Initial report on studied innovations for agroforestry of high nature and cultural value

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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 Milestone 5 (2.4) compiles the initial results of the innovations tested by the participative research and development network (PRDN) for agroforestry of high nature and cultural value, organized in 10 national stakeholder groups. The milestone is connected with work-package 2; similar reports exist for agroforestry with high value trees, agroforestry in arable lands, and agroforestry for livestock systems.

2 Agroforestry of high nature and cultural value

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 biodiversity and are an appropriate focus for scientific research.

The work-package has five objectives:

i. to identify examples of the best practices, key challenges and innovations to address challenges identified by the stakeholder groups. These were addressed by ten individual stakeholder reports available on the AGFORWARD website (https://www.agforward.eu/index.php/en/hncv-agroforestry.html);
ii. to describe the key inputs, outputs and ecosystem services flows for selected systems,
iii. to agree within the PRDN, the key innovations or improvements in knowledge needed in order to promote adoption of agroforestry of high nature and cultural value. This was addressed by Moreno et al. (2015a);
iv. to agree and implement within the PRDN an experimental protocol to develop and test proposed innovations at existing experimental plots and through on-farm experiments. This was addressed by Moreno (2015b);
v. to provide and promote guidelines for farmers on how to establish economically viable agroforestry practice in high nature and cultural value. Initial results and conclusions that would support the guidelines are compiled in this milestone.

3 Summary of results

This section summarizes the initial results of the innovations examined by most of the stakeholder groups. The key results and technical assessment, and if possible a socio-economic assessment, is included for selected groups.

Table 1. Summary of the results of the innovations examined for agroforestry systems of high nature and cultural value.

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pasture: montado (Portugal)	Understory management to improve cork production (quality and quantity)	The effect of the treatments was different in the two trial blocks. The effect of precipitation was significant. In one block the removal of the natural shrub understory component and the installation of a lupine pasture resulted in a positive effect on cork thickness, when compared with treatment with long term (10 years) no understory management. No significant difference in cork thickness was observed in the second block. Cork quality decreased between the two cork extractions in all the plots, despite the treatments.	Climate is an important determinant of the final value of cork thickness. Understory management practices must be adapted to the stand and soil conditions. Cork quality is determined by tree genotype. Tree selection and regeneration for the long term management of the stands is a key factor for the economic results of the farms.	Economic assessment, namely considering different climate and understory management scenarios, is essential when defining the management plans (e.g. PGF's). Although an additional cost, cork sampling prior to the cork extraction allows farmers to determine cork characteristics. This is particularly important in irregular stands (structure, soil, type of management etc).

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pasture dehesa, Spain	Shade-adapted forage fodder: legumes	The sowing of seed mixtures with high number of self-reseeding legume species produced a noticeable increase of the pasture productivity and quality (protein content). The biodiversity of species-rich Mediterranean annual pastures was not negatively affected. A positive tendency in carbon sequestration was also observed	The positive effects lasted for more one decade after sowing. Positive trends were found irrespective of the habitat, beneath and beyond the tree canopy. Delayed graze is essential the first years to ensure a good establishment of the legume species. More persistent legumes species were *Trifolium subterraneum, T. michelanium, T. resupinatum, T. vesiculusum* and *Ornithopus compressus*.	A reliable economic evaluation has not yet been completed. According to the seven farmers that participated in the study, the improvement in the pasture quality and productivity offsets the high cost of seed mixture and fertilizers.
Wood pasture dehesa, Spain	Shade-adapted forage fodder: triticale	Sown triticale produced 3000-5000 kg/ha of a high-quality forage, providing additional fodder for livestock, especially in critical shortage periods, such as winter and summer in the dehesa ecosystems in the Southwest of Spain. The resulting forage had a high protein content and organic matter digestibility, especially when grazed during winter. Although the annual forage yield decrease in general terms under shade conditions, the tested cultivars of triticale could be considered as well-adapted to grow in these agroforestry systems. Yield differences, which were not very high, depended on the specific climatological conditions of the growing season. Likewise, the winter forage yield resulted higher under shade conditions, which is very interesting to meet livestock food requirements in this period.	Optimizing the grazing intensity and period in winter is critical to obtain a good re-growth and consequently a good total forage yield. This grazing should not be very intense and should be performed before plants reach the growth stage 30 of the Zadoks scale. The late-spring harvest should be made before the growth stage 73 of the Zadoks 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.	This practice may allow farmers to reduce the current high costs of the feeding supplements they have to acquire annually. In these farm systems of low commercial profitability, this cost reduction is important. Although the forage yield is widely variable between years due to the irregularity of the Mediterranean climate (specially rainfall), even in a low-rainfall year, the increase in the fodder yield of this crop in comparison with that produced by natural pasture, offsets the cost of all cropping practices (tillering, sowing, harvesting, seeds, fertilizers).

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pasture dehesa, Spain	Protection of young trees (natural and artificial)	While classical steel mesh protector worked well, and only few of them were damaged by livestock in the first three years, the artificial thorny protectors worked still better, with almost zero damage. By contrast natural protection with pruned brunches decayed very quickly and its efficiency seems limited to the very short term, to allow the natural emergence of seedlings. Later on, seedlings that survive to the summer drought would need a thorny protector.	In farms grazed by small livestock, such as sheep, the dehesa manager could use low-cost protectors as piling up branches over seedlings. Artificial thorny shelters ("Cactus type) are more appropriate for cattle and wild ungulates. In farms grazed by bullfighting cattle the most suitable protection method is a wire mesh protector. Using shade, increases the survival of the seedling, thus it is an appropriate method.	Piling branches to facilitate the natural emergence of seedlings + artificial thorny protectors (15 Euros per unit) for the remaining seedlings. This saves money compared to the official payments for artificial regeneration of oaks in dehesas (30 euros/plant).
Wood pasture dehesa, Spain	Animal smart collars: design and manufacture of a new smart collar for animal tracking and precision grazing.	A new smart collar has been designed and fabricated using the latest technologies in low-power electronics. Our design allows us to reliable produce low-cost collars to be used in a wide variety of experiments involving extensive livestock farming. Besides tracking, the collar has been designed to investigate several problems and situations occurring in the Dehesa, such as precision grazing for the removal of fences and optimization of pastures, protection of valuable tree seedlings for forest renewal, selective water access for cattle to prevent the dissemination of tuberculosis from wild animals.	A critical assessment in the context of this project is the potential of having our own base technology, from which a series of collars adapted to different experimental conditions are being created. Several features of our design allows us to investigate important open problems. For example, is modular design facilitates the testing of current and emerging radio technologies, such as GPRS, SigFox, Lora or Neul. Also, a mechanism to stimulate the animal with electrical or ultrasound discharges is being tested in real conditions to elicit new precision grazing strategies. Finally, the collar can be configured with different quantities of Lithium batteries to guarantee the required lifespan in each situation.	Not available

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pasture dehesa, Spain	Branding HNCV agroforestry products	Citizens see quality brands as reliable tools to place a value on products and in general they see the creation of brands associated to the agroforestry production systems as a positive measure, provided that suitable training and promotion mechanisms are articulated.	In order to become effective, quality brands must emphasise the production system, which is a secondary attribute in the eyes of the consumer.	Public policies, both those directed to the promotion of quality products and to the compensation of ecosystem services are necessary so that the agroforestry systems may continue to provide services to society. Notwithstanding the above, citizen awareness is key so that their perception and evaluation of these systems may be more positive. Public policies design in order to increase this awareness have also to be implemented
Silvo-pastoral mosaic, Italy	Shade-adapted legume-rich forage	The oversowing of legume mixtures produced an increase of pasture productivity. Shading significantly affected pasture productivity in all treatments. Hardseeded legumes delayed their contribution to pasture productivity	The most adapted species for the use in mixtures for build legume-rich pastures were *T. subterraneum* CAMPEDA and *Ornithopus. sativus*. Other legumes, such as *T. vesiculosum* and *M. polymorpha* are good producers but did not perform well in the second year because of the high level of hardseededness that characterize their seeds. This does not mean that these species may likewise have good persistence characteristics, as contributions to the persistent soil seed bank	An evaluation on the economic and agronomic efficiency can be conducted only if the improved pasture remains persistent for a time limit of no less than 4-5 years. The duration of the experiment (3 years), linked to the duration of the project, does not allow to draw conclusions about the economic sustainability of the inclusion of a legume-rich mixture. Nevertheless, the farmers are well aware of the importance of well-adapted legumes to improve the quantity and quality of silvopastures.

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Grazed valonia oak woodlands, Greece	Shade-adapted legume-rich forage	In 2016 the sowing of seed mixtures with high number of self-reseeding legume species showed no statistical increase in biomass productivity. However, shading favoured productivity for both cultivars (seed mixtures) but there were no difference for the control. No differences were noted on pasture productivity of the cultivars for 2015.	The combination of trees with pasture species is compatible with evidence of negative interactions in this study. On the contrary, shading favoured biomass production. In practical terms, one of the reasons farmers cite for removing valonia oak trees is the shading effect of the tree crown to the under-grown pasture species. Based on the preliminary results such effect was not evidenced so there is no need to harvest the trees to favour the agricultural production	Local farmers have to be activated and be involved in the protection and maintenance of agrosilvopastoral systems. They have to be informed that the traditional agrosilvopastoral system can continue to provide numerous provisioning, regulating and cultural services.
Grazed valonia oak woodlands, Greece	Protection of young trees (grazing exclusion) and understorey clearing)	Based on the results from the first two years and by examining independently the "grazing" and "understorey" treatments, it appears that there is a tendency of fencing to positively improve regeneration. On the contrary, understorey clearing appears not affecting valonia oak regeneration.	To favour regeneration of the species, there must be protection from grazing either by restrictions over a period of time or by fencing locations of a certain number of trees as to maintain an average of 20-50 trees/ha	As it was suggested from the stakeholders meeting, it is of major importance the protection of these traditional systems. So far no measures have been taken that would encourage local population to protect the trees. Local forest service has to act as a liaison actor.
Grazed valonia oak woodlands, Greece	Attitude of local communities towards ancient trees	Local people were informed on the numerous services these systems provide.	Locals are reluctant to accept the duty to protect the system	More effort should be made for the environmental education and information of the local people.

