Agroforestry of high nature and cultural value: Guidelines for farmers

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Contents

AGFORWARD (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

1 Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This Deliverable 2.6 (2.3) contributes to the second and the fourth objective. It contains guidelines on innovative practices to enhance the economic, environmental, and social outputs of agroforestry systems of high nature and cultural value. Similar reports exist for agroforestry with high value trees, agroforestry in arable lands, and agroforestry for livestock systems.

2 Leaflet titles

Fifteen innovation leaflets derived from the "high nature and cultural value agroforestry" participative research and development network have been produced and presented with other innovation and best practice leaflets in a folder (Balaguer et al. 2017) (Figure 1; Table 1).

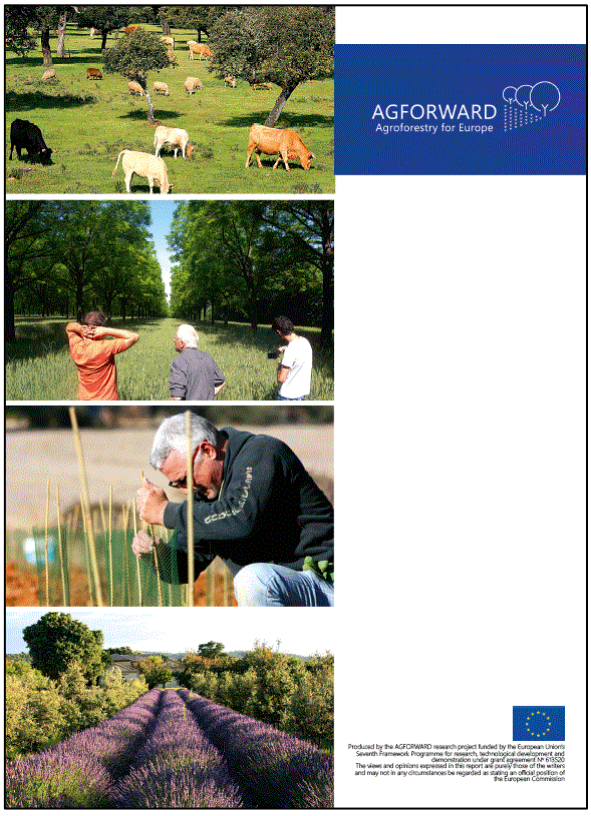

Figure 1. The 15 innovation leaflets focused on agroforestry of high nature and cultural value were included in a folder with a total of 46 innovation leaflets and 10 best practice leaflets (Balaguer et al. 2017)

Table 1. Titles of the 15 leaflets addressing innovations for agroforestry systems of high nature and cultural value (see reference list for authorships)

Number	Stakeholder group and *lead partner*	Title of leaflet
1	Spanish dehesa, *University of Extremadura, Spain*	Establishing pastures rich in legumes How to develop a more sustainable dehesa farm
2		Triticale in Iberian dehesas Searching for shade-adapted forage crops
3		Fast rotational intensive grazing A holistic management approach
4		Tree regeneration in grazed wood pastures How to assist natural regeneration?
5	Portuguese montado, *Instituto Superior de Agronomia, Lisbon, Portugal*	Managing shrub encroachment in cork oak montado Implications for tree regeneration, tree and cork growth
6		Modelling livestock carrying capacity in montados. Do trees really promote pasture production?
7	Greek Valonian oak woodlands *TEI Stereas Elladas, Greece*	Rediscovering valonia oak acorns. Getting more income from your valonia oak trees
8	Italian open oak woodlands *CNR, ISPAAM Sassari, Italy*	Shade tolerant legumes. Improving the productivity of Mediterranean silvopastures
9	French bocage *INRA UMR, Rennes, France*	Multi-functional hedgerows in the bocage systems of France. Rejuvenating a traditional system through farmer-led innovation
10	British wood pastures *Cranfield University, UK*	Invisible fencing in wood pastures. A comparison of costs
11	German Spreewald floodplain *Brandenburg University of Technology Cottbus-Senftenberg, Germany*	Trees and the restoration of waterways in the Spreewald floodplain Maintaining the benefits of historical land use
12	Hungarian wood pastures *University of Sopron KKK, Hungary*	Restoration of abandoned wood pasture Renewing the past for the future
13	Transylvanian wood pastures *Babes-Bolyai University and Sapientia University, Romania*	Protecting large old trees in wood-pastures A keystone for biodiversity in Romanian wood pastures
14		Grazing and biodiversity in Transylvanian wood-pastures
15	Scandinavian Reindeer husbandry *European Forest Institute and Swedish University of Agricultural Sciences*	Enhancing reindeer husbandry in boreal Sweden. An economic evaluation of the use of GPS collars

The 15 leaflets focus on innovations and practices that were tested to improve the economic, environmental or social aspects of the management of agroforestry systems of high nature and cultural value. Each two page leaflet describes the challenge addressed, the innovation, the advantages and the recommendations in a user-friendly format. Although each leaflet was produced by a specific stakeholder group, the 15 leaflets together should also be viewed as collective guidelines that may have relevance to other regions and systems.

3 Brief description of the key messages

3.1 Maintenance of the tree cover and the two-layer structure

One of the main innovations demanded by stakeholders (Moreno et al. 2015a, b) concerned the maintenance of the trees and the two-layered vegetation that characterize wood pastures. This is because traditional wood pastures systems are either being degraded through the progressive loss of trees or plot abandonment. Leaflet 13 (Hartel 2017a) focuses on the importance of protecting large old trees in wood-pastures and highlights the importance of engaging local communities in the protection of historical, cultural and natural heritage sites and the need of funds to actively maintain the multiple values of these systems. Leaflet 4 (Caceres et al. 2017) proposes a series of low-cost management practices to assist the natural regeneration of trees in grazed wood pastures. These include the use on seed acorns of repellents against rodents, the use of pruned branches to protect seedlings and thorny wire mesh to protect saplings, and to benefit of the nurse shrubs species.

Leaflet 5 (Paulo et al. 2017), Leaflet 11 (Tsonkova and Mirck 2017) and Leaflet 12 (Varga 2017) by contrast focus on the shrub understory management needed for the maintenance or rejuvenation of encroached wood pastures and hedge-rich agroforestry landscapes. They stress the importance of considering the temporal, spatial and economic dimensions of shrub management. In places, a current surplus of wood biomass (e.g. abundant shrubs and old, but not ancient, trees) provide an opportunity to market biomass products (e.g. wooden chips for heaters) that could finance the cost of renewing the agroforestry system. They also highlight that grazing management is important for the maintenance of renewed systems.

3.2 Grazing schemes and GPS-based technologies

Indeed, the optimisation of grazing schemes and the reduction of cost of herding was also the focus of innovation demand by stakeholders (Moreno et al. 2015a, b). Leaflet 3 (Catalan et al. 2017) explains the advantages of the fast-rotational intensive grazing (very high instantaneous stocking rates and long recovering periods for paddocks), which not only increases productivity but also enables ecosystem improvements such as carbon sequestration, soil quality, biodiversity and natural regeneration of tree cover, Leaflet 10 (Burgess et al. 2017) and Leaflet 15 (Berg et al. 2017) show the interest of introducing new technologies to reduce the costs of herding livestock (cattle in UK and reindeers in Sweden, respectively). Invisible fencing operates with cattle collars that produce an audible or electric stimulus when cattle are close to a buried wire. GPS collars seem very efficient to manage reindeer herds in very extensive silvopastures. Whilst these technologies are currently more expensive than other options, they can offer social and management advantages and future price reduction for devices is probable.

3.3 Increasing system productivity and creating new market opportunities

Low productivity and profitability is a general feature of agroforestry systems of high nature and cultural value. Increasing on-farm fodder production could reduce farm costs and making use of on-farm resources can help support the branding of high quality foods. Leaflet 1 Hernandez-Esteban and Moreno 2017) and Leaflet 8 (Franca et al. 2017) report that sowing self-seeding legume-rich mixes can increase the protein content of understory pasture, which increases pasture quality and productivity without compromise biodiversity of plant community. Leaflet 2 (Santamaria et al. 2017) demonstrates that the cultivation of triticale as a double-use fodder crop (grazed in winter and mowed in late spring to produce hay which can be consumed later in summer). Leaflet 6 (Palma et al. 2017) describes some modelling work that shows that intermediate levels of tree cover in Mediterranean wood pastures extends the number of days when the system can support a given population of livestock. Leaflet 7 (Papadopoulos 2017) provides an example of creating new market opportunities for an abandoned use of agroforestry product. The use of acorn cups for tanning and nuts for flour production can provide supplementary income from high nature and cultural value agroforestry systems.

3.4 Reinforcing the provision of ecosystem services

The enhancement of ecosystem services is also considered is the guidelines. Leaflet 9 (Thenail et al. 2017) describes the renewing of hedge-based agroforestry systems in the bocage of Brittany in France under multi-purpose objectives. These objectives (as with Leaflet 11; Tsonkova and Mirck 2017) include the production of marketable biomass. Other objectives include the reconnect of sections of old hedgerows to reinforce the structure and ecological functions of the whole bocage landscape, with positive effects on biodiversity and soil quality. Leaflet 12 (Hartel 2017a) and Leaflet 13 (Hartel 2017b) describe the importance of the conservation of scattered trees in pastures, including large ancient trees, and the conservation of traditional breeds for the conservation of the biodiversity in wood pastures.

4 Acknowledgements

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Appendix A: The innovation leaflets

Agroforestry Innovation leaflet 01: Establishing pastures rich in legumes (Hernandez-Esteban and Moreno 2017).

Agroforestry Innovation leaflet 02: Triticale in Iberian dehesas (Santamaria et al. 2017).

Agroforestry Innovation leaflet 03: Fast rotational intensive grazing (Catalan et al. 2017).

Agroforestry Innovation leaflet 04: Tree regeneration in grazed wood pastures (Caceres et al. 2017).

Agroforestry Innovation leaflet 05: Managing encroachment in cork oak montado (Paulo et al. 2017).

Agroforestry Innovation leaflet 06: Modelling livestock carrying capacity in montados (Palma et al. 2017).

Agroforestry Innovation leaflet 07: Rediscovering valonia oak acorns (Papadopoulos 2017).

Agroforestry Innovation leaflet 08: Shade tolerant legumes (Franca et al. 2017).

Agroforestry Innovation leaflet 09: Multifunctional hedgerows in the bocage systems of France (Thenail et al. 2017).

Agroforestry Innovation leaflet 10: Invisible fencing in wood pasture (Burgess et al. 2017)

Agroforestry Innovation leaflet 11: Trees and the restoration of waterways in the Spreewald floodplain (Tsonkova and Mirck 2017).

Agroforestry Innovation leaflet 12: Restoration of abandoned wood pasture (Varga 2017).

Agroforestry Innovation leaflet 13: Protecting large old trees in wood-pastures (Hartel 2017a).

Agroforestry Innovation leaflet 14: Grazing and biodiversity in Transylvanian wood-pastures (Hartel 2017b).

Agroforestry Innovation leaflet 15: Enhancing reindeer husbandry in boreal Sweden (Berg et al. 2017).

