Agroforestry of high nature and cultural value: Results of innovations

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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 report contributes to the second objective as it summarizes the results of the innovations tested in the participatory research and development network (PRDN) focused on agroforestry systems of high nature and cultural value (work-package 2). Similar reports exist for agroforestry systems with high value trees, agroforestry in arable lands, and agroforestry for livestock systems.

2 Agroforestry of high nature and cultural value and the lesson learnt reports

Within the AGFORWARD project, high nature and cultural value (HNCV) agroforestry includes semi-natural farming systems valuable for biodiversity where cultivation and/or grazing is practiced among trees. HNCV agroforestry comprises a range of farming systems and practices that have often co-developed with regional livestock breeds and crops and resulted in distinctive "cultural landscapes" adapted to specific climate and geographic areas. The processes leading from "natural" environments to "cultural landscapes" make a major contribution to the world heritage of biodiversity and are an appropriate focus for scientific research.

The work-package was developed in five steps:

i. Identification of examples of the best practices, key challenges and innovations to address challenges identified by the stakeholder groups. This was addressed by ten individual stakeholder reports available on the AGFORWARD website. Results are summarized in Moreno et al (2016a);
ii. Description of the key inputs, outputs and ecosystem services flows for selected systems, summarized in the paper Moreno et al (2017a). The full synthesis report (Moreno et al 2016b) and individual reports are also available online;
iii. Agreement within the PRDN, on the key innovations or improvements in knowledge needed in order to promote adoption of agroforestry of high nature and cultural value. This was addressed in the report by Moreno et al. (2015a);
iv. Implementation within the PRDN of an experimental protocol to develop and test proposed innovations at existing experimental plots and through on-farm experiments. This was addressed in a report by Moreno (2015b). Initial results of these experiments are described in the report by Moreno et al (2017b);
v. With this last step we aim to provide and promote guidelines for farmers on how to establish economically viable agroforestry practice in high nature and cultural value. We have produced a booklet with 15 leaflets describing how to implement on farm different innovations and their advantages and difficulties. This report compiles the main lessons, based on 10 stakeholder group reports, available online, and on some cases also the content of the leaflets.

This summary is based on the ten "lesson learnt" reports elaborated by the respective partners in ten European countries (Table 1).

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

Lead partner	Report title	Reference
University of Extremadura (UEX), Spain	Lessons learnt: Iberian dehesa	Moreno et al. (2017c)
Instituto Superior de Agronomia (ISA), Portugal	Lessons learnt: Montados in Portugal	Faias et al. (2017)
Technogiko Ekpedeftiko Idrima Stereas Elladas (TEI), Greece	Lessons learnt: Valonia oak silvopastoral systems in Greece	Papadopoulos et al. (2017)
CNR, Italy	Lessons learnt for grazed oak wood pasture in Sardinia, Italy	Franca et al. (2017)
INRA, France	Lessons learnt: Bocage agroforestry in France	Thenail et al. (2017)
Cranfield University, UK	Lessons learnt – Wood pasture and parkland in the UK	Burgess et al. (2017)
Brandenburg Technical University Cottbus-Senftenberg (BTU), Germany	Lessons learnt: Agroforestry in the Spreewald flood plain, Germany	Tsonkova et al. (2017)
Soproni Egyetem Kooperacios Kutatasi Kozpont Nonprofit KFT (SoE KKK), Hungary	Lessons learnt: Wood pastures in Hungary	Varga and Vityi (2017)
Bases Bolyai University (BBU), Romania	Lessons learnt: Wood-pastures in Transylvania, Romania	Hartel et al. (2017)
European Forest Institute (EFI) and Swedish University of Agriculture Sciences, Sweden	Lessons learnt: Reindeer husbandry in Sweden	Valinger et al. (2017)

The partners' reports present details of the main findings for a total of 21 innovations tested in field experiments and related studies done in collaboration with stakeholders groups of the WP2 Participatory Research and Development Network.

