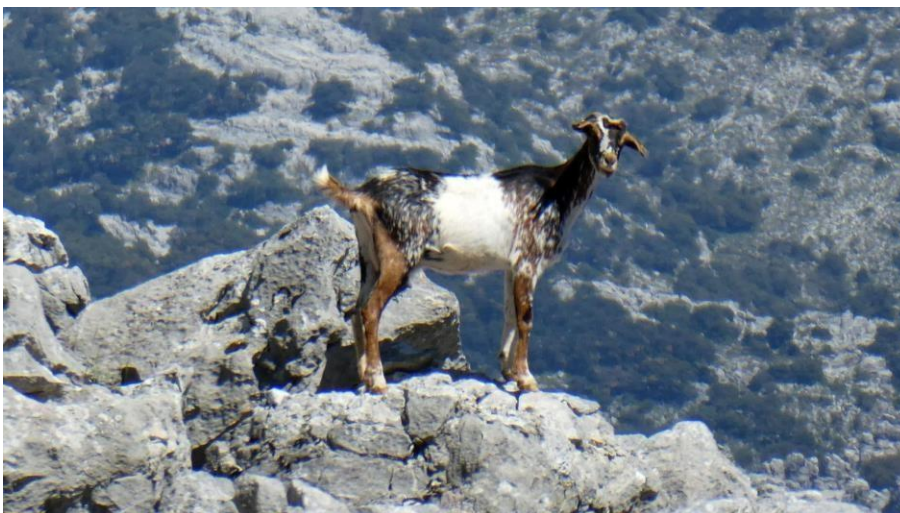
Figure 48. The Grazalema Merino breed is well adapted to grazing in rocky mountain areas and to the use of bush vegetation.

Author: Ildefonso Caballero.



Figure 49. Segureña sheep grazing on grass and shrub pastures in the Sierra de Baza (Granada).

Author: Ildefonso Caballero.



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Figure 50. Goats are highly adapted to grazing in rocky mountain areas and to the selective use of bushes. Payoya breed in Grazalema (Cádiz).

Author: Ildefonso Caballero.



Figure 51. Iberian pig grazing in the pasture.

Author: Ildefonso Caballero.

2.2. Recommendations for grazing shrub formations

Table 3 summarises some recommendations for optimal utilisation of the different shrub formations.

Table 3. Particular recommendations for the use of shrub vegetation.

Shrub management	Autumn	Winter	Spring	Summer
Enclosures of reserved areas for tree regeneration	Light grazing to prevent damage to new stock of <i>Quercus</i> . Iberian pig grazing (montanera).	Rest. Iberian pig grazing (montanera).	Reserve grazing for the first 2 years. From the third year onwards protect stands and graze lightly. Iberian pig grazing (rearing).	2 to 5 first years: light grazing in late summer if dry grass or stubble is scarce (optional). Iberian pig grazing (rearing).
Climax or serial coppice enclosures	Intense grazing by any species until autumn is available. Iberian pig grazing (montanera).	Occasional rest or grazing in dry years. Iberian pig grazing (montanera).	Occasional grazing of new shoots without exhausting them. Iberian pig grazing (rearing).	Occasional grazing in late summer if (dry) grass or stubble is scarce. Iberian pig grazing (rearing).
Riverside vegetation	Intense grazing and/or pruning until autumn.	Rest.	Rest.	Light grazing (except in dry years).

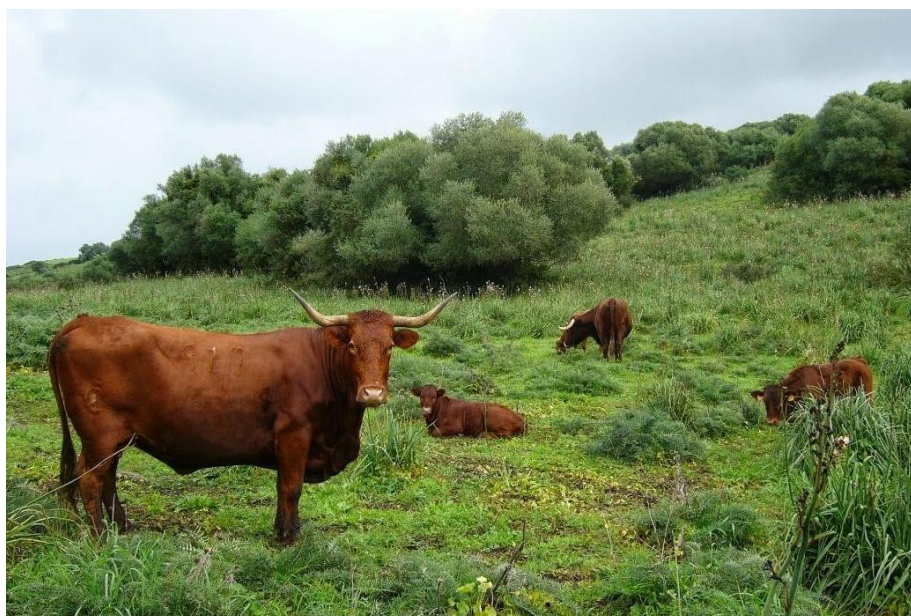


Figure 52. Acebuchal pasture grazed with Retinta cattle.

Author: Ildefonso Caballero

2.3. Sensitive periods

In general, when livestock do not have sufficient grass pastures, they start to consume more intensively the shrub pastures available to them. This is why it is recommendable to have woody species that can provide good feed, whether leaves, shoots or fruit, when grasses are not available or to provide a more varied diet.

However, this consumption can be counterproductive when the aim is to protect the natural regeneration of the woodland. If overloading occurs during the spring, the animals will consume the shoots of these patches of scrub, including the small new-born holm oaks or cork oaks, and they will be lost. It is therefore important that in regeneration plots the stocking rates are low or very intense and fast (only for a few days), so that there is high competition between the animals, forcing them to focus on the grasses.

After spring, when the plants are more developed and lignified (which may require more than 5 years for acorn-born plants), and the future trees are more protected by the increased shrub development, grazing times could be increased.



Figure 53. Heavily grazed scrubland protecting the growth of trees in its center.

Author: Ildefonso Caballero.

Once the shrub species of forage interest are well established, it is important to apply a sufficiently high stocking rate to allow short, intensive grazing, which limits the expansion of these species but stimulates their regrowth in a manner analogous to and compatible with the principles of rational grazing devised for herbaceous grasses (Voisin & Bressou, 1957).

3. GRAZING SYSTEMS APPLIED TO SHRUB VEGETATION

3.1. Behaviour of grazing animals

Grazing is an adaptive foraging behaviour that combines genetic inheritance (species, breed, individual) and the accumulated experience of each individual in the herd. It is a behaviour in which animals continuously make decisions to ingest nutrients and avoid ingesting toxic substances contained in certain plants or parts of plants (Launchbaugh, 2020).



Figure 54. Herding is an adaptive behaviour fixed in heredity (species, breed).

Author: Ildefonso Caballero.

Under grazing conditions, herbivores continuously decide what to eat (preference, diet), where to eat (stand or grazing site) and how much to eat (level of intake related to palatability), adapting the behaviour of each species and breed through accumulated experience. This learning based on experiences results in changes of animal behaviour, what can condition the management, the local biodiversity and the development of the plants themselves, the plant communities and the landscape.