Establishing pastures rich in legumes

How to develop a more sustainable dehesa farm
www.agforward.eu

View of pasture rich in legumes sown in November 2013 (picture taken in May 2014) in plots grazed by sheep in the dehesa farm in "Atoquedo", located in the National Park of Monfragüe (Torrejón el Rubio, Extremadura, Spain). *Ref : G.Moreno*

Why establish biodiverse pastures rich in legumes?

Dehesa is a man-made silvopastoral ecosystem. It is characterised by a high biodiversity, but pasture production can be low, especially in winter and summer. Consequently, many farmers are dependent on external fodder sources, making the dehesa a less economically sustainable ecosystem.

Establishing permanent pastures rich in legumes could result in a substantial positive change for farmers and stock breeders by mitigating seasonal yield differences, and reducing the critical grazing period for cattle. Through sowing commercial varieties which were previously present in the natural pastures, there is minimal risk for native communities. The potential benefits have been demonstrated on seven dehesa-farms in Extremadura, Spain, on parcels that were sown with legumes, at various times, over the last 20 years.

Detail of the biodiverse sown pasture species.
Ref : E. Juárez

What kind of seed mixture is the most appropriate?

The dehesa is a distinctive ecosystem characterized by a mosaic of shade imposed by scattered *Quercus* spp. trees and shaped by the moderate grazing pressure (<0.5 Livestock Unit ha^{-1}). The biggest challenge to estabishing leguminous pastures is the spatial heterogeneity in terms of light, temperature and humidity, which produces two main microhabitats: beneath and beyond the tree canopy. In addition to meeting this challenge, the seed mixture species must have a high self-reseeding capacity, and also be able to establish deep roots to deal with cattle pressure and long dry summers.

Taking all these considerations into account, some species (such as: *Trifolium subterraneum, Ornithopus compressus, T. michelianum, T. striatum and T. glomeratum*) seem to be very well-adapted to the dehesa system. These species performed better than the rest of the legumes trialled, were more productive and also more persistent. Consequently, they are considered suitable candidates for mediterranean silvopastoral systems. Seeds were sown at a density of 20 kg/ha, buried around 0.5-1.0 cm. Re-seeding is not usually needed before 20 years.

Sown pasture rich in legumes in the dehesa farm Casablanca (North Cáceres, Spain)
Ref : Ana Hernández

Produced by the AGFORWARD research project funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No 613520

Advantages

- Sown pastures perform well both beneath and beyond the tree canopy.
- Noticeable increase in yield (up to 300% in the first years).
- Improvement of pasture quality (protein content almost doubled) due to the increase in the proportion of legumes.
- Reduced costs as commercial nitrogen fertilization is replaced by rhizobium fixation.
- Enhanced economic and ecological sustainability of the dehesa system.

View of the pasture in winter, comparing a native pasture (right) with a sown pasture rich in legumes (left)
Ref : Ased Agro Company

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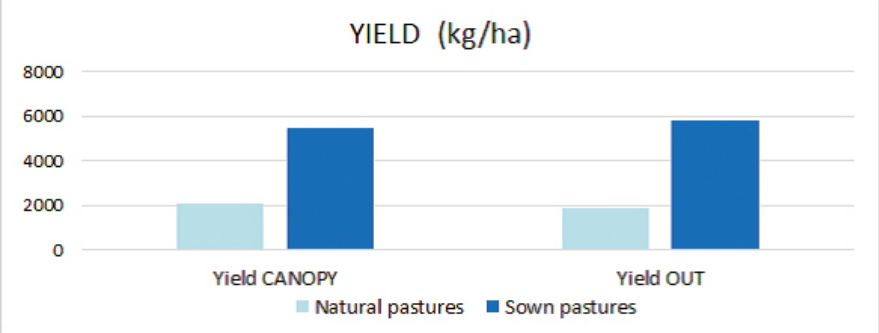
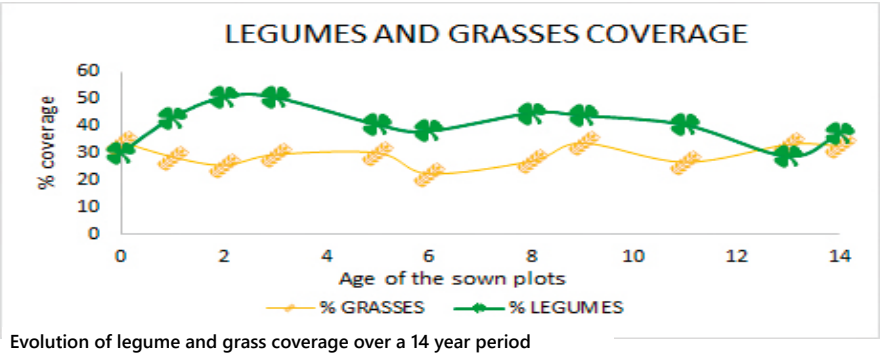
Improving pasture and soil quality

Greater yield is obtained (almost tripling the natural pasture level) and, over time, the coverage of legumes increases significantly. In comparison with the natural pastures, during the first years after the sowing, legumes coverage improved by 66%, stabilizing at an increase of 35% 12 years after initial sowing.



Average yield (kg/ha) beneath and beyond tree canopy in natural and sown pastures

The increase of legumes coverage is accompanied by an increase in nitrogen fixation, thus the need for nitrogen fertilizers is dramatically reduced. In addition, the content of carbon accumulated into the soil shows a positive tendency with age, both under and beyond canopy areas. This underlines the potential of sown legumes as a means to increase the resilience of this silvopastoral systems against the negative effects of climate change.



Evolution of legume and grass coverage over a 14 year period

Further information

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Triticale in Iberian dehesas

Searching for shade-adapted forage crops

www.agforward.eu

Dehesa Los Llanos in Siruela (Extremadura, Spain) cultivated with triticale to feed livestock. *Ref : G.Moreno*

Why triticale?

Productivity of natural pastures in Iberian dehesas is usually low and very variable (on average 1440 kg dry matter (DM) ha/yr). They also provide low nutritive value forage, containing 4-20% legume fraction, 9-12% crude protein, 44-59% neutral detergent fibre and 28-37% acid detergent fibre.

In order to improve the productivity and quality of herbage biomass, and to supplement the natural pasture during shortage periods, farmers have traditionally implemented two practices: the sowing of well-adapted productive pasture species, and/or the sowing of forage crops. In dehesa ecosystems, those fodder crops often play a fundamental role in livestock feeding as a complement to natural pastures, both in productivity and in quality. Triticale, a hybrid of wheat and rye, is now becoming a popular fodder crop on Mediterranean livestock farms.

Livestock (cattle, goats and Iberian pigs) grazing in triticale crop in winter.

Sowing and management

It is recommended that triticale sowing is carried out in late autumn, after the first autumn rainfall, following light tillage and using a seeding rate of around 200 kg/ha. Depending on the initial mineral soil levels, a N-P-K fertilization might be applied either before or during sowing (70 N kg/ha, 40 P_2O_5 kg/ha and 70 K_2O kg/ha).

The recommended crop management is direct grazing by mid winter, to meet the livestock food requirements during this period. The spring forage should be harvested and preserved as hay to be consumed in summer. Optimizing the grazing intensity and period in winter is critical to obtain strong re-growth and, consequently, a good total forage yield. Grazing should be performed before plants reach the growth stage 30 of the Zadocks scale and should not be very intense. The late-spring cut should be made before the growth stage 73 of the Zadocks scale to obtain a good nutritive value forage.

Due to the poor and shallow soil usually found in dehesa ecosystems, a yearly rotation in the crop area is highly recommended.

Harvesting cereal fodder crop in the dehesa
Ref : HOY Agro - www.hoy.es/fotos/agro

AGFORWARD Agroforestry for Europe

Produced by the AGFORWARD research project funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No 613520

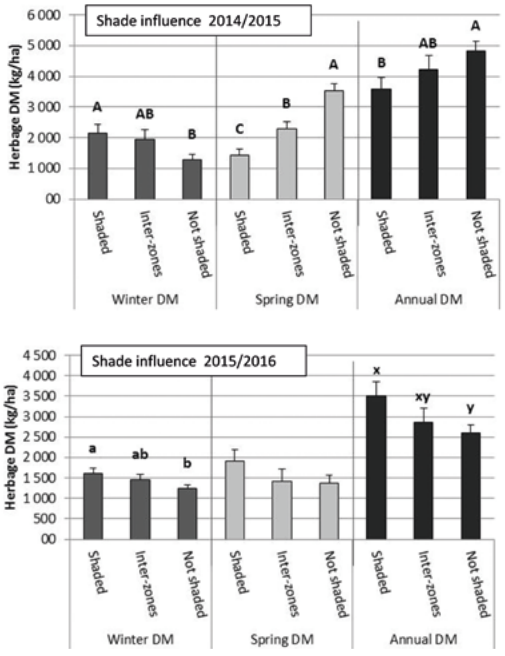
Advantages

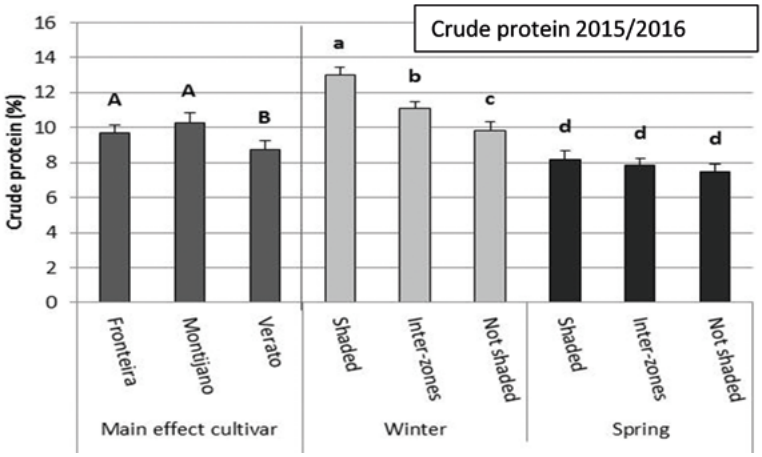
Among forage crops, the cultivation of triticale, a high-productive cereal under Mediterranean conditions, is increasingly recognised by farmers as a potential alternative. This is due to its great capacity to be grazed in winter, and then cut in late spring for hay production.

Under this dual-purpose use, the triticale crop can produce 3000-5000 kg/ha of high-quality forage, providing additional fodder for livestock rearing. This is especially valuable during critical shortage periods, such as winter and summer, when the natural pasture production is very scarce in these areas.

Under trial conditions, with scattered oak trees in the field (5-30 trees/ha; 3-25% cover), rainfed, moderate fertilization and no spraying with herbicides, triticale produced 3000-5000 kg/ha of a high-quality forage, providing an additional fodder for livestock rearing. Triticale was first grazed in winter (January - February) and then grazed again, either in June or, in more productive fields, by the end of May.

The results showed that tree cover has a high and clear influence on the biomass yield and quality parameters of the triticale forage. Whilst the winter herbage production was enhanced by tree cover, spring and annual productivity decreased by around 30% under shade conditions. The nutritive value of the forage was generally enhanced by tree cover, particularly in terms of crude protein and fibre in the spring harvest. None of the cultivars examined showed a special aptitude to grow under shade conditions. Yield differences among cultivars, which were not very high, depended on the specific climatological conditions of the growing season.