Innovations are presented in Table 2 grouped according to the main challenges identified by the stakeholder groups in the initial stakeholders' meetings (Moreno et al. 2015a). It includes innovations to increase the economic and ecological resilience of agroforestry systems of high nature and cultural value. Each innovation was tested by a specific stakeholder group in/for a specific agroforestry system/regions but findings are frequently of interest for many other cases/regions, therefore lessons must be viewed as a collective guidelines as innovations. Other lessons of local interests can be read in the respective reports.

Table 2. List of innovations tested grouped by main challenges and indicating the partners involved (details can be checked in the respective partners reports included in the Annex).

Experimental topic	Specific experimental work	Partners
System design and management	Restoring and planting new multipurpose hedgerows Renewing abandoned wood pastures Alternative managements to control shrub understory	INRA, BTU CRAN, EFI, SoE_KKK, ISA, TEI
Tree regeneration	Tree natural regeneration in wood-pastures: nursery shrubs and grazing exclusion Seeding vs planting Artificial wire thorny shelters and natural protectors	BBU, UEX, TEI BBU, UEX UEX
Livestock management	GPS collars Invisible fencing system Fast rotational intensive grazing	EFI, UEX CRAN UEX
Fodder resources	Evaluation of cultivars of triticale as forage crop Effect of shading on legume species The forage value of shrubs	UEX CNR, UEX, TEI WP5
New products	Assessment of biomass potential of hedgerows and the effects on additional benefits Rediscovering oak acorns Branding products of agroforestry systems Increase awareness with education	BTU, INRA TEI UEX, SoE_KKK SoE_KKK
Conservation	Valuing and protecting large old trees in wood-pastures Restoration for biodiversity Integration of grazing with biodiversity Soil carbon content Water quality	BBU BBU, INRA BBU, CNR INRA, CRAN, BTU, UEX INRA

3 Lessons learnt

3.1 System design and management

3.1.1 Restoring and planting new multipurpose hedgerows

Thenail et al. (2017) explain that hedgerow restoration can include increasing the density of trees and enlargement (e.g. from single to double rows of trees) and, in some cases, the removal of decaying trees and the shrub understory. Both hedgerow establishment and restoration can require a significant financial investment. Fencing is costly but indispensable in the first years after planting, due to the risk of damage by wild animals and/or livestock. Maintenance labour costs remains a challenge for the farmers, with some of them reporting up to 10-20 days - of 5 hours- per annum being spent on all tasks.

The farm use and the sale of biomass (e.g. wood chips and logs) can cover hedgerow maintenance costs. However marketable biomass (either from old semi-abandoned or new planted hedgerows) does not appear to cover the costs. Further innovation is required to reduce labour demands and thus ensure the sustainability of hedges-based agroforestry landscapes. For instance, selective thinning seems to be more effective, cheaper and less strenuous than traditional management practices such as tree pollarding. Because hedgerows provide ecosystem services of wider societal benefit, there is an argument that hedgerow management receive public financial support.

New hedgerows can be affected by the field operations in the adjoining field. In the bocage system in Normandy in France, farmers kept cultivation practices and fencing at least 50 cm from the bottom of the new planted hedgerows, and at least 1 m if alongside long duration or permanent grassland. This is more than for herbaceous field margins and old hedgerows.

Farmers reported that grass and crop yields were different within the first metres of each side of hedgerows, with the effect depending on hedgerow orientation regarding sun and wind conditions. They also reported that these differences were compensated at field to farm scales. They reported that at field level, crop yields were similar for fields surrounded by flat herbaceous field margins, old and/or new planted hedgerows.

According to the farmers, the new hedgerows reached the targeted objectives such as: protection and limitation of cattle in pasture, regulation of runoff and soil erosion, improved landscape aesthetics, and the designation of field limits. Firewood production and the protection of wild fauna were recognised as supplementary benefits.

3.1.1 Renewing abandoned wood pastures

In recent decades the most serious threat to European wood pastures has been their abandonment, where the cessation of management results in encroachment. However an increasing number of farmers have started to restore wood pasture into their high nature and cultural value status.