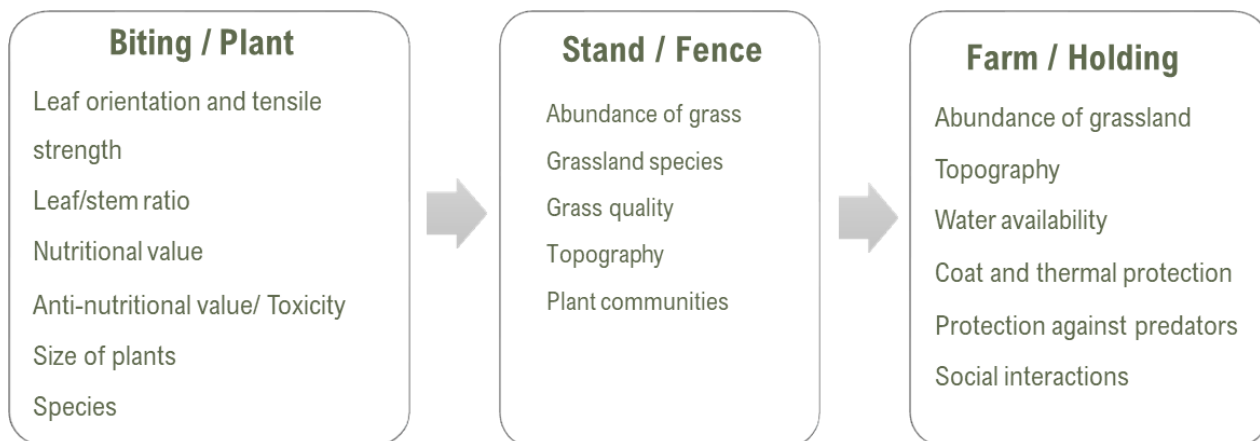


Figure 55. Hierarchy of decisions made by grazing animals.

Adapted from Launchbaugh, (2020).

Preference for or rejection of the consumption of certain plants or grazing in certain stands is therefore the result of learning. If the experience is positive (improvement of health and well-being), preference will develop, and if the experience is negative (toxicity, disease), rejection will develop, even to the point of modifying the value and perception of taste by the animals (this is a consequence of experience and post-ingestive feedback).



Figure 56. Selective herding is a cognitive process that can be reinforced by interactions with other animals, including humans.

Author: Ildefonso Caballero.

Genetic inheritance determines differences in the morphology, physiology and metabolism of individuals, so that within the same species there can be important variations at breed or herd level that are reflected in their

behaviour and grazing abilities in relation to certain plants (Launchbaugh, 2020). These decisions can also be influenced by physiological-productive status, nutritional deficiencies, health or disease, changing the preference towards the same plant. Parental learning and hierarchical interactions within the herd also facilitate rapid learning. All this will be developed further below.

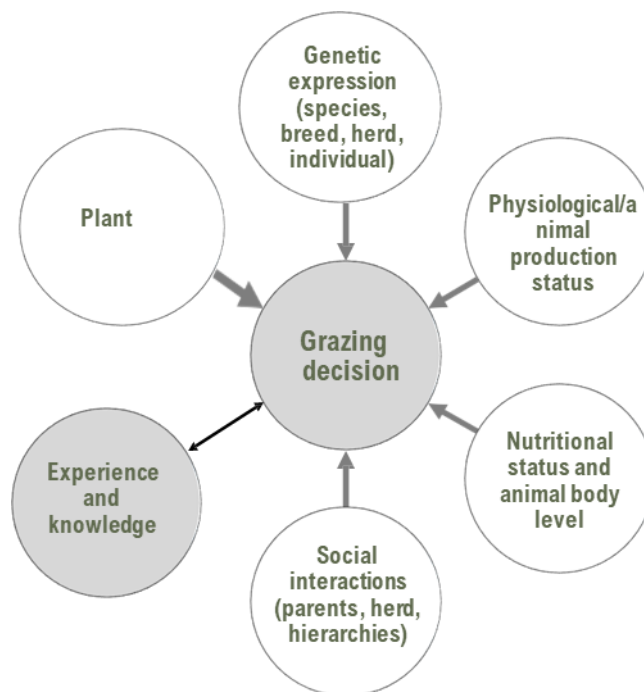


Figure 57. Main factors influencing grazing decisions.

Adapted from Launchbaugh (2020).

It should be taken into account that the vegetative development of plants changes during the year, as well as the chemical composition of each of their parts, even during the same day or according to the type of soil or topography. This is particularly evident in herbaceous species, but also in woody species, so that a plant or plant part may be toxic at one stage while being highly nutritious at another.

Preference is strongest when feedback or experience is rapid, which explains the direct relationship between preference/palatability and nutrient richness or very strong rejection by rapid toxicity. The balance in energy/protein and its digestibility also develops a stronger preference than if the plant is too rich in protein or energy. With age, accumulated experience allows grazing against each species to become more efficient.

Taking all the above factors into account, grazing techniques can have a major influence on the utilisation of both herbaceous and shrub and tree species. Whether the aim is to avoid the consumption of certain species or patches of shrubs or to favour their optimal consumption, some of the strategies explained below should be considered.



Figure 58. Cows of the native Retinta breed in the Sierra del Retín (Cádiz) grazing herbaceous and shrub pastures.

Author: Ildefonso Caballero.

3.2. Free or continuous grazing

The continuous grazing of a territory (free grazing or extensive grazing) is carried out by free-ranging animals that move around seasonally in search of the best areas/regions at any given time. Rather than a system, it is an "absence of a system" or grazing technique, since the whole farm is managed as a single plot of land; therefore, the pastures and especially the most desirable species may never have an adequate rest (unless transhumance/transterminance is carried out). This lack of rest could be compensated by a very low stocking rate in arid or semi-arid Mediterranean regions, below <0.1 LU/ha; but the low mowing frequency would allow non-grass species to complete their cycle and would not lead to a dominance of palatable species with high regrowth capacity (grasses) and, therefore, high forage production. As there is no control, this leads to animals preferring some places over others (preferences) and rejecting others.

Over time, this leads to overgrazed and undergrazed areas, known as "stocking" of pastures. Unless there is a high stocking rate, in which case the whole area is overgrazed and only certain unpalatable multiannual herbaceous plants, such as thistles, and even other toxic species, such as *Senecio jacobea* and *Marrubium vulgare*, are favoured.

3.3. Directed grazing

When the herds were guided by shepherds and dogs, they were herded with the aim of using the grazing resources at their optimum time and according to their availability. Nowadays, however, this type of grazing has almost disappeared due to labour problems. Transhumance is a practice that requires directed grazing, but transhumance herds have also been disappearing with the shepherds in favour of stationary herds, which remain in the same territory all year round regardless of the seasonality of the pastures.



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Figure 59. Directed grazing in an area of great aridity and abundance of shrubs. Sheep of the Segureña breed. Sierra del Segura (Albacete).

Author: Ildefonso Caballero.

3.4. Rational or rotational grazing

To avoid the disadvantages of continuous grazing, favour a more homogeneous use and achieve higher production, it is recommended to divide the farm into several grazing enclosures that allow the pastures to rest, leaving them empty of animals for a period of time so that the plants can regrow and grow sufficiently before they are consumed again. In other words, rational or rotational grazing. Under these conditions, in order to make optimal use of the pastures, it is necessary to divide the land into a sufficient number of enclosures to make it possible:

- To keep different species and batches of livestock separate.
- Intensive grazing for a few days, without overgrazing the grass so as not to exhaust its regrowth capacity.

- To maintain several growing plots without the pressure of continuous livestock grazing.
- To set aside some land to try to harvest hay or make silage.
- To set aside some land to seed and renew pastures.
- Fallowing, sowing and fallowing of some plots as a means of combating diseases (e.g. gastrointestinal parasites) and for the regeneration of the soil structure.
- To enclose a part of the land to encourage the controlled regeneration of shrubs and thus of the tree layer itself, especially in those areas of the farms that do not allow a rapid establishment of natural grassland or the establishment of meadows (e.g. steep areas, rocky areas or very fertile countryside).

The design of fences is complex and, as it is a costly investment, it is preferable to initially make provisional layouts and/or use electric grazers so that they can be corrected later if necessary. The key to fence layout in semi-arid pastures is to follow the criterion of presence or availability of water in all plots or to install fixed or portable water troughs in all plots.



Figure 60. Subdivision of a livestock farm into enclosures for rational or rotational grazing.

In any case, planning must be carried out taking into account the size of the herds, the supply of pasture, the days needed for optimum use, the terrain, access to water, available protection, etc. However, the rotation of the plots and the occupation and rest times will be adapted to the weather conditions at any given time. In each of these fences the animals must find a supply of good pasture, with sufficient protection from adverse weather conditions or other threats (tree cover, bush protection, sheds or buildings) so that grazing allows optimal use of the parcel or enclosure. This grazing system allows the pasture to be "fine-tuned", with the aim of achieving maximum abundance of species of high grazing value. The technique involves intensive grazing at the right time, neither before nor after, combining the action of the teeth (consumption) and the trampling of the cattle together with the natural fertilisation of their manure, repeatedly over time (Voisin & Bressou, 1957).