Left: Influence of the shade conditions on the biomass dry matter (DM) production under the trees (*Quercus ilex*), in the edge and in the open areas.
Above: Influence of the cultivar, shade condition, and season on the protein content of the triticale cropped in the dehesa Los Varales (Badajoz, Spain)

Further information

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Fast rotational intensive grazing

A holistic management approach

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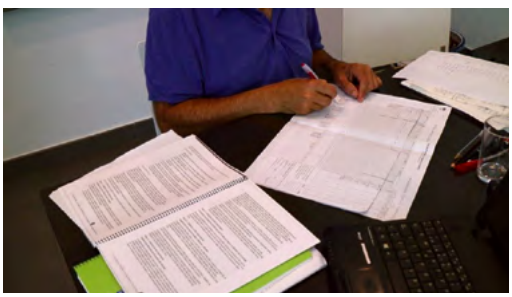
Sheep grazing under an intensive fast-rotation scheme in Mundos Nuevos Farm (Campillo de Llerena, Extremadura, Spain). *Ref : María Catalán*

Why holistic management?

The increased demand for meat is driven by a rising human population, and a dramatic growth in meat consumption per person. Farmers and scientists have sought to curb the adverse environmental impacts of livestock by increasing production efficiency, and reducing its contribution to human consumption. Reduction in livestock feed components, which compete with human food crop production, is one approach to mitigating negative environmental impacts and strengthening future food security.

Mediterranean pastures, such as dehesa and montado, face considerable challenges. Continuous grazing results in dramatic seasonal variations in grass production and difficulties in providing sufficient fodder for livestock throughout the year. Consequently, the dependence on external feed supplies compromises the profitability of many farms. Better adapted grazing management schemes are needed to enhance the resilience of the dehesas and montados.



Planning how many animals and time per paddock, and periodical monitoring of soil and pasture are the bases of holistic grazing. *Ref : María Catalán*

How it works

The concept of Holistic Management emphasises that the sward not only provides nutrients to the ruminants, but also contributes to "feeding the soil" (Savory 2013). The basis for this approach is the grazing patterns of wild herbivores roaming unrestricted over large rangelands.

These animals will often spend a short time in a small area before moving on, leaving behind concentrated manure, urine, and considerable plant residues both above and below ground, including remaining root material. These contribute to soil organic matter and nutrients.

How to implement

The basis of the intensive fast-rotation grazing is planning. After estabishing the values of the farm (the holistic context), three stages of planning should be developed: grazing, financial and land. Monitoring is essential to ensure timely feedback, and to makes changes if the current approaches do not satisfy production or holistic goals.

Two separate grazing plans should be developed in areas where, due to excessive cold or dry conditions, there is insufficient time for pasture recovery. To know and respect the recovery period (*RP*) of the grass, it is important in order to maximize pasture production and its environment-side effects. It is also important to avoid grazing too early, and when grasses are still recovering. The grazing period (*GP*) can be estimated according to the following function:

GP=Recovery period (*RP*) / (n-1), where n is the number of paddocks.

More paddocks equates to a shorter grazing period. This leads to a better grass response, less disease problems (parasites mostly require seven days to complete their life cycle) and has a positive animal impact (e.g. less compaction).

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Advantages

This new pasture management approach was introduced to Spain and Portugal five years ago. The farmers who have adopted the approach have increased stocking rates while improving the health of *Quercus* trees and water cycle, and reducing erosion.

As this is a new system, there is still limited knowledge regarding how it works in practice, especially the animal performance (growth and health) and pasture quality.

For effective Holistic Management, the whole farm should be split into many small paddocks using electric fences.

In addition, a low-cost network of pipes and livestock waterer is needed to provide the livestock with sufficient water.

Natural holm oak regeneration under Holistic Management (Defesinhas Farm, Elvas, Portugal)
Ref : María Catalán

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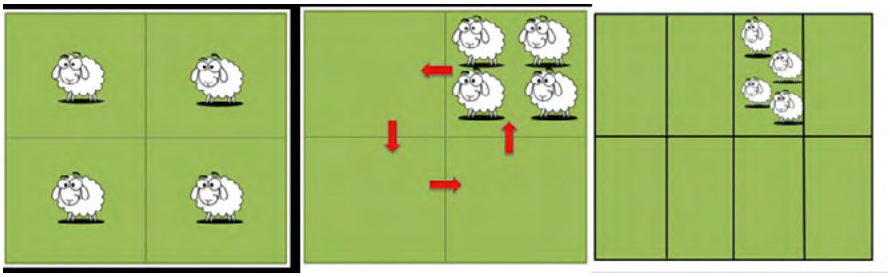

Comparison of continuous grazing (left) vs fast-rotation grazing (center and right) in an example with 4 and 8 paddocks and 180 days of growing season for the pasture layer.

Continuous grazing: 4 paddocks, grazing period of 180 days (the whole growing season), with no time for recovery; days of use per paddock: 100 % of the days of the growing season.

Fast-rotation grazing: 4 paddocks, grazing period of 20-40 days with recovery periods of 60-120 days; days of use per paddock: 33%.

Fast-rotation grazing: 8 paddocks, grazing period of 8-16 days with recovery period of 60-120 days; days of use per paddock: 13%.
Ref : María Catalán

The most important commercial activity in dehesa and montado is free-range livestock farming (Campos et al. 2013). The management of natural pastures aims to increase the pasture quality (legumes, protein, minerals) and quantity. Consequently, management is focused on three fundamental issues: livestock management, legumes introduction and phosphorus fertilizer application. The sustainability of dehesas has been questioned in recent years as a result of the adoption of more intensive and simplified management systems which have impacted negatively on vegetation and soil properties, and increased soil erosion rates.

The Holistic Management approach, based on time-controlled grazing systems, not only increases productivity, but also enables ecosystem improvements: this includes soil properties (soil structure, amount of organic matter, water efficiency, and availability of soil nutrients), and pasture species cover and composition. Long recovery periods also provide an opportunity for the natural regeneration of tree cover.

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Tree regeneration in grazed wood pastures

How to assist natural regeneration?

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View of the young surviving trees a few years after an artificial plantation in an open dehesa stand. *Ref: M. Bertomeu*

Why do we need to support tree regeneration?

Dehesas and Montados are very suitable for pasture production. However, livestock grazing hampers the natural regeneration of the tree layer, especially in areas with challenging soil and climate conditions. Seed predation by domestic and wild animals, abiotic stresses (drought, high summer temperatures and infertile soils), and the lack of suitable microsites for seed germination are major impediments to seedling establishment and survival.

The maintenance of Iberian dehesas and montados depends on the sufficient regeneration of the trees. In many areas, however, natural regeneration does not compensate the loss of trees and the tree population is too old. To safeguard the sustainability of these pastures, it is necessary to take steps to actively support tree regeneration and ensure that sufficient number of young trees are established well before the old ones die.

The constraints of current approaches to tree regeneration

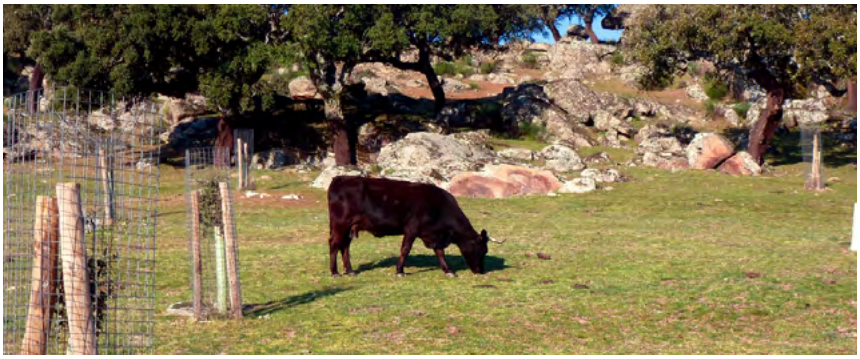
The three most common techniques to enhance the tree regeneration of Iberian dehesas and montados are (i) planting young plants (1-2 years old) at high density (400-600 plants/ha) with complete exclusion of grazing for 20 years; (ii) planting and protecting a small number of young trees scattered in very open stands and maintaining grazing; and (iii) simply fencing-off large areas to prevent livestock grazing and waiting for trees to establish naturally.

The first approach entails using nursery grown seedlings, mechanized land preparation, hired labour for planting, and results in a loss of rent by grazing exclusion. The second approach requires sturdy tree shelters to protect against grazers. A standard wire mesh protector has been widely used in subsidized wood pasture tree planting projects. However, the high cost of up to 30 Euros per unit limits its use.

Both these options (fully artificial regeneration) are challenging on a large scale (300-700 Euros/ha for 20 trees/ha) without external financial support. Furthermore, these approaches lack flexibility to adjust to contingencies that compromise project success (e.g. a drought), and frequently the survival of planted seedlings is very low (Moreno and Franco 2013).

For the third approach (natural regeneration by grazing exclusion) tree recruitment is very slow (15 to 25 years), and only small portions of the farm can be regenerated, as farmers cannot afford to have sizable areas of exclusion for so long.

Iberian wood pastures grazed with low stocking rates and with abundant natural regeneration of oaks. *Ref: F. Pulido*

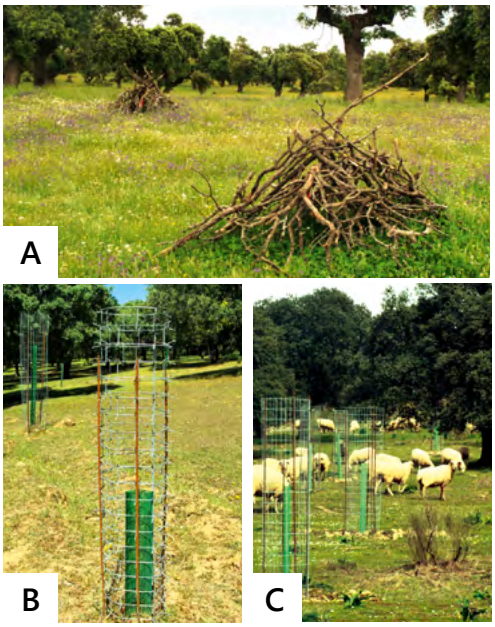


Artificial tree regeneration in grazed wood pastures, by using individual shelters. *Ref: M. Bertomeu*

Produced by the AGFORWARD research project funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No 613520

Advantages

- In farms grazed by small size livestock (e.g. sheep), the dehesa manager could use natural low-cost protectors created by piling up branches over seedling (5 Euros per unit).
- Artificial thorny shelters ("Cactus type"), 15 Euros per unit could be used for protection from cattle and wild ungulates.
- Wire mesh protectors are the most appropraite method on farms grazed by bullfighting cattle.
- To use shade shelter increases the survival of the seedling, thus it is an appropriate method.



Alternatives types of protectors for oak seedlings: natural protection with piling up branches (A), artificial thorny protector (B) and standard steel mesh protector (C).

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A multi-approach to regenerate trees at low cost

1. Collecting seeds

When? Preferably, acorns should collected during "masting" years of high production to ensure the selection of large, mature and healthy high quality seeds.

How? To ensure the genetic variability, acorns should be collected within the target stand from around 30 to 50 trees that are at least 100 m apart. Acorns can be stored for a few weeks in moist sand kept in cool conditions.

2. Sowing

Acorns should be sown as soon as possible after seed collection, preferably in late autumn or early winter, planting 2 acorns per hole at 5 cm depth.