Although adult trees compete with the pasture for light and/or water, the improved microclimate delays the onset of grass dryness in late spring, and trees provide forage resources (e.g. browse and acorns). 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. In a Portuguese case study (Faias et al. 2017), an open tree structure of 40-100 medium-sized trees per hectare was recommended corresponding to 20-50% soil coverage by the trees. Such a density favours acorn/fruit production, which is the primary use of the trees of wood pastures, allows good grass production and facilitates grazing.

Burgess et al. (2017) describes an alternative simple model that can be used to predict the future density and age distribution of different tree species, which can be very useful to plan wood pasture management. The Kirby model applied to a British wood pasture, is relatively easy to use (only three parameters) and gave sound results. Nevertheless, it is not possible to apply the same management template for all wood pasture designs. Before the implementation of renewing/regeneration projects it is important to understand the history of land management, and to acquire sound knowledge of environmental and climatic conditions. The understanding of the local and traditional ecological knowledge of the related landscape and management should enhance the success of any intervention.

Varga and Vityi (2017) report that in Hungary ethnographic and historical sources related to wooded-forested pasturing systems were insufficient to reconstruct exactly the traditional systems. One particular issue is that the terms wood pasture and grazed forest are used inter-changeably by traditional land use operators. This has been studied with detail in Hungary but it seems the situation for most of the European countries.

3.1.2 Alternative managements to control shrub understory

The shrub layer that frequently occupies wood pastures can often have positive effects. Benefits include natural tree regeneration, soil protection, increased carbon sequestration and biodiversity, and diversification of fodder resources. However, there can also be negative impacts such as tree-shrub-pasture competition for natural resources (water, nutrients and light), reducing the forage resources and increased fire risk.

Effective shrub management is a dynamic process. It is important to take a holistic approach and consider temporal, spatial, economic and social dimensions. The impact of understory management practices on tree growth (and products such as cork) depend on the local edaphoclimatic conditions. For instance, Faias et al. (2017) reports that shrub removal and lupine cultivation (a legume fodder crop) could favour cork growth during one or two years if favour conditions prevailed, but the effect could be null in years characterized by drier conditions.

In overgrown shrubland, pasture establishment requires bush clearance. This can be done in several ways: shrubs lower than 3 m 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 (or chipped), 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 could be necessary, because remaining stumps may result in injuries. Wherever the shrubs are not too dense, 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.

3.2 Tree regeneration

3.2.1 Tree natural regeneration in wood-pastures: nursery shrubs and grazing exclusion

While abandoned or underused wood pastures evolve in few decades to thick forests, an alternative scenario is that grazed wood pastures frequently have deficient tree regeneration, few young trees, and a progressive loss of tree cover. To avoid the complete loss of trees, tree regeneration of grazed wood pastures should be a part of regular wood pasture management.

Where grazing is an important traditional management activity of farmers, it cannot and should not be banned but properly regulated. In cases where natural regeneration is caused by overgrazing, the stocking rate and grazing season should be adapted. A rotational scheme of grazing exclusion per plot should be included in the farm management plan to guarantee the continuous renewal of the tree cover.

Wood pastures with an open shrubby layer and areas temporarily abandoned (intentionally with fences or not intentionally through the exclusion of grazing) provides ideal arenas for tree regeneration. Shrubs frequently act as nurse plants for oak and other tree species, with brooms and thorny scrubs in particular facilitating tree regeneration. Hence, the conservation of certain cover should be also promoted (especially in the more open areas) and not penalise by the payments from the EU common agricultural policy. However on occasions, a dense and tall shrub-layer can hamper the natural tree regeneration by competing with saplings, and in this case the layer must be periodically thinned to facilitate regeneration and grazing.

Some assistance could be also needed to make compatible grazing with tree recruitment, especially in areas with very low tree density. Assisted regeneration is likely to be needed in areas which are most attractive for livestock and where grazing intensity is high.

3.2.2 Seeding vs planting

In oak-based wood pastures, assisted regeneration can be based either on seeding acorns or on planting nursery-grown seedlings. Planted seedlings frequently have low survival rates, depending on the edapho-climatic conditions and planting practice. Sowing acorns (rather than planting seedlings) more closely resembles the process of natural regeneration, and the resulting seedlings are typically more resilient in dry areas and shallow soils. Regeneration from seeds could be then a key condition for the viability of saplings in such areas.