In other words, and in the words of Montserrat Recoder, (2008): "proper use creates what is needed".

With regard to the use of pastures at the right time, it should not be forgotten that pastures (their grassland species) become established and are maintained only if they are grazed. They are not an occasional or supplementary resource, and should not be left as a standing reserve, as they would eventually become overgrazed, but should form the basis and backbone of the feeding strategy (Terceño Ramos, 2006).

Grasses can dominate the vegetation cover if the conditions are right for them to be able to compete to their advantage. These conditions are that the grass is repeatedly cut during an adequate period of occupation and rest, so that thanks to their ability to resprout, they remain and colonise the soil in comparison to grasses that do not have this ability. By applying high stocking rates from time to time, grasses (especially legumes) will be favoured.

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Figure 61. Grasslands and their botanical composition can be eternal if managed correctly.

Author: Ildefonso Caballero.

According to the management and rotation of the grazing plots, different types or modes of grazing can be distinguished (Table 4).

Table 4. Advantages and disadvantages of different grazing techniques.

	Continuous grazing	Rotational grazing	Strip grazing
Fencing and water infrastructure	Very low	Medium	High
Work needs	Very low	Medium	High
Grass productivity and quality	Low	Medium	High
Losses due to trampling	High	Medium	Low
Manure distribution	Irregular	Regular	Homogeneous
Use of grass	Irregular	Regular	Homogeneous
Grass growth	Low	Medium	High

Different variants of rotational grazing are presented below.

3.4.1. Alternate grazing

Alternate grazing is the simplest form of rotational grazing and offers a slight improvement over continuous grazing, as it consists of having the farm divided into two parts, so that all the cattle are on one part, while the other part rests. When the food decreases in one part and the other part is ready to be grazed, the cattle are changed, "alternating" the grazing.

The disadvantage of continuous grazing persists, because the cattle are given the option to eat the most palatable plants again before they have recovered; and the younger the grass is consumed, the less productive it becomes and the less carrying capacity it can support, so alternate grazing also requires low stocking rates.

For these reasons, among others, the rationalisation of alternate grazing is a progressive evolution to rotational grazing, as the initial farm is divided into successive plots; always with the objective of controlling consumption and facilitating the rest of the pasture in each plot.

3.4.2. Rational grazing

Rotating plots or moving livestock between plots is commonplace, as it improves the utilisation and maintenance of pastures. However, this does not mean that rational grazing is taking place, as it goes much further than simply rotating or shifting plots.

In order to practise proper rational grazing, and thus avoid the negative effects of trampling, selection of the most palatable pastures and overgrazing of certain areas, and to improve the persistence and productivity of pastures, a sufficient number of enclosures must be provided to allow intensive grazing of each plot for a few days, establishing very favourable competition conditions for grasses (with resistance to trampling and high regrowth capacity) in order to achieve maximum production and balance of the grazing ecosystem. This is the so-called rotational or rational grazing, which is based on the grazing laws of Voisin & Bressou (1957). This system is what some have recently called holistic or regenerative grazing.

The practice of rational grazing is facilitated when temperature and humidity conditions are predictable, as is the case in pastures in Atlantic climates or in irrigated meadows. In Mediterranean climate conditions, on the other hand, weather forecasts are more difficult or uncertain for much of the year. However, with occasional back-up irrigation, application can be improved on some plots.

Table 5. Voisin's Laws of Rational Grazing. Adapted from Voisin et al. (1957)

LAW OF REPOSE Sufficient time must have elapsed between two mowings to allow the plant to store the necessary reserves in its roots for vigorous regrowth.
LAW OF OCCUPATION The overall occupancy time of a field must be short enough so that the grass is not cut by the animal more than once. This makes it necessary to work with high stocking rates.
LAW OF PEAK PERFORMANCE To help the animals with the highest feed requirements to graze as much grass of highest possible quality. This forces us to divide into lots and plots of different needs (pregnant calves, cows, growing and fattening).
GRAZING OR CONTINUATION GRAZING First the "continuing" animals (with higher needs) graze. Then graze the rest ("discontinuers").
LAW OF REGULAR RETURNS Animals should not stay more than 3 days in the same field to achieve regular yields. For maximum yields, animals should not stay more than one day in the same field.

The use of mobile electric fences or GPS collars for virtual fencing are also useful for this technique, facilitating the sub-parcelling in strips, the management of the animals and the practice of intensive grazing for a few days. These types of systems will be further developed at a later stage. An orderly rotation of consecutive plots is not appropriate, as the conditions of utilisation and recovery of each plot can be very different depending on weather conditions (temperatures, rainfall, cloud cover, solar radiation, winds, etc.) or other circumstances. Therefore, the order must change each time the rotation is restarted, and no rules or formulas can be applied.



Figure 62. The use of mobile electric fences can facilitate the practice of rotational or rational grazing.

Author: Ildefonso Caballero.



Figure 63. Movements between plots in rotational grazing should not be timed.

Table 6. Example of records during the use of rotational grazing plots.

Occupied 7 weeks ago. Rainy days. Occupy next week.	Occupied 6 weeks ago. Low rainfall days.	Occupied 5 weeks ago. Very rainy days.	Occupied 4 weeks ago. Some days are rainy and some are hot.
Busy this week. Very hot days.	Busy last week. Days slightly hot.	Occupied 2 weeks ago. Overcast but not rainy days.	Occupied 3 weeks ago. Very rainy days.

On the basis of the times required by the herbaceous species to be favoured, it is possible to make approximate calculations of the number of plots, the size of the plots, the time required for their growth, occupation and rest, and the stocking rate that can be supported by each type or community of pasture, so that they are at the optimum time for consumption.

Example of grazing fence calculation.

Assuming that the optimum time required for the consumption of a given plant or community of plants is 30 days, it is determined:

1. Number of plots required= (days at rest÷ days in occupancy per plot) + 1. Ex: $(30 \div 6) + 1 = 6$ plots
2. Plot size in square metres = ((Number of animals to be grazed x grass consumption in kg/animal) + grass losses in the plot in kg (average stocking rate (kg of grass available per m²) x number of days each plot will be occupied).
E.g.: $((50 \text{ animals} \times 40 \text{ kg/animal}) + 30\% \text{ losses})(1.5 \text{ kg/m}^2 \times 6 \text{ days}) = 9,600 \text{ m}^2 = 1 \text{ ha approx.}$
3. Total required grazing area= 6 plots x 1 ha= 6 ha (6 ha approx.)

Result: 6 ha divided into 6 plots of 1 ha, and with a production of at least 1.5 kg of fresh grass per m², and losses not exceeding 30% of the total availability of grass produced, are required, each plot being occupied for a maximum of 6 days in order to ensure a 30-day rest of the pasture between rotations. The stocking rate may not exceed 50 animals, and the average consumption per animal may not exceed 40 kg of fresh grass.

The reality is that calculations are rarely made, only trial and error. And few farmers apply high stocking rates and move animals to other fences every few days. On the other hand, in semi-arid or Mediterranean climate areas, summer can be solved by leaving plots with a standing stock of dry grass or by transhumance or transterminance. In addition, within each fence or plot, the preferences of livestock can be modified by attracting them to certain points to exert their positive influence (grazing, manuring, trampling) in certain areas and avoiding overgrazing in others, by placing feeding troughs, watering points, watering points and/or protection.



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Figure 64. Livestock preferences can be modified by the location and rotation of feeders, drinkers and salt licks.

Author: Ildefonso Caballero.



Figure 65. The location of water points on fences that do not have water courses or sources is essential.

Author: Ildefonso Caballero.



Figure 66. *The change of location of water points for watering cattle is a great stimulus to attract them to certain areas.*

Author: Ildefonso Caballero.

Another issue to be taken into account for pasture improvement is to move livestock from areas of good pasture to areas of poorer pasture, so that they deposit seeds of species of higher interest and improve these areas. Plots with better pastures, such as 'majadales', must be conserved and managed with special care, as they constitute 'seed banks'. The end of spring or the end of the cycle is the critical time to apply this technique, starting by grazing the "majadales".