3. Creating microenvironments favourable to tree recruitment

3.1. Nurse shrubs

Trees grow and survive better under the canopy of leguminous shrubs, as the microclimate, soil fertility and soil moisture conditions are more favourable than in the open areas. Moreover, these and other thorny/dense shrubs, protect seedlings from browsing (Rolo et al. 2013).

3.2. Creating regeneration microsites

In the absence of shrubs, favourable microsites can be created by piling up fine branches left over from pruning operations. Besides, they can also function as regeneration hotspots by encouraging rodent dispersal by providing shelter for dispersed acorns and seedlings.

4. Preventing acorn predation

Seed germination rates increase if acorns are coated with commercial or home-made repellents. For instance, the removal by mice of sown acorns decreased by 50% when acorns are coated with fresh dog faeces (Pulido et al. 2016).

5. Protecting young tree recruitment

The demand for alternative, cost-effective methods to protect seedlings is increasing. In general these alternatives are aimed at reducing either the cost (e.g. of the material, the protecting devices, and the labour) and/or increasing plant survival in the long term (Cáceres et al. 2017). The use of artificial thorny protectors (https://protectorcactusworld.com/) give promising results, reducing costs and lengthening the duration of the protection.

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Managing shrub encroachment in cork oak montado

Implications for tree regeneration, tree and cork growth

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Natural tree regeneration protection in an oak montado stand with low tree cover. *Ref : G.Moreno*

Why manage shrub encroachment in montado?

The impact of the shrub layers that naturally occupy the montado ecosystem can often be positive. Benefits include:

- natural tree regeneration
- protection from excessive light exposure and animal predation
- soil protection
- increased carbon sequestration
- increased fodder diversity
- increased biodiversity

However, there can also be negative impacts. These include :

- tree-shrub-pasture competition for natural resources (water, nutrients and light)
- increased fire risk

The balance between positive and negative impacts varies between farms and even within a single farm. It depends on factors such as:

- species composition and age
- tree age and vitality
- climate conditions
- soil water holding capacity
- grazing animals

How to manage shrub encroachment?

A dynamic and holistic management of shrub encroachment in cork oak silvopastoral systems is essential to optimise the positive effects of shrubs, and reduce their negative impacts in the ecosystem. Effective shrub management involves making informed decisions regarding:

- frequency of shrub removal
- mechanical equipment used
- pasture management

Shrub management operations should consider:

- Climate conditions: dry years increase tree/shrub competition for water, therefore encroachment should be reduced
- Shrub distribution, composition and height: high percentage of *Cistus ladanifer* occurrence in extreme dry years is associated with an increase of tree mortality rates
- Ploughing management: a minimum of 5 years between soil ploughing operations should be considered
- Animal grazing: grazing can be an effective alternative for mechanical shrub control (recommended limit value of 0.4 Livestock Units/ha)
- Protection against soil erosion and tree root system damage: no tillage or minimum tillage, or an overall use of mechanical equipment that does not require a deep mobilization of the soil is recommended, especially in areas characterized by shallow soils and high slopes
- Natural tree regeneration: promote the marking and protection of young trees (natural regeneration)
- fire risk assessment: contact between shrubs and tree crowns should be avoided

Improved pasture in a cork oak stand. *Ref : Joana Amaral Paulo*

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Advantages

Effective shrub management is a dynamic process. It is important to take a holistic approach and consider temporal, spatial, economic and social dimensions. Effective management can lead to:

- reduction of management costs
- greater operational effectiveness and efficiency
- an increase in the frequency of viable young trees through natural regeneration
- increase in superficial water availability particularly during the spring
- preservation of tree root systems
- reduction of fire risk

Cork oak stand characterized by a multispecies shrub layer. *Ref : Paulo Firmino*

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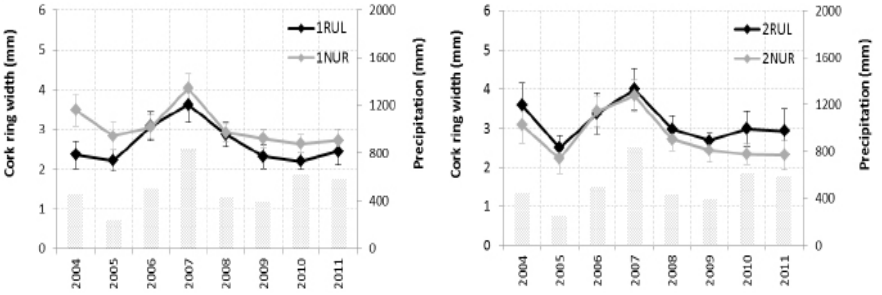
The following two management systems were compared:

a) mechanical shrub removal at 3–4 year intervals followed by lupin pasture creation. The two blocks of this treatment were named "1RUL" and "2RUL".

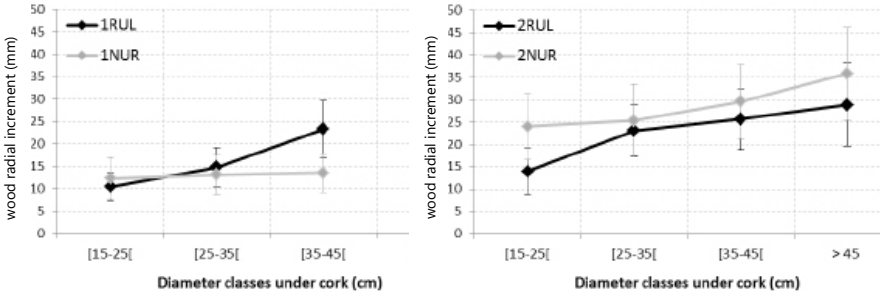
b) mechanical shrub removal at 10 year intervals (restricted to the year prior to debarking). The two blocks of this treament were named "1NUR" and "2NUR".

Results show:

- For an annual response period (short term): cork growth is related to total precipitation, irrespective of the presence or absence of shrub encroachment.



Mean annual cork ring measured in a cork samples, in relation to annual precipitation (1 October to 30 September). Vertical bars indicate standard deviation value. Block 1 on the left and block 2 on the right.



Wood diameter increment (mm), 2003-2012, by diameter at breast height class (under cork) for each treatment. Block 1 on the left and block 2 on the right.
RUL - treatment consisting on understory removal and lupine pasture installation
NUR - treatment consisting in spontaneous understory vegetation maintenance for the complete cork growth rotation period.

- For an annual response period (short term): no significant differences were found for cork annual growth between the two management alternatives.
- For a response period of 9 years (long term): no significant differences were found between the two management alternatives for cork thickness and tree diameter growth.

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Modelling livestock carrying capacity in montados

Do trees really promote pasture production?

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Why use trees on grazed areas?

First impressions are often that the presence of trees in pasture systems will lead to a reduction in pasture production due to the light and water competition. However, other effects on the system dynamics and water availability may be beneficial to nutrient cycling, yield, and pasture productivity.

Trees affect wind speed and temperature, creating a milder climate by providing shade under the canopies. This microclimate can improve pasture production and availability (more production in winter and delayed drying in early summer), and reduce livestock energy requirements (Moreno et al. 2013, Palma et al. 2016)

During cold winter, grass grows more beneath the trees. *Ref: D. Howlett*

Cattle and pigs grazing together in an Iberian dehesa/montado. *Ref : G.Moreno*

Using models to predict productivity

"Yield-SAFE" is a model that is used for predicting the productivity of agroforestry systems (Palma et al. 2016). One advantage is that it uses easily obtainable variables. The parameters for the main tree and crop species are already available, along with the main soil types, so there is only need to:

- choose the tree and/or crop species and soil type/depth
- select an area for the simulation (current and future climate data are automatically accessed)
- define initial values for biomass, leaf area, soil and water (otherwise default values will be used)
- define the management e.g. tree and/or crop density, days of planting, pruning, thinning and harvesting

The model simulates tree and understory growth, and all the interactions that exist between these two components regarding water use, light competition and the canopy effect on the microclimate. Growth is translated into energy and used to compute the carrying capacity of the system.

For Iberian dehesas and montados, the model can estimate:

- production of pasture and acorns
- the canopy effect on microclimate (temperature and wind)
- the carrying capacity (livestock units per ha)
- the effect of heat stress reduction on livestock weight gain.

The average carrying capacity values in montados/dehesas systems are between 0.3 and 0.5 (ranging from 0.15 to 0.7) livestock units per ha (López-Díaz et al. 2014). The Yield-SAFE model can be used to experiment with different climate, soil quality and tree density values to determine the system's response and the number of days the system produces enough energy to support the determined carrying capacity.

There is a delay in pasture dryness in the summer underneath the trees. *Ref: A. Carrara*

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Advantages

Adult trees compete with the pasture for light and water. The improved microclimate delays the onset of grass dryness in late spring; this increases the number of grazing days in pastures with trees and benefits livestock by reducing their daily energy needs (e.g. less heat stress).

Adjusting the number of trees can increase the number of days when the system can produce enough energy to support the pre-selected carrying capacity.

Cork oak stand characterized by a multispecies shrub layer. *Ref : Paulo Firmino*

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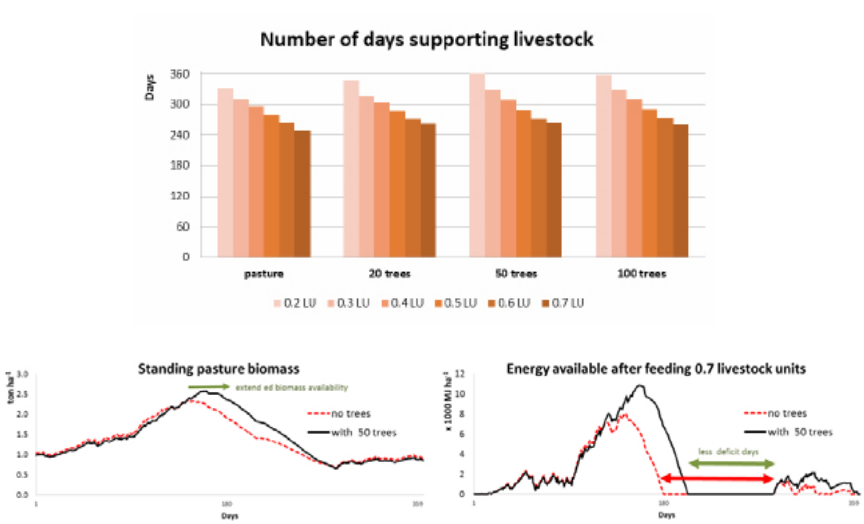

Above: Number of days the system (just pasture and pasture with 20, 50 and 100 trees) produce senough energy to sustain 0.2 to 0.7 livestock units in a year with adult trees that are 82 years old. Below: an example of a simulation (50 trees at age 50), showing the differences in pasture yield and energy availability after grazing.

Trees modify the availability of light, microclimate, soil moisture and nutrient distribution compared to open pasture areas. This affects understory species composition, nutrient quality and phenology (Oliveira et al. in review). The herbaceous understory under the canopy tends to be dominated by grasses (legumes and forbs are more abundant in less fertile spaces) and has higher content of some nutrients (mainly N and K) than plants outside the canopy. There is also a longer growing season under the tree canopy, with an earlier start in winter and less vulnerability to drying in summer. The amount of above ground biomass that is produced can decrease when trees are present, but, if the production is maintained for a longer period, the number of supported livestock units will be greater.