For direct seeding, acorns need to be protected against predators (rodents but also wild boar). Cat/dog excrements can be recommended as a cheap method for small scale and/or multiyear plans of gradual reforestations. Also the use of cheap individual “acorn shelters”, made of a degradable material are worthy of consideration. Seeding during the peak of acorn fall can reduce, by satiation, the acorn predation by predators. This could also be applicable for other tree species.

3.2.3 Artificial wire thorny shelters and natural protectors (pruned branches)

There are benefits of protecting young plants from livestock (and wild fauna such as red deer and other browsers). Fencing young tree saplings (seeded or emerged naturally) in order to allow tree regeneration in grazed wood-pastures requires major maintenance activities, either in terms of replanting to substitute the dead/dried tree saplings or the maintenance of fences.

The practice of stacking pruned branches around the young trees can sometimes help for a couple of years, but eventually (if not immediately from the beginning) the use of wire mesh treeguards is essential. Moreno et al. (2017c) reports that thorny protectors, a cheap adaptation of the classic wire mesh, is an efficient and long-lasting solution, that reduces costs because the lower need of TMT iron bars. Combining direct seeding with protected acorns and fencing new plants with thorny protectors is recommended as a cost-effective and feasible method of assisted tree regeneration.

3.3 Livestock management

3.3.1 GPS collars

In a study focused on reindeer husbandry, Valinger et al. (2017) reported that the use of GPS transponders on the collars enabled better monitoring of herds, easier working conditions of herders, real-time tracking of predators, and less risk of accident of livestock in the field and with the traffic. Some initial work indicated that it was possible to create a web-based platform to indicate the changing location of the reindeer over time. Information about livestock movements (e.g. migration routes of reindeer herd) provides the basis for better management practice, including consultation with forest owners/managers for paying proper consideration to important grazing areas when planning new forest management operations. Unfortunately the use of GPS at current prices did not pay off financially.

In Spain, Moreno et al. (2017c) reports that the duration of the battery is a current bottle-neck for using GPS with cattle, but new technologies in low-power electronics have promise. For example, the modular design facilitates the testing of current and emerging radio technologies, such as GPRS, SigFox, Lora or Neul. The research is now focussed on the search of mechanism of battery auto recharge while the animal is wearing the collar. This research idea is now looking for additional funds to go forward, and Moreno et al. (2017c) report that they hope to run field experiments on real farms in the coming years.

3.3.2 Invisible fencing system

Burgess et al. (2017) reported on the invisible fencing system which enables cattle management without above-ground physical barriers, relying on a buried wire-loop which produces a radio signal sensed by collars worn by the cattle. On approaching a boundary, the cattle hear a noise emitted by the collar, and if there is no change in direction the cattle receives a small electric shock (less than a conventional electric fence) which proves sufficient for the cattle to change direction. A financial analysis suggests that the cost of invisible fencing is generally greater than wooden fences. Hence the invisible fencing system is likely to be restricted to situations where unhindered access for the general public is valued highly

3.3.3 Fast rotational intensive grazing

Moreno et al. (2017c) reports that this time controlled grazing scheme is based on grazing paddocks with high stocking rates but for very short periods, and working with a large number of paddocks (separated by electric fences) to allow each paddock to have long recovery periods. In addition, a low-cost network of pipes and livestock waterer is needed to provide the livestock with sufficient water.

They report that long recovery periods led to a greater yield and diversity of grass production, fewer disease problems for livestock (parasites mostly require seven days to complete their life cycle) and has a positive soil impact (e.g. less compaction). Animals spend a short time in a small area before moving on, leaving behind concentrated manure, urine, and considerable plant residues both above and belowground, including remaining root material. These contribute to soil organic matter and nutrients. So, this grazing system not only provides nutrients to the ruminants, but also contributes to “feeding the soil”.

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 trees. Long recovery periods also provide an opportunity for the natural regeneration of tree cover. 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.