3.4.3. Strip grazing

This is a form of rotational grazing that consists of very intensive grazing in very high production pastures, during 1 to 2 days of grazing per strip. For this purpose, mobile electric fences are used, one at the front and the other at the back, 4-5 strips apart. In other words, each plot is made up of 4-5 strips. Although, logically, the livestock is concentrated in the freshest or most recent strip, which is accessed (by moving the portable fence forward) every 1 or 2 days.

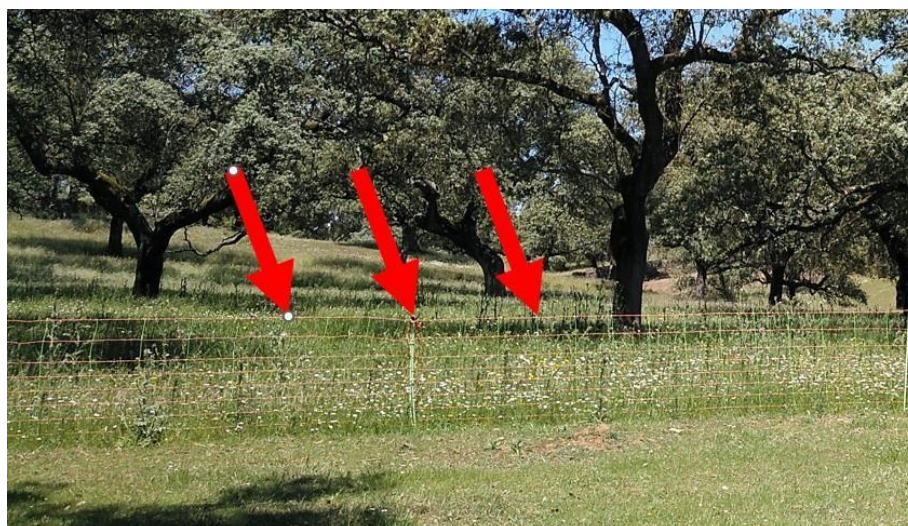


Figure 67. Electric fence for strip grazing.

Author: Ildefonso Caballero.

3.5. Adaptations of rotational grazing to favour shrub development and forage production

Techniques for managing shrub vegetation and maintaining an appropriate balance of its presence in grassland and pasture, in line with the objectives of the LIFE ScrubsNet project, may combine the reservation or enclosure of some fences with more or less intensive grazing, and the use of low browsing species and breeds. The choice of one strategy or another, or a combination of several, will depend on the objective pursued by the presence of scrub, ranging from promoting islands of biodiversity to encouraging natural regeneration of the woodland. The latter may be either saplings (seed-born plants) or chirpiales (root sprouts). In this respect, it should be pointed out that the capacity of holm oaks and cork oaks to resprout from the stump or roots is an excellent reproductive strategy, which has enabled them to survive in a seasonally and interannually adverse environment, where regeneration is conditioned by felling, clearance or clearing of scrub, overgrazing and even fires.



Figure 68. Holm oak saplings in a natural regeneration.

Author: Ildefonso Caballero.

3.5.1. Fence reserve

When the objective is to encourage the natural regeneration of the dehesas, it is necessary to set aside some fences for a few years until the new saplings have reached a certain stage of development and can withstand seasonal grazing by browsing livestock. The length of the reserve will depend on whether or not there are scattered small bushes, shrub seedlings or a seed bank of shrub species, and the diversity of these. Thus, the higher the biodiversity of the initial shrubland, the shorter the time needed for it to colonise target sites and islands of biodiversity where its presence is of interest, or for natural regeneration of the shrubland to occur.

During these years, grazing should in any case be carried out with low stocking rates and only on a few days, always outside spring, preferably at the end of summer and beginning of autumn, which are usually the most advisable periods. In this respect, it is worth noting the exception of the Iberian pig, which can take advantage of the “montaneras”.

3.5.2. Stand selection or grazing in strips

As an alternative or complement to the previous section, within each fence or grazing area, some stands could be enclosed to protect the growth of woody species and to take advantage of the rest through more intensive grazing. This enclosure could be done with fixed fences or with an electric pasture, which could also be used for strip grazing.

3.5.3. Utilisation with low browsing species or breeds

Cattle are generally not very prone to browsing, as their mouths are not particularly adapted to this type of behaviour. Therefore, low stocking rates with cattle can allow woody species to thrive. However, it should be borne in mind that there are some indigenous breeds linked to certain ecosystems which, on the contrary, are very well adapted to grazing on steep and abrupt terrain where shrubby vegetation predominates, as is the case with the Pajuna breed in the Sierra Nevada or the Berrenda breed in many mountain ranges.

In the case of sheep, which are more adapted anatomically and behaviourally to grazing, there are breeds such as the native Merino and its derivatives that do not tend to graze. But others, such as the Segureña breed, can behave perfectly well as grazers.

On the other hand, the goat is the browsing animal par excellence, especially native breeds with a meat-producing attitude such as the Serrana or Blanca Andaluza goat. In any case, herd management habits and grazing experience will ultimately determine how to favour the development of woody species or their rational use as a fodder resource.

3.5.4. Mixed grazing of various species

Mixed grazing is the simultaneous or successive combination of different species and even breeds to make the best use of the pasture. Mixed grazing can be highly recommended when it comes to establishing natural pastures on large farms or enclosures with abundant shrubby vegetation, so that each one is entering, zoning and creating its own grazing preferences according to its behaviour and that of the grassland species with which it is associated. If successive grazing is carried out, it should be borne in mind that cattle are generally not very selective and cut the grass at a certain height, while sheep and goats can take small bites almost at ground level and select small shrub shoots (Manuelian Fusté, 2014). Therefore, it is recommended that the pasture be used first by cattle before sheep and/or goats are introduced. Mention has already been made of the Iberian pig, which during the “montanera” season will concentrate on eating acorns and grass, without harming the regeneration of the grove or the shrub species.



Figure 69. Mixed grazing of sheep and cows.

Author: Ildefonso Caballero.

4. CONDITIONED TASTE AVERSION

Two processes come into play in the diet selection process of animals: on the one hand, the affective process, involuntary and previously explained, and the cognitive process, through which the animal relates taste, appearance and smell of the food with the effect after ingestion; which generates positive or negative feedback or knowledge (*feedback*). This point is fundamental, as it determines that in future animals can consciously select or avoid such foods through smell and appearance (Howery et al., 1998). Thus, the use of a substance, drug or treatment that produces nausea or discomfort, allows the modification or manipulation of the animals' food preferences (Bernstein & Koh, 2007; Provenza, 1995; Provenza et al., 1994). This process is known as conditioned *taste aversion* (CTA). This is a type of conditioning in which an animal learns to associate a taste (conditioned stimulus) with a substance, drug or treatment that produces nausea, gastrointestinal illness or discomfort (unconditioned stimulus), thus allowing taste to begin to be avoided Bernstein & Koh, 2007; Garcia et al., 1974). For example, lithium chloride (LiCl) has used to induce aversion to the consumption of certain shrubs and grasses in lambs and cows respectively (Conover, 1995). However, the group of inducing substances to achieve this aversion or rejection by animals is very broad, ranging from natural substances to synthetic products. In the first group are different types of essential oils, bitter or pungent plant extracts (such as quassia, wormwood or chilli) or even other types of repellent or unpleasant-smelling substances, such as diluted dog urine and excrement (popularly known as "perrear" and widely used in the protection of seedlings).

Induced aversion or CTA is used to protect cultivated vegetation, from crops to tree seedlings (tree saplings or low branches), but it can also be used to protect small islands of biodiversity in the early stages of their creation. When a particular substance is applied to protect a homogeneous and densely vegetated plot, it may

be sufficient to treat a perimeter strip, as if to warn the animals that everything else will be the same. In this sense, the different substances or inducing agents that can be used today to trigger CTA, and that could be effective for grazing conditioning, are very diverse.

4.1. Factors affecting conditioned aversion

4.1.1. Dosage and number of administrations of the inducer substance

CTA has a close dose-effect relationship due to the degree of discomfort caused by the inducing substance used in each case, with food intake decreasing as the amount of inducing substance increases. This effect has been studied and observed in different types of substances, with lithium chloride (LiCl) being one of the most commonly used inducers (Egber et al., 1998; Massei & Cowan, 2002; Mazorra et al., 2006). In any case, the specific characteristics of the inducing substance to be used should be studied.