YieldSAFE estimates show that:

- Tree cover reduces temperature in the summer and increases temperature in the winter, leading to increased growing time for the grass and so improves conditions for livestock grazing.
- Above ground biomass (pasture) production can also be greater in the spring and summer seasons, depending on climate and soil quality. The impact of trees is more positive in lower quality soils.
- Increasing the number of trees leads to an increase in the number of days that the system produces enough energy to support livestock.

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Web version of the model (to be used freely): http://www.isa.ulisboa.pt/proj/ecoyieldsafe

Rediscovering valonia oak acorns

Getting more income from your valonia oak trees
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Why sustain valonia oak agroforestry systems?

Two valonia oak systems are present in Greece: ancient open forests (silvopastoral systems) and agricultural fields with valonia oak trees (agro-silvopastoral systems). Both have significant socio-economic, ecological and cultural value. They provide ecosystem services and support traditional uses including, grazing, acorn cup and nut collection, harvesting wood (for shipbuilding, firewood and charcoal) and collection of aromatic and medicinal plants.

Valonia oak forests are one of the habitats of the NATURA 2000 network and include monumental trees in many places in Greece. The harvesting of acorn cups for leather tanning rendered it a very important traditional economic activity up to 1970s, significantly contributing to the localeconomy. The average annual production of acorn cups in the past reached 14,000 tonnes. Most were exported as raw material or processed to produce powder, liquid or extract. In recent years, there has been a growing interest in reassessing the productive value of these systems within the context of acorn harvesting, organic agriculture and animal husbandry, as well as for environmental protection reasons. There is also increasing interest in the history of this traditional practice.

Valonia oak acorn (*Quercus ithaburensis ssp. macrolepis*)

Why acorns today?

Demand for valonia oak acorn cups has recently increased. The traditional tanning and extraction industry is again returning to the use of natural, organic tanning substances in their production processes, replacing the chemicals that had formerly replaced natural tannins. There is also demand from yarn dyeing, cosmetics and pharmacology. High quality acorn cups may contain up to 20-30% tannin while content in the scales of the cups can vary between 30-40%. Thre is also increasing demand for acorn nuts for human consumption and use (e.g. as flour and oil). Acorn flour is gluten free with high concentration proteins, K, Mg, Ca, B6 vitamin and fibre.

Extracts are used in the pharmaceutical and fragrance sectors, and also in cooking due to their nutritional value. Valonia oak acorns also have a high value in animal nutrition in organic farming and contribute to the production of livestock products of high economic value.

Silvopastoral system (Xeromero forest- W. Greece)

Agro-silvopastoral system (Kea Island- Cyclades Greece)

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Advantages

- The harvesting of valonia oak acorn cups for tanning and nuts for flour can provide a supplementary income without incurring additional costs for their production.
- The acorn nuts and the rich herbaceous vegetation of the understorey constitute an important feed for livestock, especially sheep, goats, and free-grazing pigs. The high plant diversity of the valonia oak systems results in the production of high quality livestock feed.
- Ground covered by the dead organic material accumulated from the large canopy of the trees protects soil from erosion and helps groundwater recharge and infiltration.
- Valonia oak trees provide wildlife and domestic livestock with shelter, forage and shade during the summer, and conserve and increase ecosystem biodiversity.

Valonia oak sized acorns provide double profit: acorns are consumed by livestock and acorn cups are used for tanning.

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Harvesting and storage

Harvesting commences from mid-July to mid-August with the collection of the immature and small acorns that have fallen prematurely. Acorn collection continues from late August to late September, when the seeds mature. Acorn harvesting is carried out using sticks to knock the acorns off the tree. Finally, the remaining acorns that fall to the ground are collected in the middle of autumn. (These are of are of lower quality.) The harvested acorns must not remain in sacks or heaps for a long time. After the separation of the acorns from their cups, which must be done immediately, acorns are spread out in sunny places on woollen cloths or cement surfaces for natural drying. During the drying process, they must be frequently turned around and protected from rain and moisture to avoid infection. They are then stored in well-ventilated and watertight rooms or warehouses until they are sold.

Production yields and prices

A medium size valonia oak tree with a short trunk and wide crown can produce between 50-100 kg acorns cups, while a large-sized tree produces, on average, 128 kg of acorns cups in a productive year. A valonia oak tree starts production at an average age of 15 years after planting. In 2017, the selling price of quality dried cups started between 0.25 €/kg and 0.50 €/kg for dried nuts. Currently, acorn production does not meet the worldwide demand for oak extraction, dyeing and traditional tanning, and this shortfall in supply is likely to increase future prices.

Acorn harvesting by the "sticking" method in Kea (island of the Aegean sea). *Ref : M. Mayer*

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Shade tolerant legumes

Improving the productivity of Mediterranean silvopastures

www.agforward.eu

Plots of legume-based mixtures under dense tree canopy *Ref : G.A. Re*

Silvopasture quality and productivity

In silvopastoral systems, light interception affects productivity of flora beneath the canopy in various ways. In general, herbage production decreases with reduced light intensity. Thus, the use of shade tolerant cultivars of selected species can play an important role in successful silvopastoral management.

Due to their nitrogen fixing ability, the incorporation of shade tolerant legume species may have a special role in increasing the quality and productivity of silvopastures and in enhancing soil fertility.

Grazing cattle on unshaded plots over-sown with legume-based mixtures, near to the dense tree trial. *Ref : G.A. Re*

Shade tolerant legumes for agroforestry

Farm-scale field experiments in agroforestry systems using legume species are very rare. Some species have been reported to have adapted to shaded environments including: *Medicago rugosa, M. polymorpha* and *Trifolium spumosum* (Mauro et al. 2014). In addition, positive effects on shade for the persistence and productivity of pasture mixtures with burr medic (*Medicago polymorpha*) and subterranean clovers (*T. yanninicum and T. brachycalycinum*) under silvopastoral and vineyard agroforestry systems have been seen (Franca et al. 2016, Muscas et al. 2017).

Innovative mixtures

The study compared two mixtures: a commercial mixture from Fertiprado in Portugal, and a mixture from the ISPAAM institute in Italy with a native sward.

ISPAAM mixture:

T. subterraneum cv Campeda (40%)
M. polymorpha cv Anglona (40%)
Lolium rigidum cv Nurrav (20%)

Fertiprado mixture :

T. subterraneum (60%)
T. vesiculosum (3%)
T. resupinatum (3%)
T. incarnatum (6.5%)
T. isthmocarpum (1.5%)
T. glanduliferum (1.5%)
Ornithopus sativus (20%)

Produced by the AGFORWARD research project funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No 613520

Advantages

The efficacy of sowing legume-rich mixtures depends on:

- the adaptation of species within the mix to the specific pedo-climatic conditions and shading levels,
- the level of hardseededness,
- the persistence of the species from year to year.

In silvopastures, the grazing management/cutting regime is very important for establishing and, thereafter, maintaining a balanced ratio between introduced legumes and native grasses.

Unshaded (top) and shaded (bottom) plots of legume-based mixtures under scattered tree canopy. *Ref : F. Sanna*

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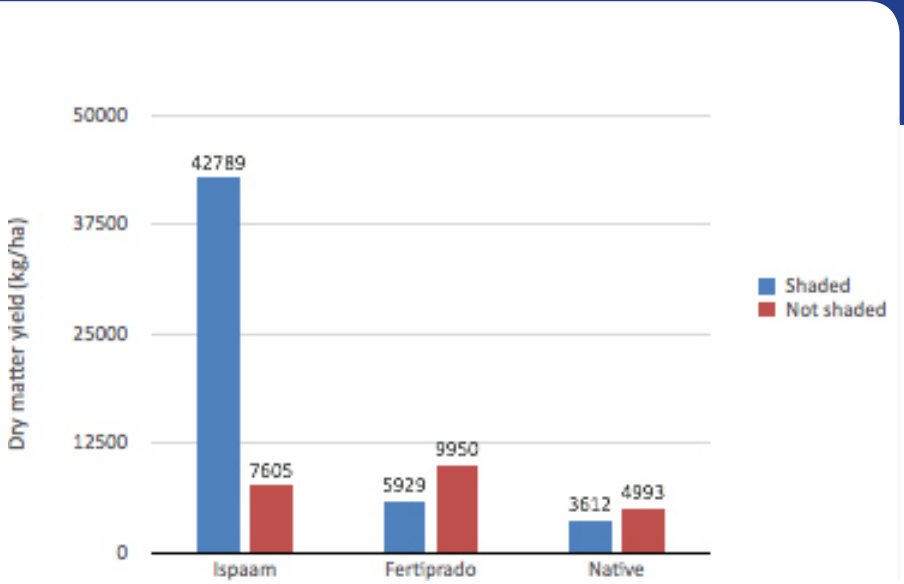

Total dry matter yield (kg/ha) in the first year of the trial

Scattered trees (8-10 trees/ha)

- The oversowing of adapted mixtures improved silvopasture productivity up to 2 times.
- The best adapted species to shade are T. subterraneum CAMPEDA (Ispaam mixture) and Ornithopus sativus (Fertiprado mixture).
- Shading reduced the productivity of the legume-rich mixtures by 70%-90%.
- Shading conditions facilitated the seed hardening of *T. michelianum*, which favours longer persistence.

	CP		NDF		ADF		ASH	
	Shaded	Not shaded	Shaded	Not shaded	Shaded	Not shaded	Shaded	Not shaded
Fertiprado	18,5a	12,5b	41,6a	37,2b	29,3	27,6	12,3a	9,3b
Ispaam	14,9a	9,5b	47,3a	44,7b	32,6a	28,5b	9,8a	6,1b
Natural pasture	9,5	9,6	52,5	54	30,2b	33,8a	6	6,2

Crude Protein (CP), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and ashes (ASH) of different species in shaded and not shaded conditions. Acid Detergent Lignin and Ether Extract did not differ significantly and are not reported.

Dense trees (30-40 trees/ha)

- *M. polymorpha, T. incarnatum* and *T. michelianum* significantly showed longer stems in shaded conditions, producing a more fibre-rich forage.
- Leaf area was significantly higher in all species in shaded conditions.
- Shading reduced the productivity of mixtures by 50-60%.
- Shading resulted in an increase in the nutritive value.
- ISPAAM mixture results indicate that it is more competitive against unsown species than the Fertiprado mixture.

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Multi-functional hedgerows in the bocage systems of France

Rejuvenating a traditional system through farmer-led innovation
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Why bocage agroforestry today?

In Brittany, the main period for creating the bocage landscape stretched from late 18th Century to early 20th Century. The hedgerows drew on the discontinuities of the physical environment; they signified the limits of ownership or use, while delivering fuel and timber wood for local and regional use. During the last 50 years, agricultural and broader rural changes have led to the deconstruction of the bocage and to the loss of ecological functions it provides. To date, initiatives of bocage restoration have primarily emphasised the value of hedgerows as providers of environmental services rather than productive resources, and creates a problem in terms of sustainability.

The principle of bocage agroforestry is to develop a holistic approach, whereby hedgerows are considered as multi-functional components of landscapes and agricultural systems. This requires a change in both mindset and practices.

Strengthening the bocage network is achieved by enhancing the social linkages between farmers, and other stakeholders. Here we see a participatory planting day.