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pastures, UK	Wood pasture restoration including the use of a management tool	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.	The study also showed that it was possible to use the "Kirby" model to make predictions regarding the future age distributions of different tree species	
Wood pastures, UK	Economics of invisible fencing	The cost of single loop invisible fencing covering about 25 ha is about 44% greater than with a wooden fence over a 30 year period	The invisible fencing system is technically possible.	The invisible fencing system is likely to be restricted to situations where unhindered access for the general public is valued highly.
Wood pastures, Romania	Protection of young trees (pruned branches and thorny shrubs)	In 97 wood-pastures surveyed in 2015 and 2016, no evidence was found about the deliberate use of thorny shrubs for protecting young trees. Oak regeneration was associated with thorny shrubs only in those regions of wood-pastures where the grazing intensity dropped temporarily (ca 5-7 years). These areas were always the marginal areas of the wood-pasture. Fencing with thorny shrubs as well as artificial (metal) fences in the Breite ancient wood-pasture in 2010 suggests that these methods have a good potential to be efficient.	Fencing young tree saplings in order to allow tree regeneration in grazed wood-pastures requires major maintenance activities. The mortality of the planted trees was large; in our case about 70% of the planted trees died at the end of the second growing season.	While tree regeneration in wood-pastures is possible with fences, the social capital (to maintain fences) and the institutional support are too weak to assure the sustainability of such an intervention. For example fences and saplings can be damaged by shepherds or unknown persons roaming in the area, uncontrolled (illegal) pasture burnings and/or stealing the saplings. 'Tree plantation' activities as conceived by forestry institutions still follows the conventional plantation to regenerate high forest; this is damaging the wood-pasture.

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pastures, Romania	Managing vegetation structure and biodiversity with different livestock types	Findings by research carried out in 2015 on an oak wood-pasture with mixed livestock grazing (buffalo, cattle, sheep, about 1 LU/ha) shows that sparse trees and shrubs are small natural features which have disproportional effect on the plant and spider diversity on wood-pastures. Sparse trees without shrub under canopy, sparse trees with shrubs under canopy and open pasture surfaces with no woody vegetation had distinct plant and spider communities, with sparse trees + shrubs attracting the highest levels of biodiversity.	This study showed that sparse trees and shrubs can increase the biodiversity value of even moderately intensively grazed pastures. Furthermore, trees and thorny shrubs provides several ecosystem services which are recognized by farmers.	High level formal institutions such as the CAP should actively and explicitly encourage the maintenance of sparse trees and shrubs on pastures. In this way the integration of food production and biodiversity conservation could be advanced.
Wood pastures, Romania	Attitude of local communities towards ancient trees	The attitude of local communities towards ancient trees from wood-pastures was assessed within the general assessment of perceptions and attitudes towards sparse trees on pastures. In this way it was possible to contextualize the results. Locals associated mostly tangible values to mature, healthy looking trees while mostly intangible values were associated to large old trees. When the unproductive (i.e. hollowing dying) parts of the tree increase, these trees should be removed from pastures, even if they are old and large. This study was published in 2017 in Agriculture Ecosystems and Environment.	The sustainability of the large old trees in the ancient wood-pastures of Transylvania requires first of all a change in the attitudes and perceptions of locals towards the values of these trees. Only after this is done, should the technical aspects to protect these trees be implemented. If the local values and social capital are not strengthened, any technical intervention would fail.	Large old tree conservation in the wood-pastures from Transylvania requires first of all shifts in people`s attitudes and institutional support (e.g. from forestry).

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pastures, Hungary	Renewing encroached andabandoned wood pastures	It is a crucial role of the future of wood pastures, because the partly or total abandonment of the wood pastures are/were widespread in the all country. Nowadays, more farmers are started to use again former wood pastures. The renewing process requires very hard labour work and is time and money consuming. But it has a positive effect on biocultural diversity and farming. It is important to leave some shrubby patches at wood pasture for young trees and for the birds.	Informing farmers to leave shrubby patches on their wood pasture. Guidelines of the best methods to encourage natural friendly renewal. Natural friendly renewal has time and machinery implications. The best solution is human labour, but is very hard and expensive.	Agroforestry subsidization should provide money for renewing wood pasture, not just for planting. The CAP should accept trees and shrubs on grassland.
Wood pastures, Hungary	Protection of young trees (nursery shrubs vs artificial thorny protectors)	The best protection of young trees is the natural thorny protectors with metal or plastic mesh. The natural thorny protectors have a nursery role as well. It is especially important for oak. It is best if the trees are planted as seeds and not as young tress.	Sometimes it is hard to provide or even buy nursery shrubs. To leave nursery shrubs on the pasture land is not supported by the CAP. Support only native species for plantation.	Policy should accept and encourage the retention of nursery shrubs on grassland to help to create or maintain high nature and cultural wood pastures.
Wood pastures, Hungary	Recovering pannage practice	It has an important role 50 years ago in Hungary, but in the 70's the extensive pig keeping stopped. The interest is high from farmer and gastronomy, but there are not supporting forestry policies.	The Mangalica (curly-hairy) pig could be a perfect breed to recover pannage in Hungary.	It is not possible to recovering pannage practice in Hungary, because the different strict policies against of the extensive pig keeping. First the policy should give permission for research and testing. The Hungarian Mangalica Breeder Association would take part this process.

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pastures, Hungary	Application of local knowledge to improve grazing practice in wood pastures	Mainly in this research we focused on role of solitary trees and closed canopy parts of wood pasture systems. Based on the traditional ecological knowledge the main tree species are the best: oak and wild fruit. Closed canopy part of wood pasture has essential role during the grazing management, because it could provide shelter during hard weather conditions.	Knowledge can be learnt from books, but local knowledge needs personal communication between older and young farmers and herders. This knowledge depends of the location, this why sometimes it is hard to generalized. This knowledge could give answers for questions, which comes from the local environment and endowments.	Herder meetings could encourage the use of local and traditional knowledge. We organized a final meeting of the project a meeting and festival of wood pasture farmers and herders. It was an idea of one of the farmer, who renewed an abandoned wood pasture in his village. The festival will be at his wood pasture on 3 June 2017.
Wood pastures, Hungary	Attitude of local communities towards ancient trees	1. We completed a survey about the relationship between childhood and wood pastures and ancient trees. It is shows that ancient trees are important for local people, because the tradition, local heritage and beauty of nature. In the past they visited local wood pastures more and had a stronger connections of the area and ancient trees then nowadays. Local children mainly had knowledge about the wood pasture and ancient trees from school and their parents, but in the past sometimes they did not know anything 2. We developed an education program with a local school to improve knowledge and awareness of ancient trees and wood pasture.	It is very hard for local communities to connect with ancient trees and wood pasture nowadays. Not just because the abandonment and cutting our ancient trees. Whereas most of the wood pasture was once owned and used by the local community, now it mainly owned by private farmers. The private wood pasture farms are usually fenced, which was not the case before, and the livestock are grazing without human herder.	We are developing an innovation for the best methods on how you should encourage local people awareness of the wood pasture and ancient trees values and important from local level to national level. 1.co-operation of the local people, school 2. education program in local school 3. talks at the local village 4. festival of wood pastures and herders 5. local and national YV program about wood pasture, Gastroangel, reports at the main radio with wood pasture farmers 6. maintain Facebook page

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wood pastures, Hungary	Branding HNCV agroforestry products	The branding has a high interest, but it is very time and money consuming to develop such a big project. We asked gastromarketing people and their suggestions was that the quality and personality is much more important that a brand nowadays. We did some steps further for example wood pasture products was one of the topic of the most popular Hungarian gastronomy TV show: Gastroangel. This led to many people got knowing about the high nature and cultural value wood pasture products.	Nearly every day a new branding is presented. It is sure, that a good marketing could encourage the popularity of the HNCV products. A key question is the financing. The farmers are not willing to money for this branding, because they believe and focus more on quality and personality. It is based on their previous experiences. Technical questions is that is hard to maintain a "branding control" or even the definition is not clear for the farmers.	Branding and consuming of HNCV agroforestry are really a socio-economy questions. A good project which involves professional marketing as well could solve this issue. Some initial examples shows the potential.
Wet meadows with hedgerows, Germany	Best and cost-efficient method for hedgerows rejuvenation	As a consequence of recent extreme events severely affecting the hedgerows in the area, rejuvenation of several hedgerows was necessary. In order to restore the historical look of the system that was created with human intervention, the developed rejuvenation strategy, should take into account the limitations of the regulations in this nature protection area.	The planting activities should be carried out in accordance with the local regulations preferably by a company that has experience with similar projects and knowledge of the area. The trees and shrub species selected should be native species with main proportion of the currently predominating tree, i.e., *Alnus glutinosa*. Fencing is an indispensable measure in the area and should be applied in the first five years after planting.	The costs of planting and fencing were high. No benefits from harvesting the biomass can be obtained from the degraded hedgerows, as the wood is of old age and consequently low value. Moreover, harvesting and removing the wood from the site is costly. Hence, the cost efficiency is reduced and replanting of degraded hedgerows which requires a significant investment with no financial returns is possible only if an external funding source is found.

System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Wet meadows with hedgerows, Germany	Valuing hedgerow biomass	The area of the individual hedgerows follows the hydrology of the area having the smallest proportion in a previously flooded location. A positive tendency of trees on soil carbon was suggested.	Recent flooding events have reduced the area of trees and have inhibited their regeneration. Trees are important to store carbon in their biomass and in soil. Degradation of tree rows may result in loss of carbon transforming the wetland from a sink into a source of carbon.	A reliable economic evaluation has not been conducted yet. When trees are managed in a sustainable way, it can be expected that the harvested biomass could become a source of funding the maintenance of tree rows. This remains to be confirmed

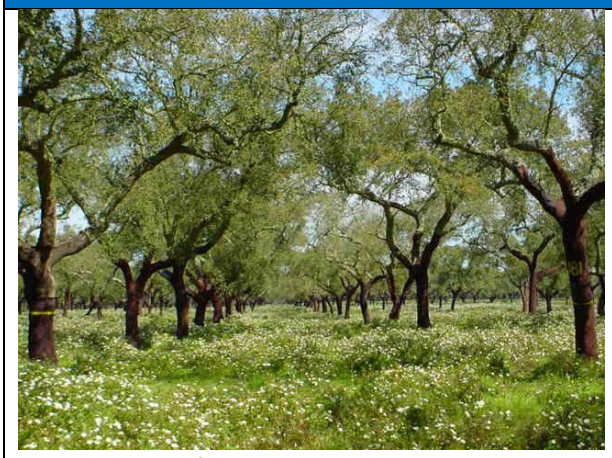
System	Innovations suggested	Key result	Technical assessment	Socio-economic assessment
Mixed farms rich in hedgerows, France	Design and planting of new hedgerows as source of wood resources and other ecosystem services (innovation developed by Terres & Bocage Association)	New planted hedgerows (≤ 15 years) and old hedgerows contain flagship species (butterflies and forest carabid species) and plant herbaceous species, but new hedgerows contain more tree and shrub species. New hedgerows have a similar potential as old traditional hedgerows and grassy field margins, in terms of diversity of predatory carabid beetles. The trend to higher carabid activity-densities in annual crops adjacent to new planted hedgerows suggests that they might contribute to pest regulation services, but over the longer term. The highest SOC (Soil organic Carbon) content is next to the hedgerows (at about 1 m) in the surface layer for both new and old hedgerows. It is lower for new hedgerows, but SOC contents are beginning to be marked by the impact of the plantation. Under grassland or wheat, soil chloride concentration were higher in the vicinity of new or old hedgerows (- 6 m): this indicates the water uptake by trees.	The amount or configuration of semi-natural woody habitats in the landscape context of field margins have strong effects on the diversity of all studied biological groups. The land use of the plot adjacent to the hedgerows affect the nitrate and chloride concentrations: the concentrations measured in spring were significantly higher in maize plots highly fertilized at that time. At this stage, the antagonist or synergetic effect of field or field margin management on biodiversity and soil/water quality has not been tested thoroughly.	Farmers reported yield loss or gain 6-8 m from the hedgerow according to its orientation, but no whole field effect. This was confirmed by the wheat yields we registered for the surveyed fields. Farmers consider that the variability of yield at a farm scale is firstly due to the variability of soil quality, still they point this antagonist effect of hedgerows at a farm scale. Farmers have several objectives related to the new hedgerows: protection of grazing cattle and crops, regulation of water flows and soil erosion, and improved aesthetics and neighbour relationships. The new hedgerows of 10-15 years are starting to produce firewood: interviewed farmers use wood logs for their principal heating (consumption of at least 10 m^3 per year). At a farm level, the management of old hedgerows is difficult and time consuming (tree pruning and mechanical bush clearing): several tens of days per year are dedicated to this management. The maintenance work of new hedgerows of 10-15 years has just started (lateral pruning and bush clearing). The costs from establishment to first maintenance of the new hedgerows (supplies and labour) would be compensated by the value of the first productions of wood logs, if sold 10-15 €/m^3, plus of wood chips, if sold 30 €/m^3. Wood logs are mainly used by the farmers themselves. Wood chips are made of branches of very different size and quality, hence dedicated to mulching. A market, at this price, is still difficult to find. Wood chips have been mainly used for mulching new hedgerows.