4.1.2. Characteristics of the target food and previous experience

The ability of ruminants to develop CTA is also affected by the characteristics of the feed in question (the plant to be protected) and previous experience with it. However, it should also be borne in mind that if the feed in question provides irreplaceable nutrients, the development of CTA may not occur (Conover, 1995). At this point, it is important to mention the term neophobia, a very common behaviour in different vertebrate species whereby animals feel fear or rejection towards the consumption of unfamiliar foods (Provenza & Balph, 1988). It is an innate protective mechanism by which animals learn the post-ingestion consequences of eating a new and potentially toxic food prior to being affected and has been described in different ruminant species such as sheep (Provenza & Balph, 1988; Van Tien et al., 1999). When ruminants gain access to a new feed source, they usually start by ingesting only a small amount and then, if there is no negative effect, gradually increase their intake (Thorhallsdottir et al., 1987). Therefore, it is much easier to establish and develop CTA for new foods, and it is stronger and more persistent than for a familiar food (Burritt & Provenza, 1989; Villalba & Provenza, 2000), with which it is more difficult because no prior negative consequence is associated (Ralphs, 1992).

CTA is specific to each target food, or plant in this case, although there is evidence that it can be generalised to all plants of the same species (Ginane & Dumont, 2006). In mixed diets, when animals become ill after ingesting familiar and novel foods, they are able to generate CTA against novel foods (Burritt & Provenza, 1991; Provenza, 1996), whereas, if the diet is composed of familiar foods, they will avoid the most recent one.

4.1.3. Immediacy of the consequence

Regarding the establishment of CTA, animals can react to the discomfort generated by the feed in question and learn with a certain delay between ingestion and discomfort. Thus, some studies have observed a reduction in

intake in lambs when the induced discomfort or disease occurs within four hours post-ingestion. When this time is increased to six hours, it has been observed that reduced intake is achieved either by repeated doses of the inducing substance, by increasing doses or by both (Burritt & Provenza, 1991). On the other hand, when the inducing substance is administered prior to the ingestion of the target food, anticipation must be taken into account. For example, in a study with sheep it was observed that of different administrations given to the animals (2 hours, 1 hour or just before ingestion of the target feed), only those ewes that received the dose of the inducing substance (lithium chloride) just before ingestion were able to develop CTA (Provenza et al., 1993).

4.1.4. Age and social factor

These two factors are very important and have a major influence when working with this type of strategy. In general, adult animals are more reluctant to accept relatively new food than young animals (Provenza & Balph, 1988). In addition, young animals have a more cautious nature when tasting food and a less durable memory. Therefore, CTA would be more durable in adult animals than in young animals. In fact, there are studies where a greater avoidance of foods that cause gastrointestinal discomfort has been observed in adult animals compared to young animals (Provenza & Balph, 1988). For example, in cattle, young animals require higher doses of inducing substance than adult animals to retain CTA to a given feed (Ralphs & Cheney, 1993).

Social modelling is one of the most important ways in which selective feeding behaviour is learned, in addition to experience itself, which influences animals more decisively (Launchbaugh, 2020). At the grazing level, cattle are generally gregarious, living in social groups where information about diet can be easily transmitted from experienced to unexperienced animals. Young cattle have little dietary information available to them after birth. Thus, the animals' food preference or avoidance can be modified by social facilitation, due to the influence of the behaviour of other animals in the group, e.g. the mother, siblings or close companions of the animal in question. In this sense, in different ruminant species it has been observed that animals that have been induced to eat a particular plant species tend to eat it more when grazing with other non-induced animals, compared to when grazing alone (Provenza & Burritt, 1991); and a reduction of CTA has also been observed in animals that have been grazing for long periods of time when grazing with non-induced animals (Lane et al., 1990; Ralphs, 1997).

Finally, social facilitation is also affected by age, with adult animals being less influenced in food selection (Provenza & Balph, 1988; Thorhallsdottir et al., 1990b). Of note is the social facilitation that occurs between mothers and offspring, although this influence changes with the age of the animals. For example, lambs under eight weeks of age pay more attention to their mothers' behaviour (Thorhallsdottir et al., 1990c), stay closer to their mothers and are more influenced by maternal behaviour (Mirza & Provenza, 1990). Thus, ewe-lamb facilitation could allow lambs to learn to avoid a target plant when grazing with dams (Mirza & Provenza, 1990,

1994; Thorhallsdottir et al., 1990a). However, young animals also learn from other adult animals and mates, not only from the mother figure. For example, heifers start grazing earlier if accompanied by experienced cows compared to alone (Costa et al., 2016). Both factors, age and the influence of the social factor between animal groups, must be taken into account when introducing AWC on a given feed, especially in grazing, where young animals tend to imitate the behaviour of adult animals.

4.1.5. Alternative food and persistence

It should be noted that, although animals tend to avoid target foods once CTA is in place, depending on the animal species, this aversion is reduced if there are no negative consequences each time they try the food. This is because some induced animals never completely stop eating the target plant, and continue to eat small amounts of food (Thorhallsdottir et al., 1987). In this sense, it is essential that alternative food is available to prevent animals from feeding on the target food and thus maintain the persistence of aversion (Burritt & Provenza, 1990; Thorhallsdottir et al., 1990b). The duration of CTA is variable, with studies reporting up to nine months in sheep (Burritt & Provenza, 1990; Doran et al., 2009), and up to two to three years in cattle (Lane et al., 1990; Ralphs, 1997).

In summary, in order to establish long-term CTA in grazing cattle, it should be remembered that it is advisable to apply it to adult animals, with sufficiently high doses of the inducing substance to ensure the negative effect, and to keep the induced animals grazing separately to avoid social facilitation (Ralphs, 1997).

4.2. Operant conditioning

Operant conditioning, also known as instrumental conditioning, is an associative learning methodology whereby an individual repeats more of the behaviour that has positive consequences, and less of the behaviour that does not have positive consequences or has negative consequences. In this sense, livestock can be trained to perform certain behaviours using negative and positive reinforcement. In addition to being able to learn when and where these food reinforcers are found, animals can spatial memory and can develop a series of foraging patterns (Edwards et al., 1996; Hewitson et al., 2005; Laca, 1998). Animals associate sounds and visual stimuli with food, taking advantage of certain areas when such stimuli are presented. It would therefore be possible to develop animal feeding systems based on 'food rewards' that would allow the movement of livestock on the ground to be controlled (Laca, 2009).

Thus, there are different studies that show the above, for example, where sheep and cattle relate visual signals (flowers and coloured flags) with food rewards (Edwards et al., 1996; Laca & Ortega, 1995). , sheep that have learned the locations of the food by experience, on subsequent occasions they tend to go to these areas first to look for it, and once this is done they use the visual cues or stimuli. Cows, on the other hand, use the aforementioned colour stimuli directly to find food. One study found that a group of sheep can learn to

associate a particular (preferred) food with certain types of plants (clover or ryegrass), from a distance of up to 5 m, and showed up to 86% success in identifying locations with the preferred food (Edwards et al., 1997). Even cattle have been shown to relate the location and quality of hidden food to visual cues such as road signs and cones (Howery et al., 2000): trained animals were more efficient at finding food and consumed more food per distance travelled than untrained animals. This series of examples demonstrates that foraging behaviour is amenable to modification using different types of visual cues and training schemes.

In this sense, there are authors who establish two spatial levels to be considered when controlling livestock selectivity (Laca, 2009). On the one hand, the selection of plots (large scale) can be modified through the use of attractant points (permanent or intermittent) consisting of the placement of highly palatable feed in specific areas. On the other hand, selectivity at the trough level, specific patches of grass or shrubs, or even at the bit level (small scale), need to be addressed in a more specific and individual way, at the digestive level, by resorting to fasting, supplementation or CTA (Villalba & Provenza, 2009).

5. FENCING AND GRAZING INFRASTRUCTURE

In the world of agriculture and livestock farming, efficient management of natural resources is essential to ensure long-term sustainability. Among the key practices that enable this sustainable management, fencing and grazing infrastructure emerge as fundamental elements. These not only delineate the physical boundaries of properties, but also play a critical role in optimising the productivity and health of crop and livestock systems (Teague et al., 2011; Vallentine, 2000).