The bocage can be managed as a form of agroforestry that operates at the field boundaries. Here several hedgerows have been planted on a bank (centre and top of the photo), in order to reconnect, on the basis of the current field borders, the remnants of the old hedgerows.

Farmer innovation – the experience of the "Terres et Bocages" Association

Renewing the perspective on hedgerows and bocage landscapes

The T&B Association considers hedgerows as part of the agricultural productive space which should be fully incorporated into the management at the field, farm, and collective levels. Emphasis is placed on the multi-functionality of hedgerows at the farm and local levels. Paying attention to the integration of hedgerows in the landscape in order to re-establish a diversity of ecological functions is an important aspect of this approach.

An adaptative process of renovating the existing bocage is envisaged. The aim is to build upon the existing "foundations" when they are of interest and value, and to develop flexible systems which meet current demands but can also be adapted to meet future needs and interests.

Renewing the practices of plantation and management

The T&B Association integrates silvicultural thinking in their farming practices. The aim is to shift from practices that focus on limiting encroachment of hedgerow growth into the field, to those which promote tree development. To achieve this, the Association has been working to increase the density of trees in new hedgerows and also on the enlargement of the structure of existing hedgerows (e.g. from single to double rows of trees). They also practice selective thinning, which they consider to be more effective, cheaper and less strenuous than traditional management practices such as tree pollarding.

The tree species and modes of establishing the hedgerows (e.g. banks, mulching) are chosen according to farmers' objectives, the use of their fields, the nature of the terrain, the observed vegetation structures, and species already present in the surrounding area.

This process of renewal mobilizes many different sources of knowledge including agriculture, silviculture and ecology. Through participatory fieldwork and action-learning sessions, the Association ensures relevant information and experience is shared among key stakeholders.

AGFORWARD Agroforestry for Europe

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Advantages

- Reconnecting sections of old hedgerows through new hedgerows reinforces the structure and ecological functions of the whole bocage landscape.
- 10-20 years after planting, the expected agroecological benefits can already be perceived.
- Crop and livestock production have been maintained, even enhanced, as crops and livestock in pasture are now sheltered against inclement harsh weather.
- The farm use and the sale of wood chips and logs have made it possible to cover on-going hedgerow maintenance costs.
- The involvement of the Farmers' Association, and the support they provide, have made it possible to adapt and extend bocage management to the wider farming community.

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Example of a new single row hedgerow planted on flat ground, and now 13 years old where ecological observations (on the photo: syrphid flies and butterflies) and soil measurements were made. Soil profiles sampled to a depth of 1-m showed an increase in soil organic carbon.

New hedgerows, biodiversity and soil quality

Fifteen years after planting, new hedgerows harbour a similar species diversity to that of old hedgerows, and are providing needed habitat and refuge for fauna and flora. Predatory arthropods tend to be more numerous in crops adjacent to new hedgerows, suggesting that they might contribute to pest control in crops over the longer term. Spatial connectivity of new and old hedgerows is also crucial for enhancing biodiversity in hedgerows and adjacent fields.

Soil organic carbon content is beginning to increase under the hedgerows, even though this is not always significantly different from that measured in the middle of the fields and away from the area of influence of the trees. Building up soil organic carbon is a slow process: planting regularly and managing hedgerows will, in the long run, enhance soil organic carbon storage at the field and the landscape scales.

New hedgerows on farms

According to the farmers, the new hedgerows have met their desired objectives such as: protecting and enclosing cattle in pastures, regulation of runoff and erosion, enhancing the beauty of the landscape, and the designation of field boundaries. Firewood production and the protection of wild fauna were mentioned as supplementary benefits. Farmers have also observed that crop yield is different on each side of hedgerows (within the first few metres), and varies according to the orientation of the hedgerows. According to the farmers, these differences are compensated at the field scale, and the yield differences at farm level are mostly explained by the variations in soil quality.

The labour required for hedgerow maintenance remains a challenge for the farmers, with some reporting 10-20 days per annum being spent on tasks such as shrub clearing and tree pruning. Further work is required to identify how to reduce these labour demands and thus ensure the sustainability of the bocage system.

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Invisible fencing in wood pasture

A comparison of costs

www.agforward.eu

Red Poll cattle wearing collars with sensors and GPS units (Epping Forest, UK)

Why invisible fencing?

Invisible fencing is an innovation that allows the control of cattle movement without needing physical barriers. In open areas, cattle can be fitted with a Geographical Positioning System (GPS) which will signal when a cow approaches a boundary.

Under trees in a wood pasture, due to the intermittent GPS signal, an alternative method is to bury an electric cable in the soil surface that emits a shortwave radio signal which is sensed by a transponder on a cattle collar. The transponder emits a noise as a cow approaches the boundary and, if she does not turn back, it provides an electric pulse similar to an electric fence. At Epping Forest, each collar also includes a GPS sensor which helps to locate the cattle.

Cow collar with the sensing unit

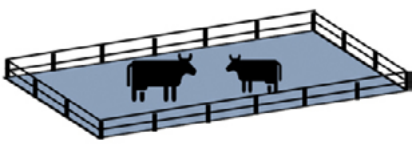
Background

The Corporation of London at Epping Forest have demonstrated the technical feasibility of virtual fencing to control livestock in areas of high recreational use that require uninterrupted access. Dr Jeremy Dagley at Epping Forest, with colleagues has developed a best practice guide covering the equipment, fitting and training, design, installation, and safety (Dagley and Phillips 2016). The focus of this leaflet is on the costs of invisible fencing. relative to wooden fencing.

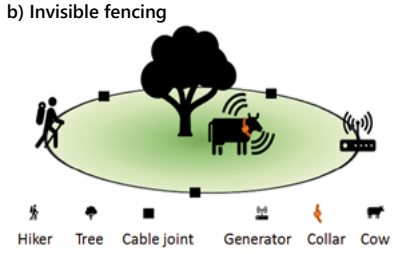
Financial comparison

Using data from Epping Forest, we examined the cost of invisible fencing relative to wooden fencing with two horizontal beams and mesh netting. A spreadsheet model was developed to describe the main costs with key variables including: fence length, the area, the cattle number, and the capital and running costs of the components. Although the model included grant support options, the results presented in this leaflet assume no grant support (Burgess et al. 2017). The costs of each system were calculated over a period of 30 years, to account for the lifetime of the different components e.g. wooden fence and collars (15 years), generator for invisible fencing (10 years), and generator batteries (5 years). Although the model allows the discounting of future costs, this leaflet presents only the undiscounted costs.

a) Wooden fencing



b) Invisible fencing



A study was undertaken to compare the costs of a) wooden fencing and b) invisible fencing where the cattle wear a collar which senses the output from a buried wire

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Advantages

Invisible fencing is an option for managing cattle movement in wood pasture of high recreational value. Cattle movement can be constrained without any obtrusive above-ground barriers restricting public access. The inclusion of GPS transponders can also help locate the cattle across large areas. It is possible to use a combination of approaches so that wooden fences are used next to busy roads and invisible fencing is used in open grassland areas.

Open space with invisible fencing

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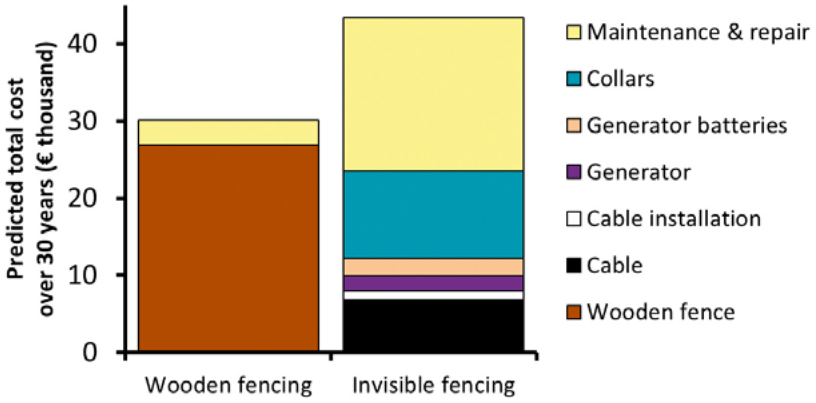
Comparison of costs with wooden fencing

On the basis of the assumptions described by Burgess et al. (2017), the costs for the wooden and invisible fencing (for an area of 12.5–50.0 ha assuming a density of 0.4 cows/ha) of €74 to €208/cow are very high in the context of commercial suckler-beef production. These high costs are justified at Epping Forest because of the high recreational value of the wood pasture. For a 25 ha system with 10 cows requiring 2000 m of fencing, the annualised cost for the invisible fencing (over 30 years) at €144/cow is 44% greater than €100/cow for a wooden fence. The high cost of invisible fencing is primarily a result of the assumed high maintenance and repair costs, as the capital costs are similar.

		Wooden fence		Invisible fence	
Area (ha)	Assumed number of cows	Assumed length (m)	Annual cost (€/cow)	Assumed length (m)	Annual cost (€/cow)
12.5	5	1414	137	1414	208
25.0	10	2000	100	2000	144
50.0	20	2828	74	5656*	175

***The maximum length of the underground cable transmitting the radio signal is 2000 m. Hence, if the length is greater than 2000 m (as demonstrated above) it is necessary to use "double loops", and this increases the length of cable required and the associated maintenance costs.**



Costs over 30 years for 2000 m wooden fencing and invisible fencing for a 25 ha system with 10 cows (Assumption £1: €1.1)

Conclusion

Experience at Epping Forest shows that the invisible fencing is effective in constraining cattle, the use of GPS is helpful for locating cattle, and visitors to the wood pasture have unimpeded access.

For a 25 ha system with 10 cows, invisible fencing was calculated to be 44% more expensive than wooden fencing, primarily because of the assumed high maintenance costs such as checking and changing batteries. These higher costs can be justified at Epping Forest because of the high societal value of providing all members of the general public with unimpeded access to a widely-used recreational area.

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Trees and the restoration of waterways in the Spreewald floodplain

Maintaining the benefits of historical land use

www.agforward.eu

Small-scale mosaic fragment retained in the Filow area in the Spreewald Biosphere Reserve. *Ref: Tsonkova 2015*

Why restore ancient waterways?

In the past, flood-prone lowlands in Germany were adapted for agricultural land use through the installation of small waterways to improve drainage. The excess sediment from the waterways was used to develop raised areas. Planting trees on these elevated areas resulted in the development of a small-scale mosaic agroforestry system, rich in biodiversity.