4 Individual results from each stakeholder group

This section describes with more details the results of the innovations examined by each stakeholder group.

4.1 Wood pastures in Portugal (Montado)

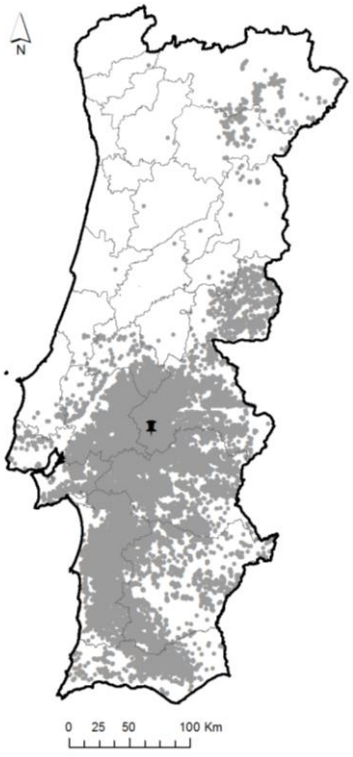
Innovation: Understory management to improve cork production (quality and quantity)



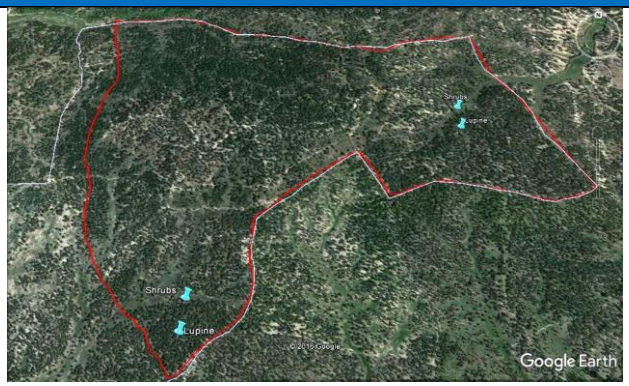
General view of the cork oak montado system in Portugal (photo: Joana Amaral Paulo)

General view of a lupine pasture (photo: Joana Amaral Paulo)

Map of System



Map of distribution of Portuguese montado (in grey). 'Pin' indicates the location of the farms that collaborated in the study.



Map of the *Chaminé* farm with the location of the plots' trial

Description tree component	Description of associated component (crop/pasture/livestock ….)
The experimental trial is located in Portugal Center, near the Montargil village, in a pure and uneven-aged mature cork oak stand. The stand is characterized by an average of 101 trees/ha, with the major percentage of trees having been debarked. Two different cork rotation cycles are present within the stand: from 2003 to 2012 and from 2006 to 2015.	The understory layer composed by spontaneous vegetation is dominated by the *Cistus salvifolius*, alongside with *Rosmarinus officinalis* and *Ulex europeaus* sparsely distributed, is characterized by a phytomass of 0.35 kg/m^3 at 4 years old. Until 2003 the natural understory was mechanical removed with an interval of 3 to 4 years.

Initial results

a) Results from the analysis made on the cork samples from the 2003 – 2012 period

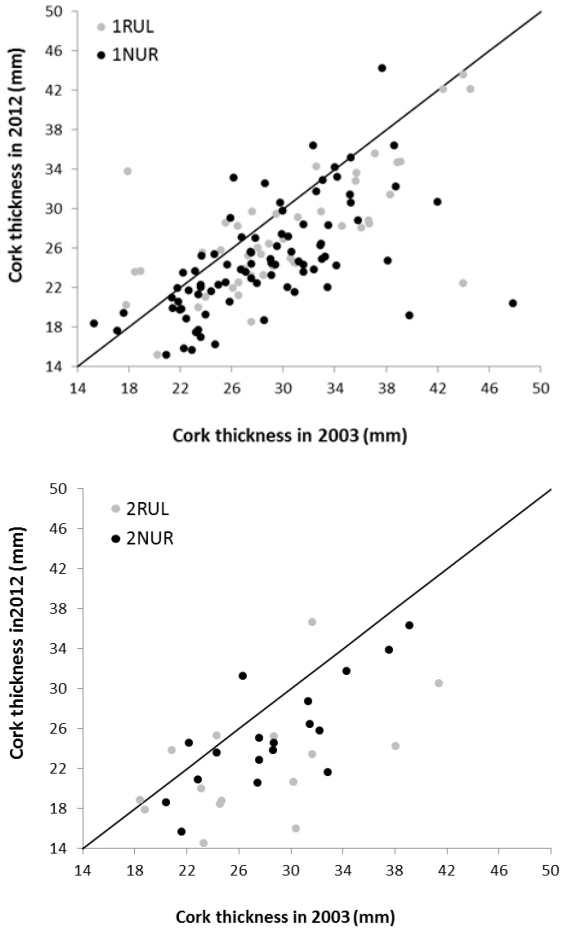


Figure 1. Relationship between cork thickness from 2003 and 2012 samples, for block 1 (top) and block 2 (bottom). RUL: understory removal and lupine pasture installation; NUR: control plot.

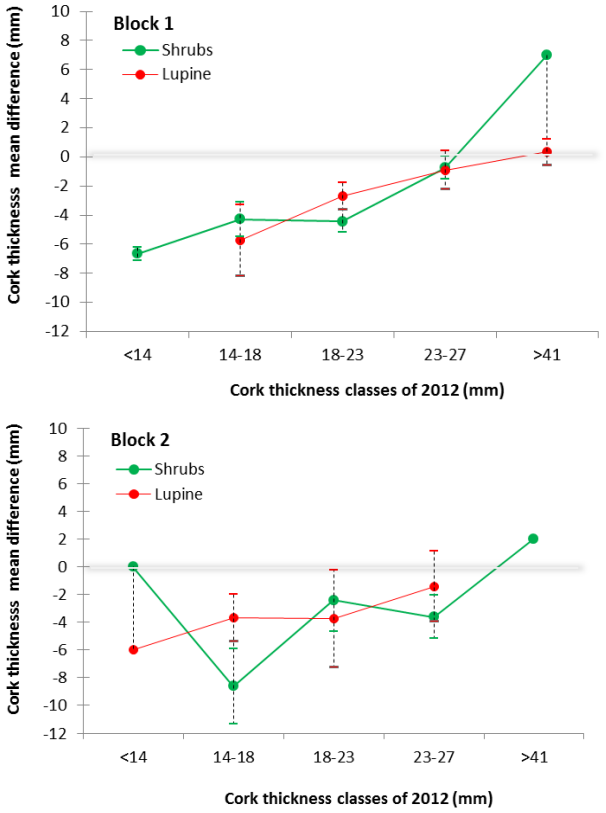


Figure 2. Cork thickness difference between 2012 and 2003 under different blocks (1 and 2) and different understorey (shrubs and lupine). Dotted lines indicate confidence intervals (α = 5%).

Figures 1 and 2 show a general decrease of cork thickness from the 2003 to the 2012 cork extractions. This decrease was observed in all the plots, and is statistically different between some cork thickness classes. Results also include annual cork ring measurements made on the cork samples that were used for assessing differences in the tree responses between the treatments using a mixed modelling approach (not shown).

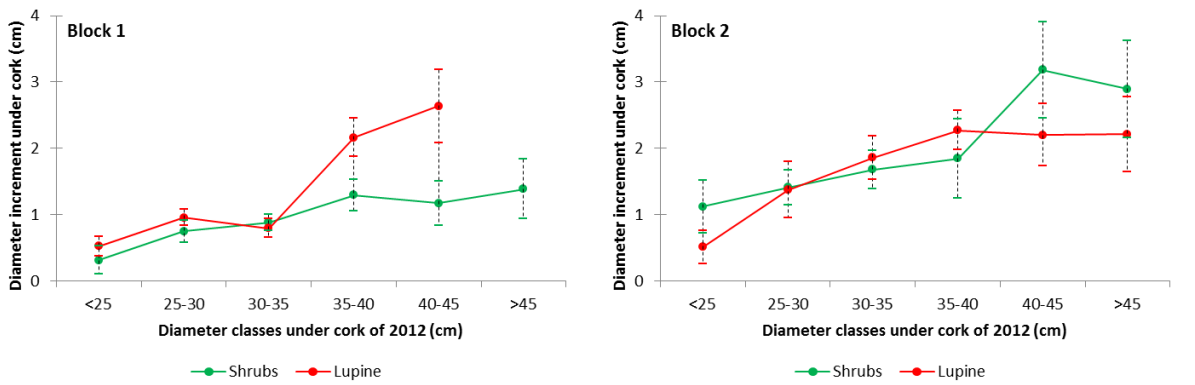


Figure 3. Average value and confidence intervals for diameter under cork (wood) increment (growth between 2003 and 2012) by diameter classes.