Fences, in their most basic form, define the boundaries of cropland and grazing land, providing security and control over livestock and crops. However, their importance goes beyond mere physical demarcation (Figure 70). Properly designed fences can facilitate pasture rotation, allowing better vegetation management and promoting balance. In addition, they can help control soil erosion by limiting livestock access to sensitive areas (Alonso et al., 2001).



Figure 70. Enclosures in the pasture.

Author: Elena Angón.

On the other hand, grazing infrastructure, which includes water troughs, walkways, management pens and water supply systems, are vital components of operational efficiency and animal welfare on livestock farms. Strategic placement of these infrastructures can reduce livestock stress, minimise competition between animals and improve the even distribution of the grazing load, which in turn promotes higher pasture productivity and improved forage quality.

In addition to operational benefits, fencing and grazing infrastructure also play a crucial role in environmental and biodiversity conservation. By effectively managing grazing patterns, the regeneration of natural habitats and the preservation of native plant and animal species can be promoted (Ordaz et al., 2022; Zhang et al., 2013).

However, it is important to recognise that the design and implementation of fencing and grazing infrastructure must be adapted to the specific conditions of each environment. Factors such as terrain type, water availability and stocking density need to be taken into account to maximise their effectiveness and minimise their environmental impact.

In summary, fencing and grazing infrastructure are essential tools for the sustainable management of agricultural and livestock land. Their proper planning and maintenance not only promote operational efficiency and animal welfare, but also contribute to the conservation of the environment and biodiversity, thus laying the foundations for a more prosperous and balanced agricultural and livestock future (Zubieta et al., 2021).

5.1. Physical barriers: fences, nets or netting

Physical barriers play a crucial role in the management of enclosures and grazing infrastructure in dehesa and similar environments. Physical barriers play multiple essential roles in the management of livestock and the preservation of ecosystems in environments such as dehesa.

Firstly, they ensure the safety of livestock by keeping them within designated areas, preventing straying and restricting access to dangerous areas. In addition, these structures provide crucial access control, allowing regulation of who can enter certain areas, which is essential for the proper management of natural resources (Vallentine, 2000). They also play a vital role in protecting crops and pastures from damage by livestock or other animals. Physical barriers also contribute to the clear demarcation of land, facilitating the organisation and planning of activities. Finally, in areas prone to soil erosion, these barriers are essential to prevent soil loss and maintain soil stability. These considerations underline the fundamental importance of physical barriers in the effective management of enclosures and in the conservation of ecosystems and rangelands.

The most common materials used in the construction of physical barriers in grassland ecosystems include:

- Wood: Wooden fences are popular for their durability and natural appearance. They are commonly used in rural settings and can be treated to resist weathering.
- Wire: Barbed wire or plain wire is widely used for fencing due to its versatility and relatively low cost (Figure 71).
- Wire mesh: Wire mesh is effective in containing animals and delimiting areas. They are available in different sizes and strengths (Figure 72).
- Stone: In some environments, stone walls are used as physical barriers, especially in mountainous areas (Figure 73).
- Concrete: Concrete is used in the construction of permanent walls and barriers, offering strength and durability.
- Electric fences: Electric fences are a modern option that uses electric current to deter animals from approaching the barrier.

These materials are selected based on durability, strength, cost and the specific environment in which the physical barriers are to be installed.

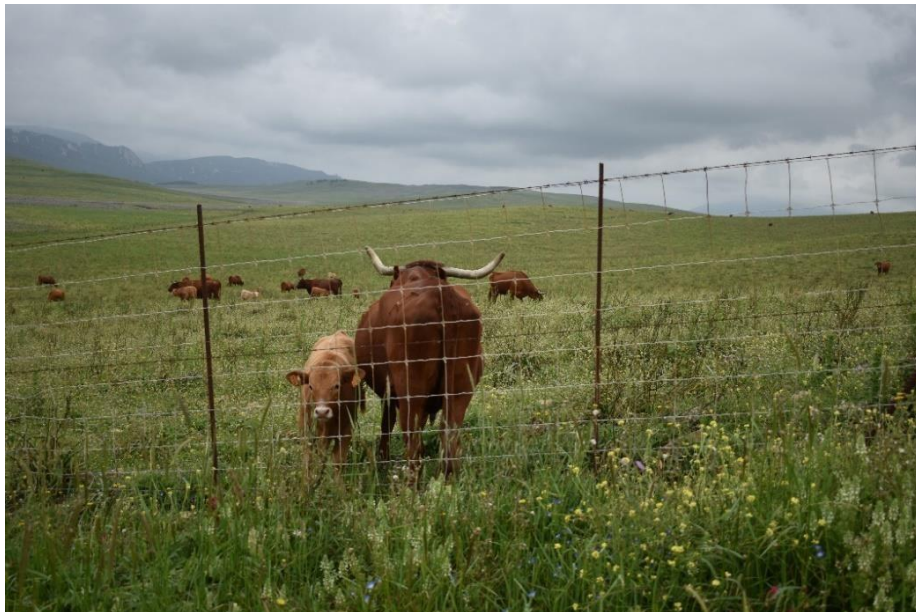


Figure 71. Detail of wire.

Author: Elena Angón.



Figure 72. Detail of metal mesh.

Author: Elena Angón.



Figure 73. Stone fence.

Author: Elena Angón.

To ensure the effectiveness and durability of physical barriers in grazing environments, it is essential to carry out a series of regular examinations and maintenance activities. Regular inspection plays a crucial role in identifying damage, wear and tear or areas in need of repair. Immediate repairs need to be made to any damage or weaknesses detected, thus avoiding major problems in the future. In addition, keeping barriers clear of vegetation, dirt and other materials is essential to preserve their integrity; this is especially important in some such as electric fences and stone walls. It is recommended to apply paint or protective treatment as necessary to protect the barrier material from weathering. Replacement of damaged or worn parts, such as posts, wires or mesh, is also a key practice to maintain the effectiveness of the barrier. Controlling weeds and vegetation around barriers helps prevent damage and obstructions, as does monitoring and controlling the presence of pests that may damage barriers, such as termites or other insects.

In the case of electric fences, it is necessary to regularly check the operation of the electrical system and replace batteries as necessary to ensure electrical safety. Finally, keeping a record of the maintenance activities performed and scheduling regular preventive maintenance will help to ensure that these activities are not forgotten and to keep the barriers in optimal condition.

5.2. Protectors

Guards used in grassland management are essential tools to vegetation regeneration and facilitate vegetation growth. These plant or tree guards can be physical structures or materials of larger or smaller dimensions that are placed around young plants or trees to provide support and protection against adverse environmental conditions and damage by herbivores (Figure 74).



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Figure 74. Holm oak tree protector in a fighting bull farm.

Author: Elena Angón.

One of the most common protectors used in grassland management is the plastic protective tube, which is placed around the newly planted seedlings (Figures 75 and 76). These tubes provide a favourable microclimate by maintaining a more stable temperature and protecting seedlings from wind and damage caused by herbivorous animals. In addition, they help to reduce weed competition around the seedlings, thus promoting faster and healthier growth.



Figure 75. Protective tubes for holm oak seedlings.

Author: Elena Angón.



Figure 76. Detail of protective tubes of holm oak seedling.

Author: Elena Angón.

Another type of shield used is netting, which can be placed over newly planted areas to protect seeds and seedlings from birds, rodents or other animals that might eat them. These nets can also help prevent soil erosion by holding seeds in place during heavy rain or strong wind events.

In addition to the physical structures, there are also biodegradable protectors made of organic materials such as paper, cardboard or coconut fibre. These protectors provide temporary protection for seedlings while they gradually decompose in the soil, avoiding the need to remove them manually once the plants are established. A natural, and also biodegradable, type of mulch is prunings or stalks, which when piled or arranged around the seedlings provide a kind of temporary barrier. It is important to select the appropriate type of shield depending on the specific site conditions and management objectives. In addition, attention should be paid to regular monitoring of protected areas to ensure that the guards are fulfilling their function and to make adjustments as necessary. Overall, the use of buffers in grassland management can significantly improve survival rates and plant establishment success, thus contributing to the restoration and conservation of these important ecosystems.