3.4 Fodder resources

Given the large seasonal limitation of most of the grass-based agroforestry systems, and the increasing costs of the feeding supplements, an increase in fodder self-sufficiency on farms is generally desirable. High productive and protein-rich fodder such as triticale, legume-rich self-seeding pastures and woody forage banks are recommended.

3.4.1 Evaluation of cultivars of triticale as forage crop

Although the biomass and grain production of triticale generally decreases with the presence of trees, Moreno et al. (2017c) report that some cultivars are well-adapted to grow in wood pastures (e.g., Montijano, Fronteira and Montijano for Iberian dehesas). Forage yield in winter was higher under trees (than in the open) and which can help to meet livestock food requirements in this period. Also the quality of the forage (protein content and digestibility) was favoured by the presence of the trees.

To assure the adequate regrowth of triticale after winter grazing, grazing should be completed before plants start stem elongation (state 30 in the Zadocks scale). Due to the poor and shallow soil usually found in many wood pastures, a yearly rotation in the crop area is highly recommended. Although the yields of triticale are widely variable between years due to the irregularity of the climate (especially rainfall), even in low-rainfall years the increase in the forage biomass in comparison with that produced by natural pasture, offset the cost of all cropping practices (tillering, sowing, harvesting, seeds, and fertilizers).

3.4.2 Effect of shading on legume species

Moreno et al. (2017c) reports that the sowing of legume-rich self-reseeding mixture can produce a noticeable increase in pasture productivity and quality extending for at least a decade, irrespective of the presence of the trees. However delayed grazing is essential the first years to ensure a good establishment of the legume species. Over time, the dominance of the legumes gradually decreases as native species become more dominant. Under Mediterranean climate conditions more persistent legumes species were *Trifolium subterraneum, T. michelanium, T. resupinatum, T. vesiculusum* and *Ornithopus compressus*.

In a series of experiments in Sardinia, Franca et al. (2017) report that the openness of scattered trees in wood pastures meant that most of the planted legume species responded satisfactorily to being sown beneath trees. Nevertheless, shading reduced the dry matter production of the legume-rich mixtures by 10-30% compared to open pasture (by 40-50% under deep shade). However crude protein levels were greater in shaded than unshaded conditions. *Trifolium stellatum* and *T. incarnatum* grew better beneath the oak canopy in the Spanish test and *Trifolium subterraneum* (variety CAMPEDA) and *Ornithopus sativus* were the most adapted species to shade in the Sardinian study. The size of individual leaves was significantly higher in all species in shaded conditions. *Medicago polymorpha, Trifolium incarnatum* and *Trifolium michelianum* showed longer stems in shaded, rather than unshaded, conditions. Locally selected mixtures were more competitive against unsown species than some commercial mixtures. A selection program of shade adapted genotypes is therefore still needed.

The increased cover of legumes produces a significant increase in soil nitrogen that can indirectly result in significant increase in the protein content of the pasture, especially of the grasses. Hence sowing legumes causes an improvement in pasture quality, both due to the higher cover of legumes (rich in protein) and for the increase protein content of the non-leguminous plant species.

The carbon content of the soil tended to increase with the age of the sown pasture, both under and beyond canopy, and this can help improve the resilience of silvopastoral systems against climate change. Although the sowing reduced slightly the "alpha diversity" of plants, the total species richness ("gamma diversity") was not affected significantly.

A reliable economic evaluation was not completed but preliminary results indicate that the improvement in the pasture quality and productivity offset the cost of the seed mixture and fertilizers.

3.4.3 The forage value of shrubs

The quantity and quality of grazed forage are seasonally variable and highly dependent on climatic conditions. Climate change in the Mediterranean will probably increase drought conditions in late spring and summer, and also the overall variability of grassland production annually. Trees and shrubs could provide a complementary forage resource on wood pastures and other livestock-based agroforestry systems. Indeed, the maintenance of an open shrub middle-layer in wood pastures is of interest as it provides a stable source of forage to animals, especially during the summer and winter seasons where herbaceous vegetation is limited. Although intake rates were usually low, the fodder trees provided a natural source of macro and micro-nutrients. In the work-package 2 network wood forage banks were not studied, but there are lessons which can be drawn from the work reported in work-package 5.