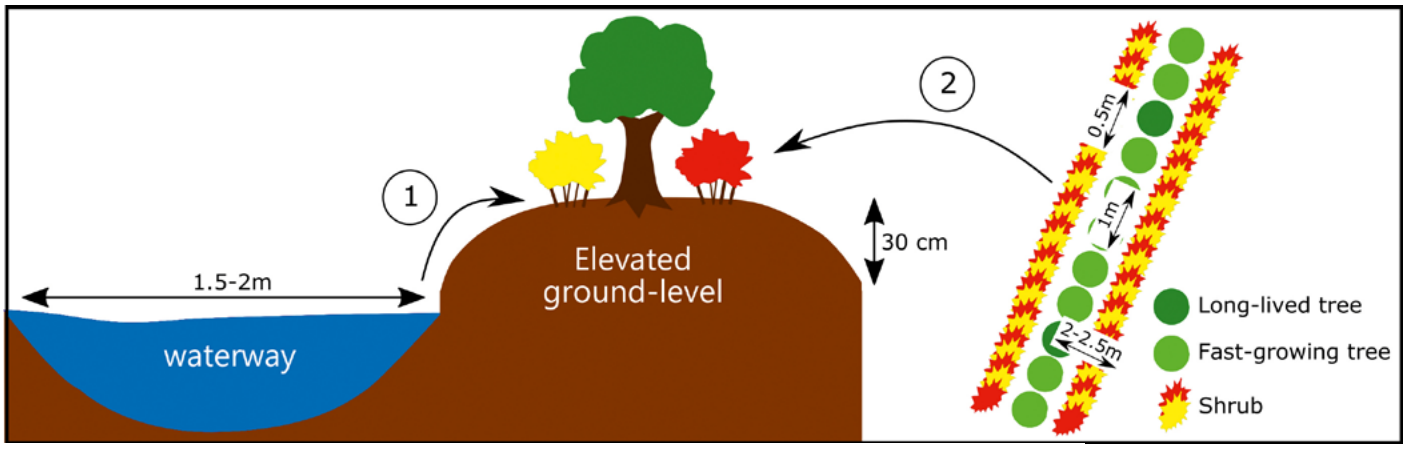
During the last 30 years, these historical waterways have become degraded, resulting in the return of flooding events and the occurrence of slack water. Slack water, unlike flood water, is alkaline and has very low oxygen levels. This can impede the vitality and growth of alder trees *(Alnus glutinosa)*, the main tree species in the area. Consequently, tree growth and regeneration in the area have been inhibited.

Where and how to plant

Trees should be established in the area exhibiting the highest degradation rates. Small waterways with widths of between 1.5 m and 2 m should be created by digging out the soil along the hedgerow. The excess soil material should be used to raise the ground level up to 30 cm. The new hedgerow should be established on this elevated area. The hedgerow should shade the waterway in order to reduce the growth of water plants. The hedgerow design is shown below.

The main tree species used should be black alder *(Alnus glutinosa)*. Blackberry *(Rubus spp.)* is the main shrub species found in the research area. Both replanting and natural seed dispersal should be used as reestablishment methods. For the replanting, local material should be used and the regulations for nature protected areas should be followed. A combination of long-lived and fast growing tree species, as well as shrubs, should be planted. Newly planted trees should be fenced during the first five years to ensure their protection from livestock and game.

Neglected waterways in the Filow area. *Ref: Mirck 2016*



A waterway is created by digging out the soil and using it to raise the ground-level (1), where a new hedgerow is planted (2).

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Advantages

- Planting trees on elevated areas improves their chance of survival.
- The created waterways hasten the drainage of water after flooding events and reduce the occurrence of slack water.
- The pasture can be grazed by cattle or mown.
- The nature protection function and the cultural value of the landscape will increase as the historic appearance and the unique character of the area is preserved.

A waterway in the Spreewald. *Ref: Tsonkova 2015*

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Heterogeneous habitat in the Spreewald. *Ref: Mirck 2016*

System benefits

In this area of nature protection, deriving economic benefits from the harvest of trees not the main priority. The main benefits of the system are related to ecological functions, such as habitat protection and increased biodiversity.

The combination of an open landscape, hedgerows and waterways creates a unique habitat with heterogeneous microclimatic conditions, and this preserves the high biodiversity levels in the area, including rare species. According to the environmental monitoring programme carried out in Spreewald, Red List species in the woodland area near the research site included Lindberg's hypnum moss *(Hypnum lindbergii*), tufted loosestrife *(Lysimachia thyrsiflora)*, greater spearwort *(Ranunculus lingua*), and marsh fern (*Thelypteris palustris*). Red List species found in the grassland area included Greenland buttercup *(Ranunculus auricomus agg*.), marsh stitchwort *(Stellaria palustris)* and fen violet *(Viola persicifolia*). (Luthardt et al. 2016)

The maintenance of the cultural landscape also benefits tourism. The Spreewald Region is an important tourist area and receives more than 2 million visitors between May and September each year. (Grossmann 2011)

Pests and disease

The degradation of hedgerow structures has increased because the dominant tree species, black alder *(Alnus glutinosa)*, has become more susceptible to the root rot pathogen *(Phytophthora alni).* (Riek and Strohbach 2004) The susceptibility of black alder to root rot is particularly high during summer flooding events. Furthermore, since 2006, the European ash (*Fraxinus excelsior*) has also become a victim of the fungal disease *Hymenoscyphus fraxineus* in the Spreewald. Planting the hedgerows on elevated areas is expected to reduce the occurrence of this pathogen as the trees will be inundated less often. (Alsop 2014)

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Restoration of abandoned wood pasture

Renewing the past for the future
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Large, scattered trees are again visible after clearing shrubs and restoring pastures (Dörgicse, Hungary). *Ref: Varga et al. 2016*

Why restore abandoned wood pastures?

Wood pastures with high nature and cultural value (HNCV) have been present in Hungary for thousands of years. Currently, there are 33 318 hectares of HNCV wood pasture in Hungary: 28 % is in protected areas and 60 % in EU Natura 2000.

In the 1950s, 88 % of productive land was wood pasture. Today, many HNCV wood pastures are now forested and overgrown with shrubbery and trees, causing serious problems at farm level.

The restoration of abandoned wood pastures is a key issue for developing the natural and cultural value of the rural region, and also for the profitability of the livestock industry. If areas are left abandoned they could be registered as forest areas, after which silvopastoral activity (grazing and/or pasture clearing) would be forbidden.

Closed and thorny shrubs on abandoned part of wood pastures *Ref: Varga et al. 2016*

How to renew an abandoned wood pasture

Status assessment
It is not possible to apply the same management template for all wood pasture designs. Before regeneration begins, it is important to understand the history of land management, and to acquire sound knowledge of local environmental and climatic conditions.

Shrub clearing
The establishment of a pasture in overgrown shrubland begins with clearing the bushes. This can be done in several ways: shrubs lower than 3 metres high can be cleared using a rough rotary mower, while older and taller stands are best removed by hand. Cleared shrubs need to be removed from the area, otherwise the grass will start to decay underneath, leading to weed infestation later on. After clearing, and before livestock are allowed onto the land for grazing, rotary mowing is necessary, because remaining stumps may result in injuries. Wherever shrubbery is not too dense, a sanitary rotary cutting might be sufficient. After shrub removal, extensive grazing is best started with cattle and goats, which are good for clearing and less prone to injuries than sheep.

Wild fruit trees (e.g. pear, apple, cherry) are important assets commonly found in traditional pastures. In addition to their shade, they also provide forage and food to stock and people.

Choosing and leaving trees and shrubs
A wood pasture consists of three structural units:

1. open parkland (5-40% canopy cover)

2. forest patches left mainly for shelter (40-100% canopy cover)

3. grassland (maximum 5% canopy cover)

Leaving shrubbery intact on 2-10% of the area provides protection for young trees and enhances biodiversity.

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Advantages

Shrub clearing give the possibility for grazing new lands, and to maintain wood pastures for longer periods.

- Shrub clearing requires a lot of manual labour, time and funding by the farmers but, over time, saves on herding and feeding costs.
- Applying for subsidies is currently possible.

Cut shrubs can be sold for fuel *Ref: Varga et al. 2016*

Scattered wild fruit trees (pear and apple) on renewed and cleared wood pasture (Váczakő-farm, Dudar, Hungary) *Ref: Varga et al. 2016*

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Closed forest patches in wood pastures are important, not just for livestock welfare but also for biodiversity. *Ref : Varga et al. 2016*

Inspiration from farm level experiences

Tibor Nagy and his family bought an abandoned farm in Bakonyregion in 2007. Previously, the land had been managed as a community wood pasture (Pénzesgyőr ancient wood pasture) and wood farms with small grazed areas, forest and arable land (Tűzkövesbörc Farm). The new owners are renewing this area to develop and maintain a high natural and cultural value silvopastoral system.

Comparing the botanical data from the time the area was abandoned with recent data shows that the percentage of the protected species has vincreased. The results also illustrate the importance of the diversity of shrub clearing methods. Botanical and management data show the significance of the different silvopastoral habitats. Clearing should be gradual and partial, in order to maintain a gradient from 0-100% canopy closure. A developing high-value agroforestry system needs time to adapt to the new environment, which provides more openness, and greater light. Young trees also need a long time to grow.

All of this highlights the importance of the remaining agroforestry systems, especially those that are partly or totally abandoned.

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Videos

Gastronomy and knowledge transfers of the Hungarian wood pastures: Gasztroangyalfásle-gelők: https://www.youtube.com/watch?v=OVeBEYc3tdk

Ancient wood pastures in education: https://www.youtube.com/watch?v=tC6bgY6w0mM

Traditional ecological knowledge of the Hungarian herders: https://www.youtube.com/watch?v=dj5iLAuWoJg&t=1135s

Facebook page and further information about Hungarian wood pastures: www.facebook.com/faslegeloerdo

Protecting large old trees in wood-pastures

A keystone for biodiversity in Romanian wood pastures

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The largest ancient oak-wood-pasture of lowland Central-Eastern Europe is in the Saxon region of Transylvania, with a size of over 1200 ha and over 450 large old trees. *Ref : Tibor Hartel*

The value of large old trees in pastures

Maintaining high biodiversity in production landscapes is a key conservation challenge.

Large old trees are keystone structures, conferring high ecological value to pastures. The hollowing parts, the ageing bark and the dry stems, while being biological and ecological legacies, create a wide diversity of habitats for many organisms.

Large old trees can have high socio-cultural importance in particular contexts (for example in expression of rural identity, and as sites for popular events and tourism).

Large old trees are in severe decline in commodity production landscapes, including pastures, because they are not explicitly recognized by agricultural, forestry and nature conservation policies.

A key challenge for the sustainability of large old trees on wood-pastures is to ensure their tangible and intangible values are fully recognised by local communities and also, more formally, within agricultural, forestry and nature conservation policies.

Farmer attitudes to large old trees

We assessed the perceptions and attitudes of farmers towards mature trees, large old trees and decaying trees from wood-pastures in Southern Transylvania. Mature trees were appreciated for many of tangible values, such as shade for livestock, fruits (including acorn), microclimate for grass, habitats for wildlife, and contribution to erosion control and soil fertility.

Large old trees were primarily appreciated for their intangible values, such as their age, beauty, cultural and relaxation value. The tangible values (e.g. shade for livestock) of large old trees were recognized by only a few farmers. Interviewees also highlighted the fact that large old trees have hollowing and dead components as well as nodes, which decrease their tangible value and creates challenges for processing. Decaying trees were perceived negatively by most of interviewees. Our study shows that, to protect large old trees in wood-pastures, it is not enough to rely on traditional local knowledge and attitudes**.**

Efforts are needed to increase awareness related to the intangible values (such as ecological, socio-cultural) of large old trees at the level of local communities and to recognize these trees in formal policies.