Figure 3 shows some significant differences between treatments, for some tree diameter classes in block 1.

b) Results from the ongoing tree monthly measurements

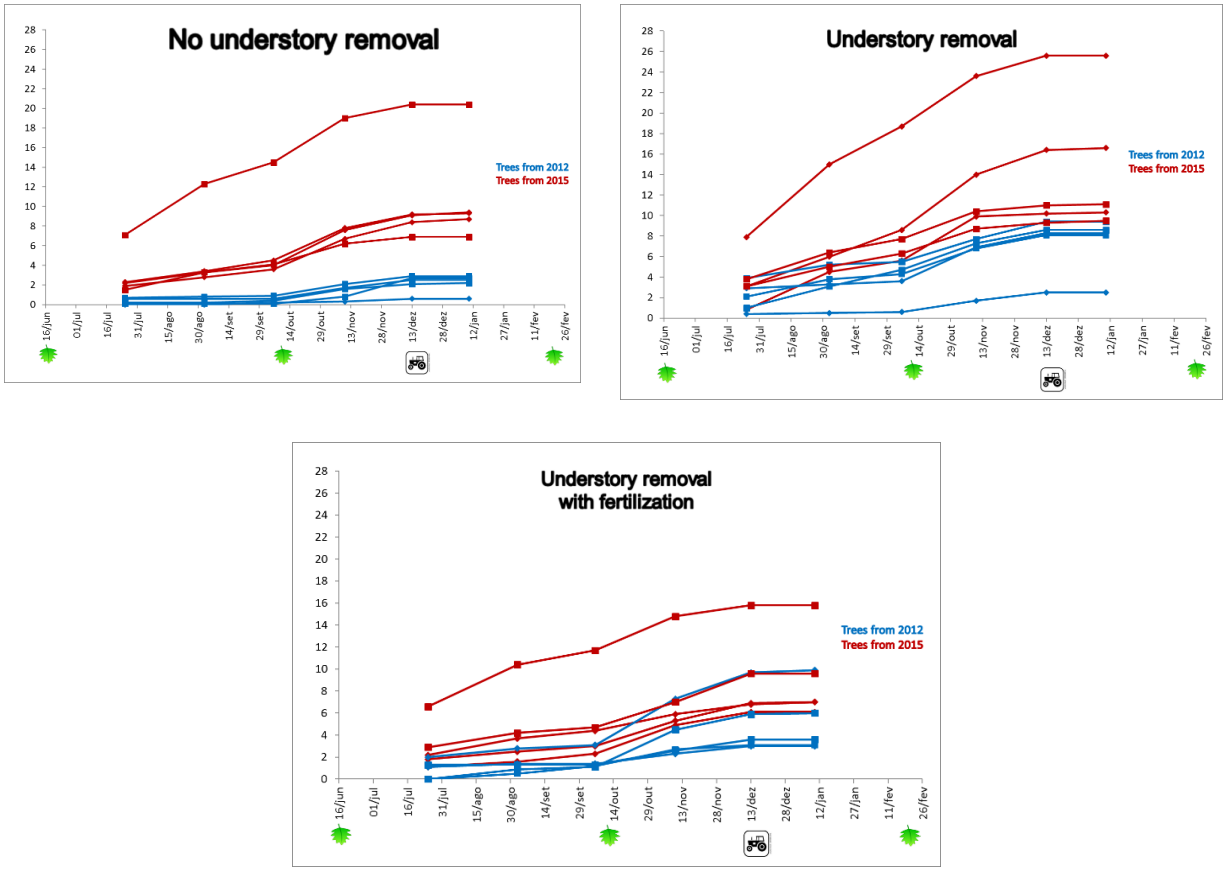


Figure 4. Tree diameter monthly growth (cork + wood) evolution. Months of leaf sampling and treatments application are identified by a leaf and tractor symbol respectively. Treatments are indicated in the graphics titles.

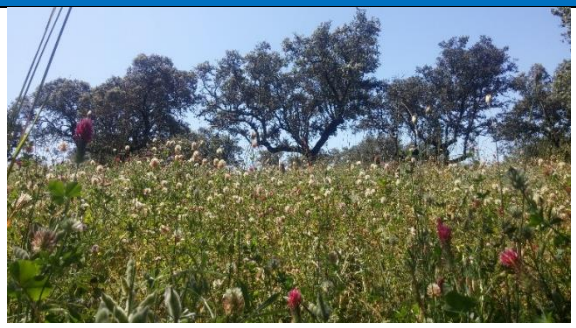
Scientific conclusions	Technical recommendations
Cork thickness and growth: periodic removal of natural understory dominated by *Cistus salvifolius,* followed by lupine pasture installation might, in some conditions, contribute in a positive way to cork growth. The conditions in block 1 that favoured cork	• Frequently access the tree – understory competition, stand growth and sanitary conditions, in particular in dry years.

growth are now being looked at and might be related to soil characteristic and stand structure (tree age). **Cork price:** despite the results on cork thickness and growth, no difference was found on average cork prices between the plots as a result of the treatments effect. **Tree:** Larger trees in block 1 (diameter > 35 cm) presented significant growth differences between the two treatments. A positive effect of the lupine pasture instalation was demonstrated.	• Define and periodically reassess suitable management practices that promote the reduction of a tree – understory inter species competition effect. • When possible, give priority to agroforestry management practices, namely by introducing legume forage species.

4.2 Wood pastures in Spain (Dehesa)

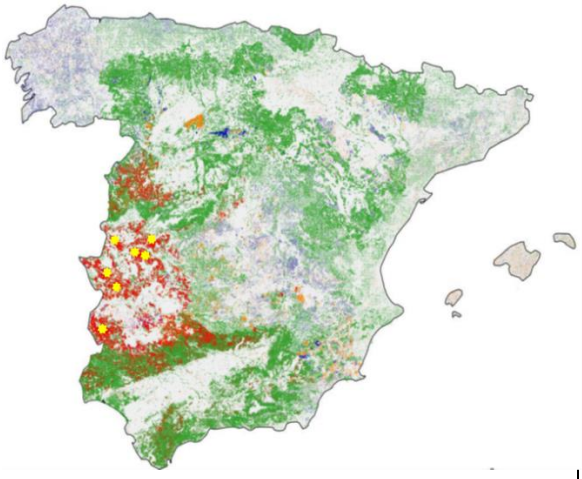
Innovation: Sown permanent legume-rich pastures

General view of the dehesa system

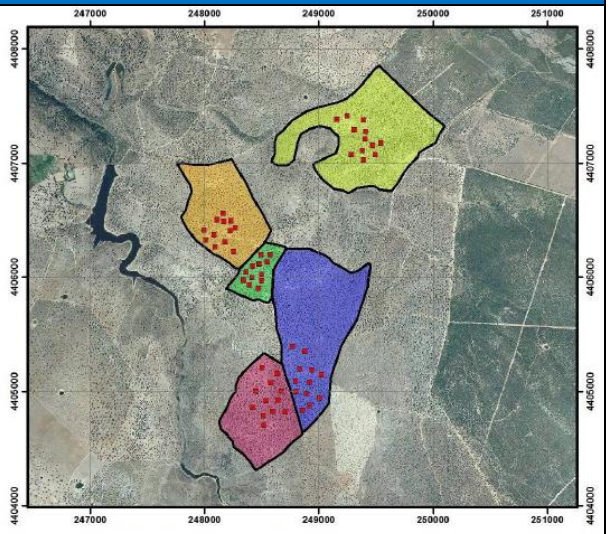


View of the pasture rich in legumes self-seeding species

Map of system



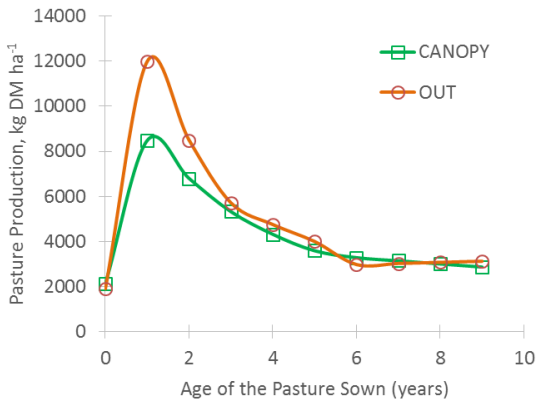
Map of distribution of Iberian dehesas (in red). With the location of the seven private farms that collaborated in the study (yellow stars). A total of 27 plots sown since the year 2000 to 2014 were studied besides of the seven respective control plots



Map of the Atoquedo farm with the five plots sown since 2010. In red are marked the location of the exclusion cages used to study the pasture production.

Description of tree component	Description of associated components
Scattered oak trees, mostly *Quercus ilex* but also *Q. suber, Q. faginea* and *Q. pyrenaica*. Low tree density and cover (10-30 trees ha^{-1}; 5-25% cover)	Natural pasture cover 100% of the soil, with a very high specie richness. Pasture productivity is usually low (1.5–3 t DM ha^{-1}), with strong seasonality (~ 80% production in spring) and interannual variability. Shrub species are frequently present by patches, mostly *Retama sphaerocarpa* and *Cytisus* spp. The main land use is the livestock breeding, with the three main species being cattle, sheep and Iberian pig. All of them range freely grazing grasses but also browsing shrubs and trees and consuming acorns in autumn (pannage).

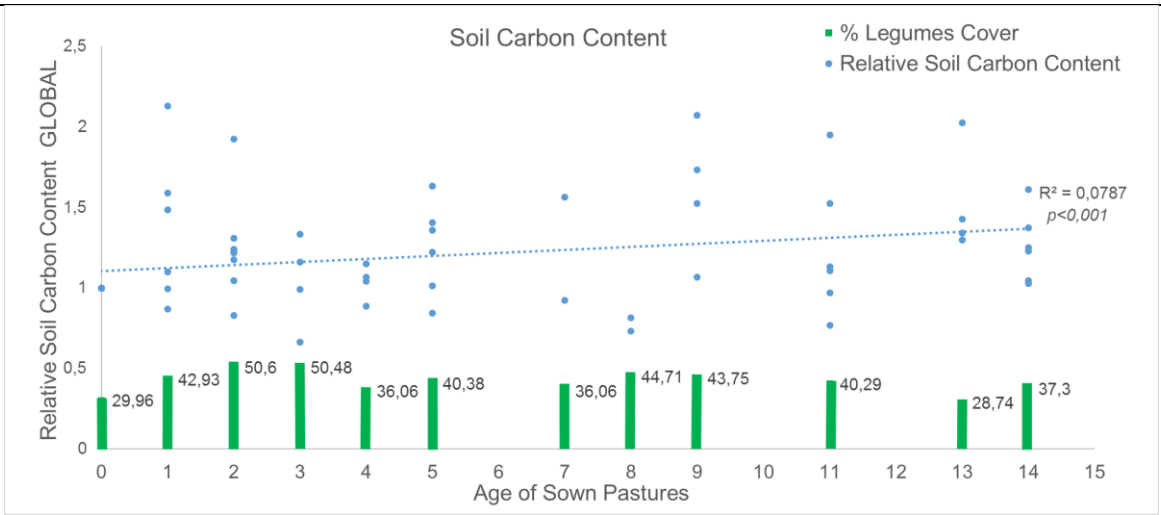
Initial results



The figure (left) shows that the production on the pasture increases after the sowing of the mix of legumes species (year 0 the control with native unmanaged pasture). The peak of production is recorded in the year of sowing, decreasing later, but even 9 years after the sown production is still roughly 50% higher than in the control plots.

Apart the increase production, the quality of the pasture is also improved, with higher cover of legumes up to 14 years after the sown (see the figure below). Except the year of the sown, results for the two habitats (beneath vs out the canopy) barely differed in terms of yield and quality.

The figure below also show how soil carbon increases gradually in the improved pastures. Similar results were found for mineral nitrogen.