5.3. Ultrasonic devices or virtual fencing

Ultrasonic devices used in grazing systems, also known as virtual fencing or electronic fencing, are an innovative technology designed to manage animal grazing remotely and accurately, without the need to construct physical fences (Ylla Carbonell & Barber, 2023). These devices use GPS technology and ultrasonic signals to demarcate specific areas where animals can graze, and emit audible warnings or aversive stimulation when animals come too close to the established boundaries.

The installation of virtual fences involves the following components:

- **Portable devices:** these devices, usually attached to collars or harnesses, are equipped with GPS receivers and ultrasonic transmitters (Figure 77).

The GPS receiver determines the location of the animal at all times, while the ultrasonic transmitter emits audible signals or vibrations when the animal approaches the boundaries of the permitted area.

- **Base or central stations:** These stations are strategically placed on the perimeter of the desired grazing area. They emit reference signals that are detected by handheld devices on the animals, allowing them to determine their position in relation to the boundaries of the permitted area.
- **Management software:** Used to set the boundaries of the grazing area and monitor the location and behaviour of the animals. This software can also provide data on animal grazing activity, which helps farmers and ranchers to optimise the management of their land (Figure 78).



Figure 77. GPS receiver collar.

Source: www.futurelearn.com.



Figure 78. Image provided by grazing area management software.

Source: www.futurelearn.com.

Ultrasonic devices or virtual fences offer numerous advantages over traditional physical fencing methods. They allow grazing areas to be flexibly demarcated and boundaries adjusted as needed, facilitating grazing rotation and vegetation management. In addition, by not requiring the construction and maintenance of physical fences, virtual fences can be more economical in the long term and reduce the need for repairs and replacements.

GPS technology provides very high accuracy in delimiting the boundaries of the grazing area, which helps prevent overgrazing and minimises the risk of environmental impact (Ylla Carbonell & Barber, 2023). In addition, by avoiding the use of physical fences, animals have more freedom of movement and can graze in larger and more natural areas, which can improve their welfare and behaviour.

5.4. Electric pasture fence or electric fence

An electric pasture fence, also known as an electric fence or electric herder, is a barrier that uses a pulsed electric current to contain animals within a given area or to protect a specific area from the entry of unwanted animals. These fences are commonly used in agriculture and animal husbandry to manage livestock grazing, control the entry of predators and protect crops from invasion by wild animals.

Electric fences work by creating an electrical circuit through conducting wires that are connected to an electrical energiser (Figure 79). This energiser converts electrical energy from a power source, such as a battery or electrical grid, into high-voltage, low-amperage current pulses. When an animal or conductive object comes into contact with the electrified wires, it closes the circuit and receives a short but intense electric shock, which deters the animal from touching the fence in the future.

There are several types of electric fences, varying in design and application:

- Wire fence: Consists of electrified conducting wires that are supported by wooden, metal or plastic posts. This is the most common type of electric fence and is used in both pastures and crops.
- Tape fence or conductive tape: Uses a wide tape of conductive material instead of wire. It is especially useful for containing horses and small animals.
- Electric mesh fence: It is composed of an electrified metal mesh that can be deployed to create a wider perimeter protection.
- Portable fencing: These fences are designed to be easily transported and temporarily mounted, making them ideal for rotational grazing and temporary protection of specific areas.

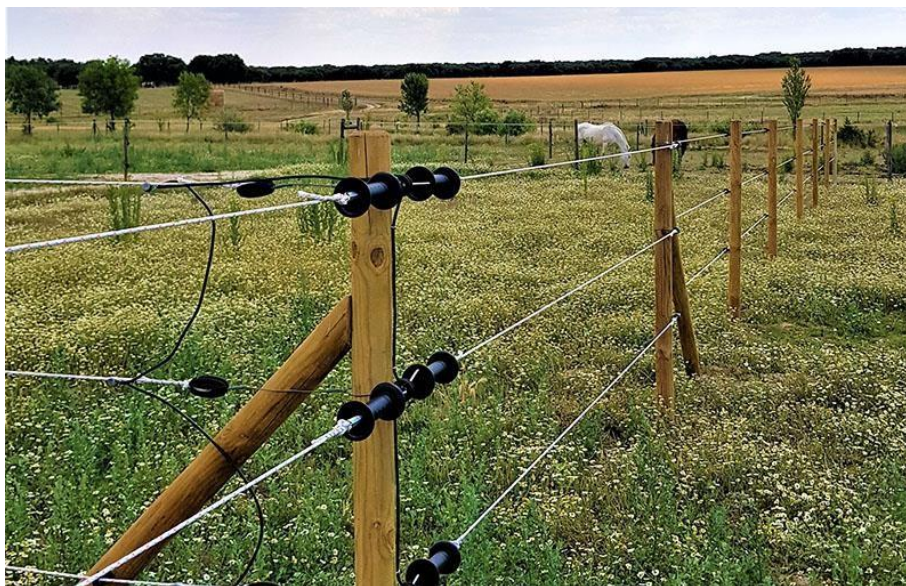


Figure 79. Electric fence.

Source: www.natur-solutions.com.

5.5. Components of electric fences

Electric fences are made up of a variety of components that ensure functionality and safety:

- **Energisers**, vital electronic devices, are responsible for generating the electrical current needed to electrify the fence wires or strips. These devices can be powered by mains electricity, solar energy or rechargeable batteries, offering flexibility in their use. They control the output power and duration of the electrical pulses, thus ensuring the efficiency of the fence and the safety of the animals.
- **Conductive wires or tapes**, which form the physical barrier of the fence, being the carriers of the electric current. Generally made of stainless steel or plastic-coated aluminium, these materials are selected for their corrosion resistance and durability. Conductive tapes, an alternative to wires, are made of conductive plastic material reinforced with metal wires, providing a more flexible and visible option.
- **Insulators**, which play a crucial role in keeping wires or conductive tapes separate and insulated from posts and other supporting structures of the fence. Made of plastic, ceramic or glass, these devices are weather resistant and ensure a safe distance between the electrified wires and the ground or adjacent structures, thus minimising the risk of electric shock.
- The **posts**, vertical and structural, support the conducting wires or tapes and provide the base of the fence. The material of the posts, whether wood, metal or plastic, is chosen according to factors such as terrain, required durability and available budget.

Installed at regular intervals along the perimeter of the fence and fixed to the ground with concrete or metal stakes, these posts ensure the stability and strength of the system.

- **Grounding rods or earthing rods**, buried in the ground and connected to the electric fence system, allow excess electric current to be dissipated into the ground, thus protecting animals and the fence from possible electric shocks. The conductive material, such as copper, ensures effective dissipation of the electric current, while the appropriate length of the rods ensures their connection to moist, well-conductive soil layers.

The design and selection of these components must carefully consider factors such as the type of animals to be contained, the size and topography of the area to be fenced, as well as local climatic conditions and the available budget. Only with careful design and proper installation can the effectiveness and safety of electric fencing in livestock systems be guaranteed.

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5.6. Considerations or differences between livestock species.

The management of electric fencing and grazing systems involves careful consideration of the differences between livestock species, which affects both the effectiveness and safety of the system. Proper understanding of the particular characteristics and needs of each species is essential to designing and maintaining a system that meets the objectives of livestock management and environmental conservation.

The size and strength of livestock species play a crucial role in the selection of fencing materials and strength. For example, cattle, with their larger size and strength, may require more robust wire or tape and support posts to effectively contain them. On the other hand, smaller species such as sheep or goats may need lighter but equally strong structures. Sensitivity to electrical stimulus is another factor to consider. Some species, such as sheep, are more sensitive to electric shocks than others. Therefore, it is important to adjust the power of the electric fence according to the sensitivity of the species to avoid injury or unnecessary stress. This is achieved by the proper setting of energisers and selection of the intensity of the electric current.