Mulberry trees (*Morus* spp.) is used as a livestock fodder in countries like India and Japan. The leaves of the mulberry are known for its high protein content (15-28%), good amino acid profile (> 46%), high digestibility (>80%), high mineral content with ash values up to 25%, low fibre content (7.1-8.1%) and excellent palatability.

Willow trees (*Salix* sp.) and nitrogen fixing alder trees (*Alnus glutinosa*) proved to be a good match for wet soils/climates, as they grow quickly and are richer in some macro and micro-nutrients than grass. For example willow leaves are particularly high in selenium and zinc. It is recommended that varieties that branch out widely, providing many young twigs within browsing height, are particularly advantageous if livestock are allowed to graze the trees directly.

3.5 New products

3.5.1 Assessment of biomass potential of hedgerows and the effects on additional benefits

Utilisation of the biomass, for example as firewood or ramial wood chip, can improve the revenue from agroforestry systems of high nature and cultural value. Small scale harvesting can be practiced in compliance with the sustainable rates of biomass harvesting, which resembles the historical biomass use of these systems.

3.5.2 Rediscovering oak acorns

Papadopoulos et al. (2017) report that the traditional tanning and extraction industry is returning to the use of natural, organic tanning substances in their production processes, replacing the chemicals that had formerly replaced natural tannins. Demand for oak acorn cups has recently increased. 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. High quality acorn cups may contain up to 20-30% tannin while content in the scales of the cups can vary between 30-40%.

There 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. 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. Hence the harvesting of oak acorn cups for tanning, nuts for flour and other uses can provide a supplementary income without incurring additional costs for their production.

3.5.3 Branding products of agroforestry systems

Among the different alternatives to overcome the constraints that threaten Spanish dehesas, one of the most promising is the development of premium brands which could help consumers identify those products generated in agroforestry systems and which could help pay for some of the public ecosystem services provided by these high nature and cultural value systems. In spite of interviewees being unfamiliar with the term "agroforestry system", Moreno et al. (2017c) report that in Spain terms such as dehesa, parklands, bocage, veteran trees are accurately recognised and described. This fact reveals that it may become necessary to use terms that are more familiar if a specific system is intended to be placed in value.

Agroforestry system of high nature and cultural value are recognised as a source of high-quality animal-origin food products. There are also socially important cultural services associated with the aesthetical and recreational value of the landscapes. There are some products which attempt to translate these services into commercial values. Moreno et al. (2017c) reports that emerging products which are viewed by interviewees as having development potential include asparagus, mushrooms, acorn products, medicinal plants and cosmetics, and herbs and herbal tea.

Varga and Vityi (2017) report that it is important to get the public more involved in wood pasture, as well as in enjoying the gastronomy of wood pasture products. They provide some examples of the synergies between gastronomy and support for high nature and cultural value farming, and how consumption of wood pasture products can help preserve biodiversity, ancient trees, and appealing landscapes. There is a hope that individuals can link personal experiences of delightful eating with the active conservation of biocultural heritage.

3.5.4 Increase awareness with education

Rethinking the connections between man and landscape is an ongoing challenge for humankind, as indicated by the current focus on nature conservation, sustainable agriculture and forestry, food sovereignty, education, human health and human well-being. Agroforestry systems of high nature and cultural value can help link people with the landscape as they have a central (historical) role in the local economy, can form beautiful habitats, and they have a high level of the local heritage value.

3.6 Conservation

3.6.1 Valuing and protecting large old trees in wood-pastures

Hartel et al. (2017) report that in Romania, large old trees are appreciated for cultural-historical values but they are removed when people perceive them as deteriorating e.g. hollows, dry parts, ageing bark, and large nodes. They consider that this happens because the tangible values are more important than the cultural values. Local communities perceives virtually no natural values related to large old trees; therefore Hartel et al recommend communication strategies to build on the historical, cultural features of these trees. One noticeable initiative is The Remarkable Trees of Romania, which brings together knowledge on large old trees in Romania. Over 2500 trees from over 110 pastures were inventoried in 2015-2016 (database can be consulted at www.arboriremarcabili.ro).