Evolution of the soil C content (blue points and line) in the chronosequence of pastures (values relativized respect to the soil C of control plots). Green vertical bars show the cover of legumes for each of the ages analysed.

Scientific conclusions

Pasture yield, quality (protein content) and biodiversity increased temporally with the sown of the mix of legume species, positive effects that last even more one decade. The positive effect is also evidenced by a slight by long-lasting significant increase of legume cover in the sown pastures, both beneath and out of the canopy. Apart of the introduced species, native species also increased their presence, explained by the improved soil conditions caused by sown species and by possibly by the increased *Rizhobium* inoculation.

The content of carbon accumulated into the soil showed a positive and significant increase with age

Technical recommendations

According to the seven farmers that participated in the study, the improvement in the pasture quality and productivity offset sufficient the high cost of seed mixture and fertilizers. Nevertheless the profitability of the sown strongly depend on the persistence of the self-seeding legume species for what delayed graze is essential, at least the first years to ensure the sufficient implantation of the legume species.

Among the species of legumes, some of them seems better adapted to tree shade conditions, e.g. *Trifolium stellatum* and *T. incarnatum* grew better beneath the oak canopy. Other species, such as *Trifolium subterraneum, T. glomeratum, ornithopus compressus*

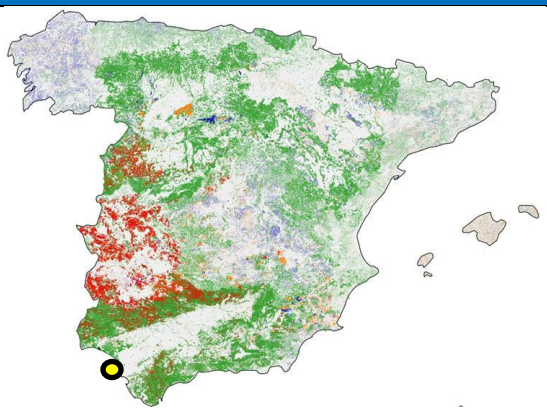
both under and beyond canopy, which enhances the importance of considering this kind of management practice to increase the resilience of this silvopastoral systems to current climate.	and *Medicago polymorpha*, grew similarly beneath than out of the canopy. All these species seem adequate for the seed formulation to improve pastures in Iberian dehesas.

Innovations: Shade-adapted forage fodder: Triticale

General view of the study area

View of the triticale crop sowed in the study area

Map of System



Distribution of dehesas in Spain (in red). Elaborated from SIOSE (2012) database. The location of the study area (Farm "Los Varales" in Badajoz) is marked as a yellow dot.

Orthophotos showing the experimental areas in the farm "Los Varales". In yellow, the study area established in the year 2014/2015; in red the study area in 2015/2016.

Description of associated components

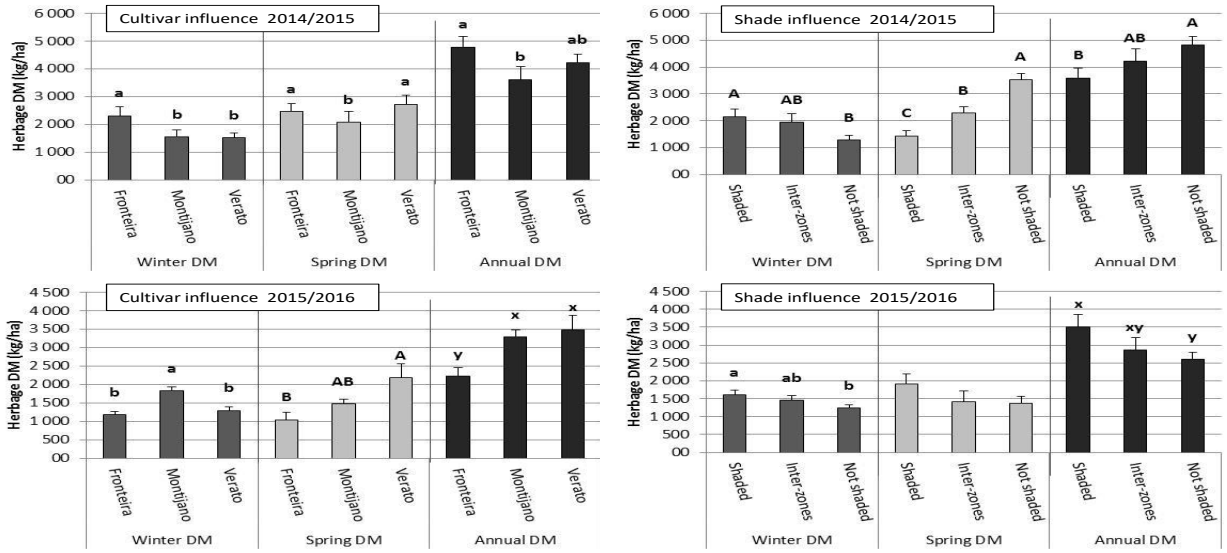
In the experimental area used in first study year, natural pasture cover 100% of the soil, with a high specie richness. Pasture productivity is usually low (1.5 – 2 Tn DM ha^{-1}), with strong seasonality (~ 80% production in spring) and interannual variability. Shrub species are frequently present by patches, mostly *Cytisus* spp. The main land use is the livestock rearing, being cattle and sheep the two main species. All of them range freely grazing grasses but also browsing shrubs and trees and consuming acorns in autumn.

The area used in the second study year is usually dedicated to cropping activity. Consequently the natural pasture layer is scarce, with very low species diversity and with a low production and nutritive value. Shrub species are absent in the area. Due to the cropping activity, the area is free of grazing most of the year. Only after harvesting, livestock is allow to graze the crop's stubble.

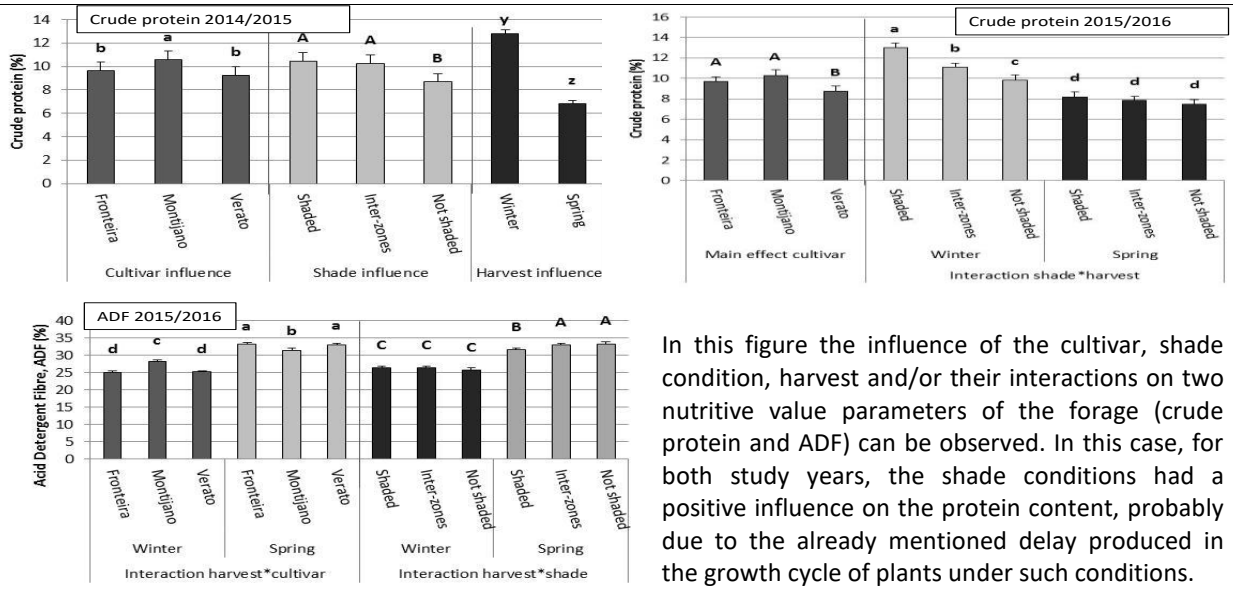
Description Tree Component

Scattered oak trees, *Quercus ilex*. Low tree density and cover (5-30 trees ha^{-1}; 3-25% cover)

Initial results



In this figure the influence of the triticale cultivar and shade conditions on the herbage dry matter (DM) production can be observed. In general, the forage yield and the suitability of each cultivar clearly depended on the specific climatological conditions of the growing season, as well as on the technical management carried out. In 2014/2015 the herbage production was on average 4206 kg/ha, being 'Fronteira' the most productive cultivar. While in 2015/2016, the annual DM production was on average 2996 kg/ha, and cultivars Montijano and Verato presented a higher production than Fronteira. On the other hand, in both study years, the shade condition produced a positive response on the winter DM yield. Such an effect was not consistent for the spring and annual DM yield. While in 2014/2015 the influence of the tree canopy was negative for the spring and annual triticale forage production, in 2015/2016 it was positive. However, in this second study year, due to the climatological conditions, the winter harvest was carried out too late. Consequently the regrowth was not produced conveniently and both the spring and annual forage yield were clear and negatively affected. This is the reason why under shade conditions, this delay in harvesting did not have so negative consequences, as under such conditions the growth cycle of plants is also delayed, and the harvest was made in an earlier growth stage. No interaction between cultivar and shade condition was observed.



In this figure the influence of the cultivar, shade condition, harvest and/or their interactions on two nutritive value parameters of the forage (crude protein and ADF) can be observed. In this case, for both study years, the shade conditions had a positive influence on the protein content, probably due to the already mentioned delay produced in the growth cycle of plants under such conditions.

Such circumstance was specially observed in the winter harvest. On the other hand, regarding fibre content of the forage, it was only affected by the shade conditions in 2015/2016, and within this year, only for the spring harvest. In this case, the shade conditions also caused a positive response in the forage by reducing the fibre content, which means an increase in the organic matter digestibility

Scientific conclusions	Technical recommendations
The sown of triticale produced 3000-5000 kg/ha of a high-quality forage, providing an additional fodder offer for livestock rearing, especially in critical shortage periods, such as winter and summer, in which the natural pasture production is very scarce in the Mediterranean conditions of dehesa ecosystems in the Southwest of Spain. 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, the spring and annual productivity decreased around 30% under shade conditions. The nutritive value parameters of the forage were also enhanced by tree cover in general terms, especially crude protein and fibre, this later parameter 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.	The triticale sown is recommended to be carried out in late autumn, after the first autumn rainfalls, by performing a slight tilling before, at a seeding rate of around 200 kg/ha. Although depending on the initial mineral soil levels, N-P-K fertilization might be convenient to be carried out before or during sowing. The recommended crop management is as follow: the winter forage can be directly grazed by livestock, to meet the livestock food requirements of this period. The spring forage should be harvested and preserved as hay to be provided in summer to livestock. Optimizing the grazing intensity and period in winter is critical to obtain a good re-growth and consequently a good total forage yield. This grazing should not be very intense and be performed before plants reach the growth stage 30 of the Zadocks scale. The late-spring harvest 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.