Natural jumping and climbing abilities must also be taken into account when designing fences. Goats, for example, are known for their ability to jump or climb fences, which requires higher fences or additional features to prevent them from escaping. Also, grazing characteristics vary between species. While cattle tend to push or hit fence boundaries, sheep may be more likely to crawl or force their way through wires. Therefore, it is essential to design the height and strength of fencing according to these natural behaviours. In addition, the nutritional and water needs of each species are different and need to be considered in the design of the grazing system, facilitating the voluntary stay of animals inside or outside the electric fence. This includes planning the layout of the fence and the animals' access to available feed and water resources in the area. Social interactions are also an important factor. Some species, such as cows, tend to be more

gregarious, while others, such as goats, may be more independent. This can affect grazing dynamics and the need to separate or group certain animals in specific areas and reinforce fencing. Finally, protection from predators is a key consideration. Some species, such as sheep, are more vulnerable to predator attacks than others. Additional protection measures, such as additional electrified fencing or the presence of guard dogs, may be required to protect these species.

In summary, understanding the differences between livestock species is fundamental to designing fencing and grazing systems that are effective, safe and appropriate for the specific needs of each species. Careful design and maintenance of these systems ensures the health and welfare of livestock, while contributing to vegetation management and environmental conservation in rangeland ecosystems.

6. MONITORING AND ADAPTIVE MANAGEMENT

An assessment of grazing on shrub vegetation should first consider two factors simultaneously (Montoya Oliver, 1996):

- Palatability or palatability of each species.
- Resprouting capacity (resistance to grazing).

Table 7. Grouping of species into classes according to their combination of palatability and regrowth capacity.

Adapted from Montoya-Oliver, (1996).

Class	Palatability	Regrowth	Species	
I	Very high	Baja	Ash (<i>Fraxinus angustifolia</i>) Hackberry (<i>Celtis australis</i>) Olive tree (<i>Olea europaea sylvestris</i> ; <i>Olea oleaster</i>) Olivilla (<i>Phillyrea spp</i>) Common skink (<i>Adenocarpus decorticans</i>) Coronillas (<i>Coronilla spp.</i>)	Brooms (<i>Teline candicans</i> and <i>Cytisus trifloms</i>) Honeysuckle (<i>Lonicera madrevela</i>) Blackberry (<i>Rubus ulmifolia</i>) Sarsaparilla (<i>Smilax</i>) Holly (<i>Ilex aquifolium</i>)

II	High	High	Carob (<i>Ceratonia siliqua</i>) Elm (<i>Ulmus spp</i>) Poplar (<i>Populus spp</i>) Willow (<i>Salix spp</i>) Mulberry (<i>Morus spp</i>) Strawberry tree <i>Arbutus unedo</i>) Laburnum <i>Philiria angustifolia</i>) Durillo (<i>Viburnum tinus</i>) Rose hips (<i>Rosa spp.</i>)	Brambles (<i>Rubus spp</i>) Herbs <i>Calicotome spp</i>) Olive bush <i>Teucrium fruticans</i>) Brooms <i>Cytisus spp</i>) Non-prickly genet (<i>Genistae non prickly</i>) (<i>Genista spp</i>) Myrtle (<i>Myrtus spp.</i>) Carqueixas (<i>Genista tridentata</i>)
III	Medium	Medium	Holm oak (<i>Quercus ilex</i>) Cork oak (<i>Quercus suber</i>) <i>Quercus faginea</i> (<i>Quercus faginea</i>) Pyrenean oak <i>Quercus pirenaica</i>) Juniper (<i>Juniperus communis</i>) Tamarisks (<i>Tamarix spp</i>)	Hawthorns (<i>Rhammus spp</i>) Hawthorns (<i>Crataegus</i> <i>monogyna</i>) Brecina (<i>Calluna vulgaris</i>) <i>Helianthemum</i> <i>Halimium.</i>
IV	Baja	Baja	Rockrose (<i>Cistus populifoliosus</i>) Cowry rockrose (<i>Cistus salvifoliosus</i>) <i>Genista</i> prickly pear (<i>Genista spp</i>) White brooms (<i>Cytisus multiflorus</i>)	Kermes oak (<i>Quercus coccifera</i>) Ruscus (<i>Ruscus aculeatus</i>) Privet (<i>Ligustrum vulgare</i>) Pyrethrum (<i>Pyrus bourgaeana</i>) Undersized heather (<i>Erica spp</i> ; <i>Calluna spp</i>)
V	Very low	Baja	Rockroses (<i>Cistus ladanifer</i> , <i>Cistus</i> <i>Monspaliensis</i>), Rosemary (<i>Salvia rosmarinus</i>) Blackthroat (<i>Phlomis purpurea</i>) Large heather (<i>Erica spp</i> ; <i>Calluna spp</i>),	Mastic (<i>Pistacea lentiscus</i>) Cornicabra (<i>Pistacia terebinthus</i>) Saw palmetto (<i>Chamaerops humilis</i>) Aladdin (<i>Rhamnus</i> <i>alaternus</i>) Broom (<i>Retama spp</i>)
VI	Null	Baja	Oleander (<i>Nerium</i> <i>oleander</i>) Oleander (<i>Nerium oleander</i>) Senecio (<i>Senecium spp</i>) Bryonia <i>spp</i>	Various ferns <i>Carpinus betulus</i> <i>Thymelaea spp.</i>

The first group would include highly palatable species with low regrowth capacity. If they are present and livestock are present, they will be consumed, so they are not very indicative of grazing intensity; or, rather, their presence will be indicative of low grazing pressure (low stocking rate).

For grazing assessment, the most important species would be the following groups or classes. At the second level would be less palatable species but with a high regrowth capacity. When they are heavily nibbled they would indicate high grazing pressure or stocking, with a level that would threaten tree regeneration.



Figure 80. Sheep grazing on broom.

Author: Ildefonso Caballero.

Next come the tree species of the Mediterranean forest, which are less palatable than the previous ones and have a lower regrowth capacity, so that if they are observed to be consumed, regeneration would already be in danger and would indicate excessive grazing intensity; in addition, the absence of the species in group I would be evident. The browsing of species with low palatability and no regrowth capacity indicates a level of grazing intensity that would prevent the natural regeneration of the trees and probably corresponds to situations of underfeeding or imbalance in the diet of the animals.

Finally, non-palatable toxic species may be consumed occasionally for their nutraceutical or medicinal properties, but when they show clear signs of browsing, and the more palatable species have disappeared, overgrazing is clearly taking place. A more detailed assessment by sites, areas or enclosures could be made at the level of each species, scoring the level of consumption or damage and thus the level of grazing of each plot. A model or template for data collection by species is proposed in Table 8.

Table 8. Model template for grazing and regeneration assessment.

Species	Class	Palatability	Regrowth	Consumption					
				0 (nil)	1 (scarce)	2 (bass)	3 (medium)	4 (high)	5 (total)
	I	Very high	Baja						
	II	High	High						
	III	Medium	Medium						
	IV	Baja	Baja						
	V	Very low	Baja						
	VI	Null	Baja						

By combining the palatability-sprouting groups and their damage-consumption level score, the degree of conservation could be rated and the capacity or possibility of natural regeneration of the shrub vegetation could be assessed. In the table below, the "Score" is obtained by vertically checking the damage-consumption level in each class.

Table 9. Rating from 0 to 10 of the degree of regeneration.

Class	Score									
	0	1	2	3	4	5	6	8	9	10
I	0	1	2	3	4	5	5	5	5	5
II	0	0	1	2	3	4	5	5	5	5
III	0	0	0	1	2	3	4	5	5	5
IV	0	0	0	0	1	2	3	4	5	5
V	0	0	0	0	0	1	2	3	4	5
VI	0	0	0	0	0	0	0	0	0	0

According to the table above, to ensure the regeneration of dehesa and shrub pastures, these should be kept below a score of 5. The most palatable species could show a high consumption or level of damage (groups I and II with a score of 4 to 5), while the species of the *Quercus spp.* group (group III) would not exceed an intermediate consumption, with only a few nibbled individuals and without reaching total defoliation. Species in the poorly palatable groups (IV, V and VI) should have very few nibbles.

By repeating these assessments over the years on selected, representative patches, they can help to interpret trends and adapt livestock management according to the intended objectives (regeneration of grassland, expansion or elimination of shrub pastures). The criteria for assessment, monitoring and interpretation would therefore only be valid on a farm-by-farm basis and may not be applicable to other farms. Therefore, the assessment, monitoring and interpretation criteria would only be valid on a farm-by-farm basis and may not be applicable to other farms.

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