Large old pear tree (Pyrus pyraster) in a traditionally managed wood-pasture from Southern Transylvania. *Ref : Tibor Hartel*

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Produced by the AGFORWARD research project funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No 613520

Advantages

Large old trees on wood-pastures provide several beneficial opportunities for local communities, including:

- *Ecological and cultural tourism*: due to their outstanding beauty and cultural values
- *Branding of local products:* meat and milk products are often produced in wood-pastures and this should be informed to consumers open to pay extra prices for landscape and biodiversity conservation
- *Genetic resources for forestry:* through large old trees
- *Cultural and educational role:* due to their multiple cultural and nature values
- *Soil fertility*: due to nutrient cycling
- *Biodiversity conservation in production landscape*: due to their habitat values

An example of a local initiative

In 2009, the Mihai Eminescu Trust initiated a citizen-based project entitled "Find the oldest tree". The largest oak (Quercus robur) in Transylvania, with a trunk circumference of 920 cm, was identified by two pupils in a pasture near the village of Mercheașa. News of the tree was widely reported on local, regional, and even national TV Channels. The tree was named, 'The Old of Carpathians'. Subsequently, The Carpaterra Association developed formal documents to declare the oak a 'Natural Monument'. Since 2016, the tree and the surrounding ancient oak wood-pasture have been the focus of a local cultural initiative, 'Go Run' organised by the same association. This has done much to raise the awareness of ancient trees in the area.

An Oak with a 920 cm trunk circumference was identified through the "Find the oldest tree" competition of the Mihai Eminescu Trust. It is now protected by the Carpaterra Association. *Ref : Tibor Hartel*

Recommendations

- Large old trees should be recognized by agricultural, forestry and nature conservation policies.
- Local communities should be encouraged to recognize and protect large old trees, for example, by including large old trees in the historical, cultural and natural heritage sites.
- Income generated by local economic activities built on ancient wood-pastures should be funded to actively maintain the multiple values of these systems.

Further information

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Remarkable trees of Romania: www.arboriremarcabili.ro [online platform for large old trees, in three languages: RO, HU and EN]

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Grazing and biodiversity in Transylvanian wood-pastures

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Wood-pastures grazed extensively with cattle and buffalo have high levels of biodiversity, and often include small, temporary ponds. *Ref : Tibor Hartel*

Grazing and biodiversity

Extensively managed wood-pastures are considered archetypes of traditional farming landscapes with high natural and cultural values in Europe. The livestock type used for grazing, as well as the structural features on the pastures, influences the biodiversity value of pastures. Scattered trees and shrubs were valued for their fruits, shade for livestock, beneficial effects on grassland and their beauty.

Within the context of Transylvanian pasture management, the livestock traditionally used for grazing were buffalo, cattle, horses and pigs, while sheep grazing was generally restricted.

Nowadays, wood-pastures are negatively affected by improper grazing management (i.e. overgrazing with sheep) and also by the removal of scattered woody vegetation.

Sparse trees and shrubs support high biodiversity in pastures

We assessed the importance of trees and shrubs for spider and herbaceous plant communities in a Transylvanian wood-pasture grazed with mixed livestock (sheep, cattle, buffalo), in a ca 1 Livestock Unit/ha. The tree community was dominated by oak (*Quercus robur, Q. petraea*), with an overall mature tree density of ca 1 trees/ha (with maximum 4-7 trees/ha, this being the characteristic density for oak wood-pastures from this region).

We identified:

- 144 species of spiders, out of which 12 were red-listed and four were new for the Romanian fauna.
- 195 vascular plant species, out of which 24 were autochthonous weeds and 32 were forest-specific herbaceous plants.

Open pastures, sparse trees, sparse trees with shrubs and forest edge had statistically distinct spider and herbaceous plant communities. Scattered trees and shrubs were the richest, while open pastures were the poorest for both taxonomic groups.

Research carried out on other taxonomic groups (birds, amphibians) in Transylvania shows that wood-pastures have rich and distinct passerine bird communities, due to shrubs, large old trees and open spaces. Furthermore, rare amphibians species (e.g. yellow-bellied toad, and the great crested newt) benefit from the ponds, created by cattle and buffalo grazing.

Sparse mature trees and shrubs are natural features which confer high natural and cultural values to the whole pasture ecosystem. *Ref : Tibor Hartel*

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Advantages

- Scattered mature trees and shrubs substantially increase the value of pasture biodiversity.
- Scattered mature trees and shrubs do not compromise production and economic profitability of the pastures.
- Scattered trees and shrubs play a crucial role in maintaining the biodiversity value of pastures, as well as providing options for alternative nutrients (e.g. fruits for people and leaves for livestock).
- The temporal continuity of scattered mature trees and shrubs can be sustained through tree regeneration (either natural or assisted).
- Certain livestock types (e.g. buffalo, cattle) can help maintain wetlands by creating small ponds across the pasture, for the benefit of rare amphibians.

Water buffalo in a temporary pond. Six amphibian species (including three protected under the Habitats Directive) reproduce in these pond systems. *Ref : Tibor Hartel*

Recommendations

On oak wood-pastures, the scattered mature tree density should be maintained at the level of 4-7 trees/ha. This will create wood-pasture systems with high natural, cultural and economic values.

The cultural and ecological values of oak wood-pastures will be maximized if grazing includes a mix of species, such as buffalo with cattle, and is carried out with appropriate management choices (i.e. adequate stocking rates, rotational grazing).

Sparsely scattered native thorny shrubs will further improve the natural value of the wood-pasture, while allowing for tree regeneration.

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Enhancing reindeer husbandry in boreal Sweden

An economic evaluation of the use of GPS collars

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Reindeer feeding on ground lichens during winter in the coastal region. *Ref: Erik Valinger.*

Why use GPS collars in reindeer husbandry?

The use of a GPS tracking system has led to a change in the labour process of reindeer husbandry, as the herd can be monitored and followed remotely on computers. It increases knowledge about migration routes and use of grazing areas as the movements are registered by the tracking devices. With the aid of the GPS tracking system, vehicle mileage could be reduced and predator attacks on the herd can be detected at an early stage. These attacks are a very serious concern for Sami herdsmen due to economic losses.

Female reindeer equipped with GPS collar. *Ref: Erik Valinger.*

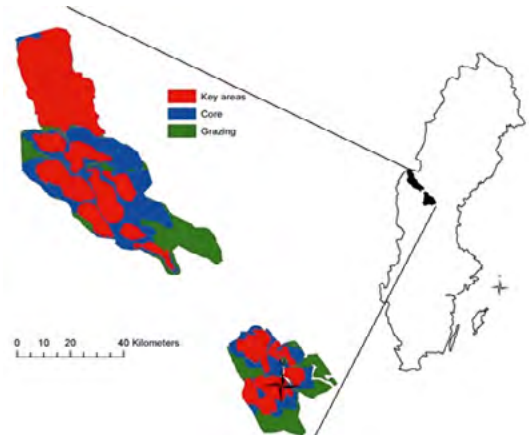
Background

The study was conducted in the area of Njaarke Sami Village in boreal Sweden. In 2014, the Njaarke Sami village consisted of four reindeer husbandry companies. The total area with grazing rights controlled by the village was about 505 000 ha in total, which included about 256 000 ha of productive forest land. The forest land is owned by several owners. The reindeer herd was about 2000 animals during winter.

The forest management in the area consisted of compartment cuttings with a rotation period of about 100-130 years. A forest management plan adapted to the needs of the reindeer husbandry would lead to a possible increased slaughter of 200 reindeer calves per year. In the study, three alternative scenarios were analysed; with or without the use of GPS collars, with no adaption of forest management i.e. business as usual (BAU + GPS or BAU – GPS) and adapted forest management with GPS collars (AFM + GPS).

In 2013, at the initiation of this study, the Sami village had 40 collars in use. The cost for GPS collars depreciated over five years of use, resulting in an annual depreciation per collar of 162 €. The annual cost for maintenance of the GPS system and these collars was €220.

Study area



Map of case study area with classification of areas based on reindeer husbandry plan. Key areas – most used and valuable areas for grazing, Core – regularly used and valuable areas for grazing, and Grazing – available areas but normally not used for grazing

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Advantages

- GPS tracking enables more effective monitoring and reduces the risk of accidents involving reindeer and people in the field, and with the traffic.
- Information about migration routes recorded by the tracking devices provides the basis for better management practice, including consultation with forest owners which is important to improve forest management for reindeer husbandry.
- A further benefit, is that the Sami villagers become skilled in using a new technique.

Several calves gathered before marking.
Ref : Erik Valinger.

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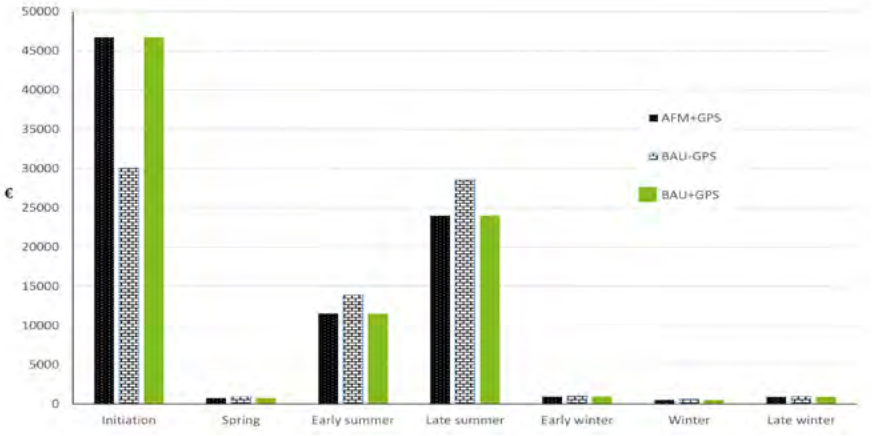
Comparison of costs per scenario with and without GPS

The adaption of forest management was calculated to ascertain the gross value added (GVA) for the reindeer husbandry. No use of GPS collars was estimated to result in increased costs for labour and energy as the extra workload required was 1.4 times a full time employee. The collars facilitated the easier allocation of reindeer to better grazing areas and it also made the operations safer and faster. These advantages were estimated to be worth €4000 in savings per year. However, these savings were not sufficient to cover the current high cost for the GPS system. Costs vary throughout the season. Significant costs are incurred at the initiation of the reindeer year and this accentuates the costs of items such as the equipment, machinery, houses and infrastructure used by the Njaarke Sami village.

	Scenario		
Indicator	**AFM**	**BAU - GPS**	**BAU + GPS**
GVA, 1000 €	115,2	90,0	69,7
Production cost, 1000 €	120,7	107,0	119,6
Labour cost, 1000 €	40,5	43,3	40,5
Employment, FTE	6,9	8,3	6,9

Indicators for three management scenarios for reindeer husbandry: adapted forest management (AFM) and business as usual (BAU) without and with GPS. Note: Gross value added (GVA) = income minus costs for capital, energy, and maintenance activities. Labour costs were thus included in the GVA. FTE = Full time employment unit of one person per year.



Seasonal distribution, across seven parts of the year, of teh costs of three forms of reindeer husbandry: adapted forestry management with GPS (APM+GPS) and business as usual without and with GPS (BAU-GPS and BAU+GPS)

Conclusions

- Use of GPS tracking enables a better monitoring of the reindeer herd.
- The use of GPS, at current prices, did not pay off finanically.
- The benefits of using GPS are easier working conditions, and better-control of the herd, migration routes and tracking of predators.
- Adapted forest management for reindeer herding was calculated to increase the gross value added from reindeer husbandry.

Further information

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