Innovation: Branding HNCV agroforestry products

A study on social perceptions and public policies in dehesa agroforestry systems was carried out by means of a qualitative approach. These systems generate commercial and environmental values, which are not always perceived by the society. The purpose of this research was to find out the value society places in these agro-forestry systems and the products and services they supply. The results revealed a lack of citizen familiarity with the agroforestry system, as well as of the services it supplies, besides those that are purely associated to food production. Other key findings were the low importance given by the consumers to the item "production system" - a key aspect in order to valorize the products derived from these systems- as well as the difficulty perceived by the citizens in finding a compensation for the proprietors of these systems as suppliers of ecosystem-related services.

Methods

Focus group design and data collection

The information has been obtained from 4 focus groups organised in Badajoz and Caceres (Spain) in May/June 2015. The discussions involved 35 people with an even distribution of age and gender being sought for each group.

Table 1 shows the structure of the focus group.

Data analysis

Content analysis was applied and given the qualitative nature of the study and with the purpose of improving the validity of the results, the analysis was also carried out by means of triangulation. The purpose of this methodology is to improve the validity of the results by analysing them from various points of view.

Table 1. Structure of the focus group discussions

Section	Contents
1. Agroforestry systems and ecosystem-related services	Familiarity with the term "agroforestry system" Familiarity with the concept "ecosystem-related services" Identification of the ecosystem services supplied by the *dehesa*.
2. Users and consumers of products generated by the ecosystem	Identification of products generated by the ecosystem Factors causing an impact at the time of purchase of food products The impact that the origin of a product has on the purchase/ consumption decision Quality labelling associated to the agroforestry systems as a measure to increase the added value of by-products
3. Compensation to ecosystem services' suppliers	Subsidies to ecosystem services' suppliers Compensation through the purchase of ecosystem products Ecosystem services and CAP

Initial results

Citizen knowledge of products derived from dehesa HNCV

For citizens dehsa agroforestry systems generate a great variety of products with commercial value, both in terms of food and non-food services. In these regards, the participants were individually asked to indicate specifically the products and services derived from the dehesas they were aware of. Table 2 includes the products identified together with the number of times they were mentioned.

Additionally to identifying typical products which are abundant in the ecosystem, other products were mentioned that are classified as emergent or with a development potential. Mushrooms and asparagus are considered as very interesting products the commercialisation of which is currently very limited. Other products the participants were interested in were the acorn by-products and they gave examples such as acorn chocolates, acorn fruit drink, acorn ice-cream, acorn bread and acorn liqueur.

Table 2: Commercial-value products and services deriving from *dehesas* identified during the focus group sessions

Consolidated products			
Food	**No. of times identified**	**Non-food**	**No. of times identified**
Pig: meat and by-products	35	Cork and by-products	31
Beef	34	Agritourism	16
Sheep: meat, milk and by-products	29	Acorn (fruit)	16
Goat: meat, milk and by-products	19	Firewood and by-products (oak coal)	13
Honey and by-products	19	Hunting tourism	10
Cereal	16	Timber	9
Game meat	14	Pasture	7
Fighting bull meat	7	Wool and furs	6
Poultry production	3	Active tourism, e.g. hiking, horseback routes, touristic cycling	3
Fish products (e.g. tench)	1	Bird watching	2
Products with a potential to develop			
Food	**Nº**	**Non-food**	**Nº**
Mushrooms and fungi	11	Medicinal plants and cosmetics	4
Asparagus	7	Aromatic plants (thyme, oregano)	3
Acorn liqueur	1	Herbs and herbal tea	1
Acorn beer	1	Crafts (cork, timber, etc.)	1
Acorn flour and other food by-products	1	Hydraulic resource	1
		Solar power	1

Consumer behavior towards products generated by dehesa HNCV

As one of the targets set out with this project was to identify the factors with an impact on the consumer behaviour towards the products deriving from the agrosystem, the discussion at this point was driven towards the consolidated food products, as they were mostly identified by all the participants. The aspects discussed were the role of the origin (geographic or production system origin) on selecting the products that had been previously identified. Another topic raised due to its potential was the use of quality brands used in order to add value to agroforestry system products. Table 3 summarizes the results related to these topics.

During the discussion a few proposals were raised to support the fact that the production system should become a key factor and that people should act responsibly at the time of purchase in detriment of price and geographic area. The participants believed that there was a need to build citizen awareness and better and more advertising of the products in order to guarantee the sales as a way to increase their added value and improve prices.

Finally and regarding the development of quality brands, the participants generically stated that the presence of a quality brand is seen as a positive attribute in any food product. However, they also pointed out that a quality brand would not make them think that the production systems are more sustainable or better for the environment.

At the same time, they pointed out that the establishment of a brand identifying the dehesa must be clear. For example, the incorporation of the term agroforestry is not seen as particularly attractive, as it is a term with which people are not very familiarised. The main advantage of a dehesa brand to designate all the products would be the simplification of the current situation, as for the majority of the participants there are too many designations of origin that may even confuse the consumer.

Table 3. Summary of questions, answers and verbatim comments arisen in the focus group sessions.

Questions raised by the moderator	Summary of answers	Verbatim comments made by the participants
Role played by product origin when choosing products	- Geographic origin is highly valued, although specially for certain types of products	*"On selecting between two products, if I see that one of them is locally produced, I buy that product…"* *"I like to know where the products come from. If I can find out, I look for it, but sometimes this information is not provided…"*
Influence of production system in consumer behaviour	- The production system used has a limited impact at the time of purchase - Participants are aware of the value of a product derived from a sustainable production system but recognise that their behaviour do not reflect this attitude	*"We should place importance on a product being originated in a dehesa system, but in reality we place the importance on the quality of the product"* *"In some cases the quality of a product is guaranteed by the fact that is has been produced in a dehesa"*
Opinion in development of quality brands	-The existence of a quality brand generates trust and guarantees the product -Many products that are designated by quality brands are not accessible due to high pricing -A quality brand must be accompanied by an adequate promotion policy	*"The quality brand is "dehesa", in this way it could be differentiated from other production systems"* *"A quality brand is not indicative of the sustainability of the system where it comes from"* *"The quality brand should be simple and get strong promotion to be successful"*

Scientific conclusions

In spite of the citizens being unfamiliar with the term "Agroforestry System", the dehesa -as the reference agroforestry system in the Iberian Peninsula- is 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.

The dehesa agroforestry system is mainly identified as a service supplier, specifically for high-quality animal-origin food products. The cultural services associated with the aesthetical and recreational value of the landscapes have also been recognised in social importance.

These services translate into products with a commercial value. The majority of them are products that are already consolidated in the market. Emerging products with little presence in the market were also described, but these were seen by the citizens as with development potential (for example, asparaguses, fungi and mushrooms, acorn beer, medicinal plants and cosmetics, herbs and herbal tea, etc.)

Citizens see quality brands as reliable tools to place a value in products and in general they see the creation of brands associated to the agroforestry production systems as a positive measure, provided that suitable training and promotion mechanisms are articulated. In order to become effective, these brands must emphasise the production system, which is a secondary attribute in the eyes of the consumer.

Although the participants agreed that certain mechanisms should be established in order to compensate ecosystem service suppliers (land owners, farmers, etc.), they were unable to specify the tools to be used. The most intuitive idea for the participants was that the compensation should be made through the prices of products that are originated by the agrosystems (although they took it for granted that the price would usually be considered more determining than quality during the product purchase process), which leaves aside products that are socially beneficial but have no commercial value. In this sense, the PESs become essential tools for these systems to stay operational and keep offering the services and products being demanded by society, as they cannot compete in productivity terms with the most intensive systems.

It may be concluded that public policies, both those directed to the promotion of quality products and to the compensation of ecosystem services (with and without commercial value) are necessary so that the agrosystems may stay and keep providing a service to society. Notwithstanding the above, citizen awareness is key so that their perception and evaluation of these systems may be more positive.

4.3 Silvopastoral mosaic in Italy

Innovation: Shade-adapted legume-rich forage

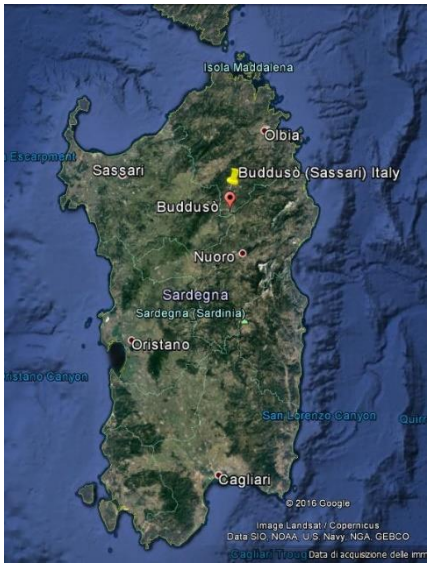


Figure 1. Location of the experimental field (Nino Taras's farm, 40°37.998N; 9°15.335E 700 m a.s.l.

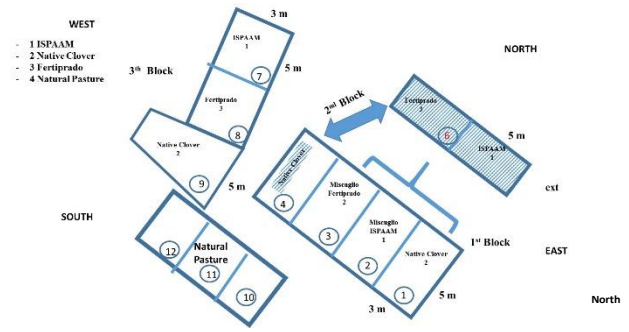
Figure 2. The location of experimental site

Figure 3. Shaded plot

Figure 4. Shaded plot (May 2016).

Figure 5. No Shaded plot (May 2016).

Experimental site and design



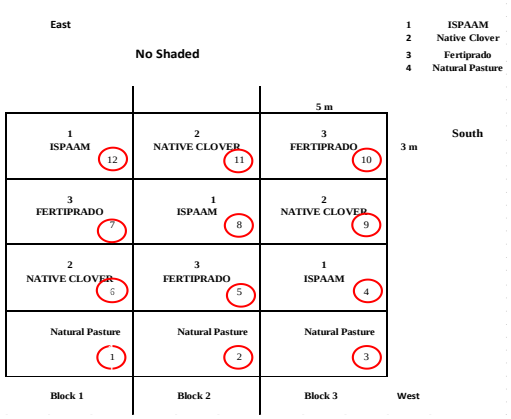


Figure 6 shaded and not shaded

The experimental area comprises a cork oak tree pasture (Figure 4). Different sown and natural pasture types such as Fertiprado commercial legume mixture; ISPAAM mixture based on native pasture species; Native Clover and Natural Pasture were compared, under tree canopy shade (Figure 3-4) and without tree canopy (Figure 5). A total of 24 plots is under study. Plot size is 5 m x 3 m each and are replicated according to a completely randomized block design with three replications.