3.6.2 Restoration of wood pastures and hedgerows for biodiversity

An important objective in managing European wood pastures is to maintain or enhance biodiversity. Burgess et al. (2017) reports that a botanical survey across i) a restored and ii) an unrestored ancient wood pasture and iii) an unrestored secondary wood pasture in UK showed that the greatest number of plant species was found in the restored ancient wood pasture i.e. the restoration which involved pollarding and opening up the woodland was successful in achieving its biodiversity objective.

In Romania, Hartel et al. (2017) reported that scattered trees contribute to increase α diversity (plants and spiders) compared to open pastures but the positive effect of scattered trees with shrub understory is still stronger. Regardless of the understory (grass or shrubs) scattered trees have substantial influence on the β diversity of the pastures.

In France, Thenail et al. (2017) reports that hedgerows (15 years after planting) harboured at least comparable levels of biodiversity of conservation interest (vascular plants, butterflies, forest carabid beetles) as older hedges. They also showed similar levels of predatory arthropods (carabid beetles) potentially involved in biological control of crop pests. The trend to higher abundances of predatory arthropods in annual crops adjacent to new planted hedgerows suggests that they might contribute to pest regulation services.

It can be argued that in many wood pastures and hedge-contoured fields (Rivest et al. 2013), tree density does not significantly reduce land productivity and hence scattered trees should be maintained because of their biodiversity benefits. There are synergistic or antagonistic effects of similar landscape properties depending on the biological groups. Therefore, integrating spatial issues in the design of hedgerow plantation and wood pastures in the evaluation of their contribution to ecosystem services is important.

3.6.3 Integration of grazing with biodiversity

In Romania, Hartel et al. (2017) argue that the cultural and ecological value of oak wood-pastures is maximized if grazing includes a mix of species, such as buffalo with cattle. For instance buffalo can help maintain wetlands by creating small ponds across the pasture, for the benefit of rare amphibians. Also grazing Mediterranean woodland provides some ecosystem services that integrate those provided by the forest itself, such as the increase of the biodiversity and the reduction of fire risk.

3.6.4 Soil carbon content in newly planted wood pastures

Soil organic carbon can be higher in wood pastures and hedgerows than in open grasslands, as demonstrated by the studies in Mediterranean wood pastures, the French bocage, and dry areas of German Spreewald hedgerows. By contrast, the soil organic carbon was also found to decrease in planted areas of silvopastoral plots and hedgerows compared to the open pastures under wet conditions (UK parklands, flooded areas of the German Spreewald hedgerows). Possible reasons for this are i) a reduced grass cover beneath the trees reduces grass root turnover which can build up soil carbon, and ii) a reduced soil water content (or lowering of groundwater table) which increases soil respiration. However Burgess et al. (2017) reports that, even in these wet conditions, the above-ground and below-ground carbon storage in the new wood pasture system (63.4 Mg ha^{-1}) was greater than the equivalent pro-rata value if the trees and pasture were kept separate (60.5 Mg ha^{-1}). This suggests that agroforestry is more effective at storing carbon, for a specified level of tree cover, than separate areas of trees and pasture.

Scattered trees and hedgerows must be maintained for several decades to significantly contribute to carbon storage in soil at the landscape scale. Preliminary results of the carbon fluxes monitoring in a Spanish dehesa, indicate a slight positive annual carbon balance (~ 0.5 t C per hectare), a noticeable C-sequestration strength given that the mean annual value estimated for European grasslands is ~ 0.15 ± 0.07 t C per hectare (Chang et al. *2*015). This carbon sequestered in trees and soil organic matter of dehesas could help offset some of the emission of other greenhouse gases associated with livestock rearing. Nevertheless, the balance of greenhouse gases in dehesas and other agroforestry systems of high nature and cultural value deserve more studies in order to get reliable estimation of the C footprint of their products.

3.6.5 Water quality

Thenail et al. (2017) in France reported a high variability in soil nitrate concentrations in hedged plots, probably due to the variability of soil management practices in the fields, and no impact of old nor recent hedgerows. They explained that a more reliable evaluation of recent hedgerows impact on water quality would involve further sampling on a longer time period.

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