Description of tree component

Trees of *Quercus suber* (Cork oak) 450 plants ha^{-1} of density in shaded plots.

ISPAAM mixture

Description of associated component (crop/pasture/livestock ….)

Table 1. Main soil characteristics

		pH	N g kg^{-1}	% C.O.	% O.M.	ppm P_2O_5
Shaded	Ploughed	5.88	1.80	1.90	3.28	5.52
Shaded	Natural Pasture	4.83	1.58	2.27	3.91	2.97
No Shaded	Ploughed	5.47	2.47	2.61	4.50	11.04
No Shaded	Natural Pasture	5.50	2.51	2.19	3.78	3.40

Livestock: 1 LSU ha^{-1} Brown Swiss cattle

Floristic composition

ISPAAM mixture

40% *Trifolium subterraneum* (TS) cv Campeda, 40% *Medicago polymorpha* (MP) cv Anglona, 20 % *Lolium rigidum* (LR) cv Nurra

Fertiprado mixture

60.6% *Trifolium subterraneum* (TS) , 4.5% *T. michelianum* var balansae (TM), 3% *T. vesiculosum* (TV), 3%*T. resupinatum* (TR), 6.1% *T. incarnatum* (TI), 1.5% *T. istmocarpus* (TIs), 1.5% *T. glanduliferum* (TG), 19.7% *Ornithopus sativus* (OS).

Before sowing, all plots were fertilizer with 92 kg ha^{-1} of P_2O_5 and ALOSCA commercial inoculants (type C and AM) were applied.

Fertiprado mixture

Native clover

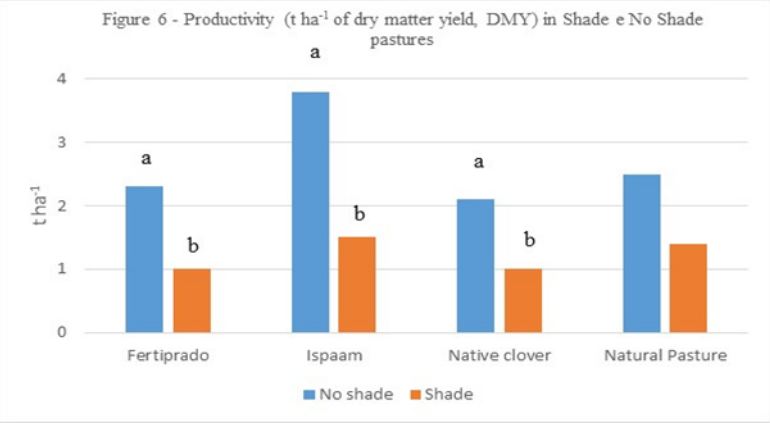
Rhizobium infection and nodule formation in *Medicago polymorpha* "Anglona" roots

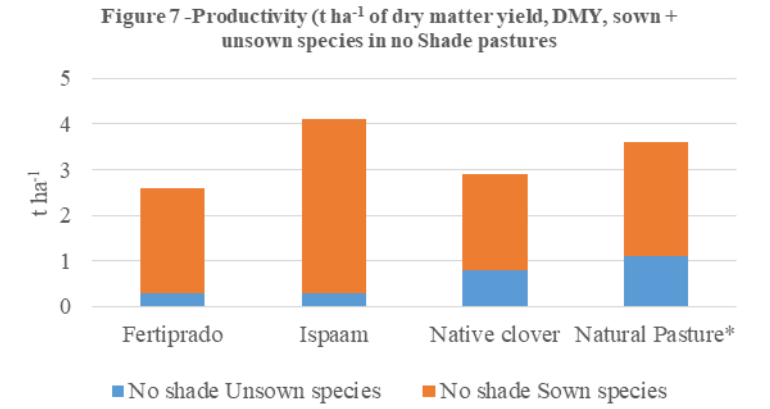
Nature pasture (% canopy cover)
Leguminosae 50% (*T. subterraneum, O. compressus* and *Trifolium* sp.)
Graminaceae 40% (*Avena sp*., *Lolium* sp.)
Compositae 25% (*Ioseris radiata*, *Tapsia garganica*, *Carlina corimbosa Asphodelus microcarpus*)
Other 30% (*Plantago lanceolata*, *Raphanus raphanistrum*, *Rumex* sp., *Sonchus oleracea*, *Daucus carota*).

Leaf area is an important measure in growth analysis. Leaf area was measured with a scanner according to the following steps: image acquisition, image pre-processing, leaf region segmentation, region filling and area calculation.

Pictures taken during Leaf area measurement

Initial results





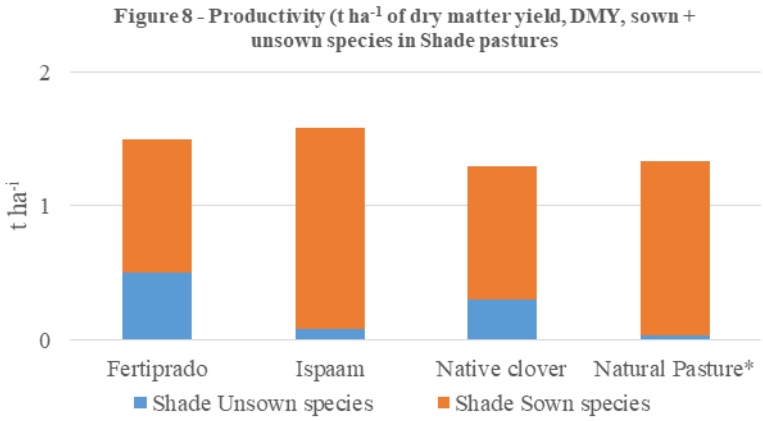


Table 2- Crude Protein (CP, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin, ASH and Ether Extract (%) of different species in Shaded and No Shaded pastures.

Values with different letters in a column are significantly at p≤0.05 (Fischer's test)

	C.P.		NDF		ADF		ADL		Ash		E.E.	
	Shaded	No Shaded	Shaded	No Shaded	Shaded	No Shaded	Shaded	No Shaded	Shaded	No Shaded	Shaded	No Shaded
Fertiprado	18.5 a	12.5 b	41.6 a	37.2 b	29.3	27.6	11.1	5.7	12.3 a	9.3 b	2.4	1.9
ISPAAM	14.9 a	9.5 b	47.3	44.7	32.6 a	28.5 b	4.9	4.0	9.8 a	6.1 b	1.9	1.5
Natural Pasture	9.5	9.6	52.5	54.0	30.2 a	33.8 b	3.8	4.3	6.0	6.2	2.1	1.6
Natural clover	17.9 a	14.1 b	40.8 a	40.0 b	29.5	28.7	10.	5.6	11.4 a	8.6 b	1.6	1.7

Significant differences (Values with different letters in a column are significantly at $p \leq 0.05$ (Fischer's test) were found between shaded and no shade treatment in Fertiprado, ISPAAM and Native clover. ISPAAM mixture was more productive than Fertiprado, Native clover and Natural pasture (Leguminosae **L** + Graminaceae **G** without other species).

Occasionally, plant damage occurred due to wild animals like wild boar and deer, despite the areas are fenced.

Both in shade and no shade canopies, the ISPAAM mixture was more competitive against unsown species than Fertiprado and Native clover.
In the *Natural pasture share of L+G was higher than other species

As shown in Table 2, significant differences were found between the establishment of shaded and no shade canopies in Fertiprado, ISPAAM and Native clover in crude protein concentration and ash. Sample taken in Shaded treatment showed higher value (%) in CP, NDF, ADF content and showed a better quality than No shaded pasture.

Table 3 – Morphological traits in relation to Shaded and No Shaded condition.

	Stem length cm		Leaf area cm^2	
	Shaded	No Shaded	Shaded	No Shaded
Medicago polymorpha "Anglona"	68.8*	39.3	5.1*	2.5
Trifolium subterraneum "Campeda"	27.8	35.2	5.5*	2.9
Ornithopus sativus	52.7	43.1	9.3*	4.4
Trifolium incarnatum	48.1*	34.2	12.3*	6.9
Trifolium michelianum	57.6*	32.0	4.9*	3.2
Trifolium resupinatum	50.5*	33.4	4.9*	2.0
Trifolium subterraneum a	12.0	17.2	4.9*	1.4
Trifolium subterraneum b	38.3	49.8	5.9*	3.3
Trifolium vesiculosum	47.4	49.5	11.1*	8.5
Native clover	43.1*	18.4	7.5*	5.9

*Significant statistical differences at p≤0.05 (Fischer's test)

Statistical analysis show significant differences in morphological traits (Stem length and Leaf area) between treatment (Shaded and No Shaded) Table 3. *M. polymorpha* "Anglona" (ISPAAM) mixture), *T. incarnatum*, *T michelianum* (Fertiprado) and Native clover highlighted longer stems length in shaded conditions. Although did not show significant differences, *T. subterraneum* both in ISPAAM and in Fertiprado mixture exhibit an opposite trend. Leaf area significantly differ between treatment for every species belonging to two mixtures as well as in native clover with greater leaf area in shaded condition.

Scientific conclusions

The hight tree density (450 plants ha^{-1}) found in Buddusò site is different from that of Monti (Sardinia) and Spanish dehesa. Nevertheless it is representative of the sylvopastoral environments in Sardinia whether that the tree canopy is *Q. Suber*, *Q. pubescens* or *Q. ilex*. Although date refers only to the first year this, results pointed out the effect of shaded/no shaded condition on productivity, quality and on morphpological characteristics. Shade reduced the productivity of mixtures and native clover by 50-60%, even if the nutritive value may benefit from increased in crude protein levels.

Technical recommendations

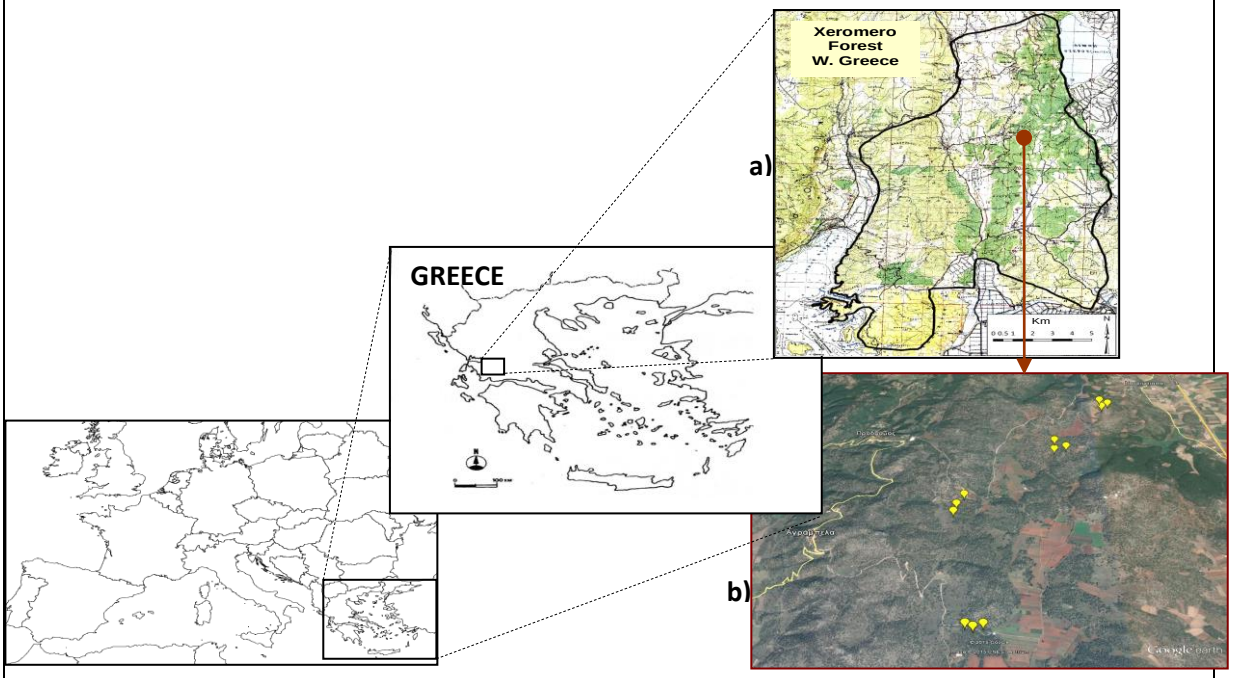
4.4 Grazed Valonian oak woodlands in Greek

Innovation: protection of young trees (grazing exclusion)

Valonia oak forms traditional silvopastoral systems in W. Greece

Four different locations were selected which were located near four different sheep holding areas. In each location, three replicated plots (total 12) were established. In each plot two factors (fenced and shrub removal) were combined with the four treatments, with a 20 m^2 sub-plot per treatment. The treatments were i) fenced and cleared of shrubs (FNS); fenced with shrubs (FWS); grazed and cleared of shrubs (GNS); and grazed with shrubs (GWS).

Map of system



Map of a) Xeromero forest and b) satellite image (from Google Earth) with the position (yellow points) of the experimental plots in the Valonia oak silvopastoral system

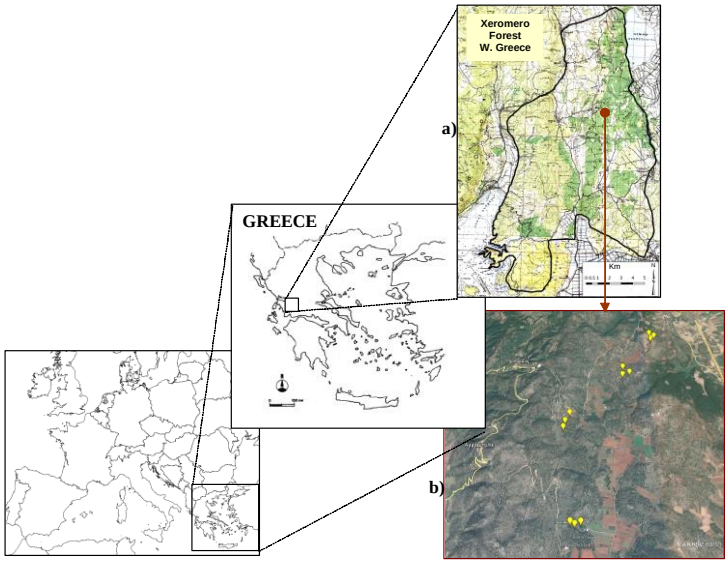
Description of tree component	Description of associated components (crop/pasture/livestock)
Quercus ithaburensis is a characteristic endemic deciduous oak species of the Eastern Mediterranean countries that appears with two subspecies: i) *Q. ithaburensis* subsp. *ithaburensis* (Tabor oak), and ii) *Q. ithaburensis* subsp. *macrolepis* (Kotschy) Hedge & Yaltirik (Valonia oak). Valonia oak forms traditional silvopastoral ecosystems in Greece that were of great value in the past. Valonia oak forests cover an area of 29,632 ha in the form of stands, thickets and groups, in lowlands and uplands of continental and insular Greece. Furthermore, isolated trees are scattered throughout the country. In Western Greece valonia oak forms typical, traditional silvopastoral systems that can be characterised as open trees similar to the Spanish Dehesas and Portuguese Montado.	Local populations take advantage of the multiple products from the system. In a recent study it was found that at least 89 common species appear in the region that have different properties or are mentioned by the ancient Greeks as having various medicinal, edible or flavouring properties. Livestock in area are composed mostly by sheep and to a lesser extent goats. Livestock breeders use separate parts of the system for grazing that resulted to the existence of areas overgrazed or under grazed with *Phlomis fruticosa* species coming in depressing valonia oak regeneration. Livestock grazing has been mostly blamed for the low regeneration of the species.
Initial results	
Fencing increased the number of acorns and seedlings and saplings. Based on the results from the first two years, understorey clearing does not affect valonia oak regeneration.	
Scientific conclusions	Technical recommendations
No statistical significant differences exist for the number of seedlings among the four treatments. The same is valid for the mean height, the acorns and the cups.	Local stakeholders should protect from grazing small plots in the forest to enhance regeneration. After seedlings has reach a height that livestock could not damage them, they can become free to grazing and other areas be protected.

Innovation: protection of young trees (grazing exclusion and understorey clearing) in the valonia oak silvopastoral system in Xeromero - W. Greece

Four sheep and goat sheds as well as the pathways that the livestock follow daily for grazing were identified and 6 paired plots, 5X8 meters in size each, were established per shed territory, a total of 24 plots. In each pair, one plot was fenced and the other plot was left free to grazing. Woody understorey vegetation was cleared in half of each plot.

Experimental site in the valonia oak silvopastoral system in Xeromero, W. Greece

Map of system

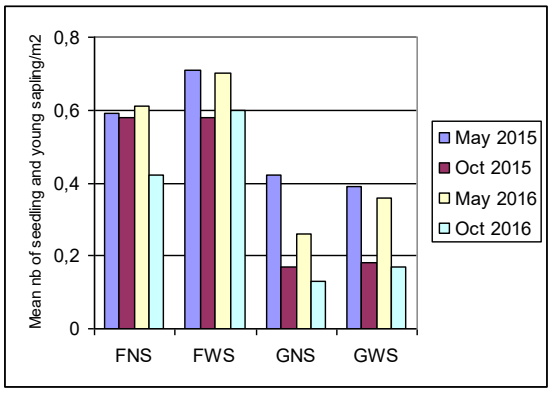


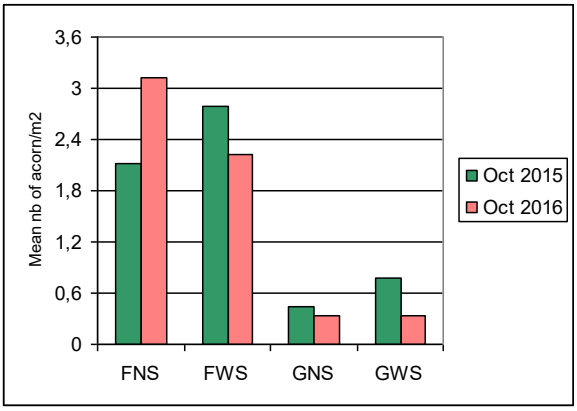
Map of Xeromero forest W. Greece with the position (yellow points) of the experimental plots in the Valonia oak silvopastoral system.

Description of tree component	Description of associated components (crop/pasture/livestock)
Valonia oak trees with density 30-60 trees ha^{-1} and crown coverage of 20-80%. In certain location there are also *Quercus pubescens.* Tree age varies between 150-250 years. Average tree height is 10-15 m.	The local population take advantage of the multiple products from the system. In a recent study it was found that at least 89 common species appear in the region that have different properties or are mentioned by the ancient Greeks as having various properties (medicinal, edible, flavoring etc). Livestock in the area are primarily sheep and to a lesser extent goats. Livestock breeders use separate parts of the system for grazing that resulted to the existence of areas overgrazed or under grazed with *Phlomis fruticosa* species coming in and depressing valonia oak regeneration. Livestock grazing has been mostly blamed for the low regeneration of the species.

Initial results

No statistical significant differences exist for the number of seedlings among the four treatments. The same is true for the number of acorns and the cups. However by examining separately the grazing and understory clearing treatments from the first two years, there is a tendency for increased number of seedlings and young saplings and the number of acorns in the protected areas as compared to the grazed ones. On the contrary, understory clearing seems not to affect the number of seedlings and young saplings and the number of valonia oak acorns. In the graphs below appear the means of each treatment: fenced and cleared of shrubs (FNS); fenced with shrubs (FWS); grazed and cleared of shrubs (GNS); and grazed with shrubs (GWS) for 2015 and 2016.





Scientific conclusions	Technical recommendations
Based on the results it appears that grazing has a negative effect on valonia oak regeneration whereas understory clearing had no effect. Since these are permanent plots, sampling and more data will be acquired in the coming years to draw robust conclusions.	Local stakeholders should protect small plots in the forest from grazing to enhance regeneration. After seedlings have reached a height that livestock could not damage them, they can become free to grazing and other areas can be protected. Grazing has to continue as a traditional practice.

4.5 Wood pastures in Romania

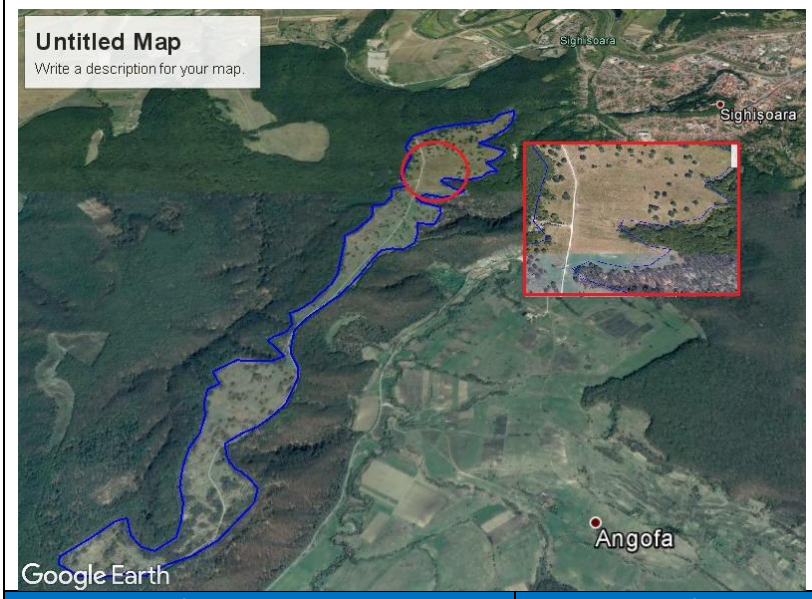
Innovation: the use of fences to allow tree regeneration in wood-pastures

General view of the system

The Breite ancient oak wood-pasture is a typical example of ancient oak wood-pastures from Transylvania, which lack tree regeneration and the large proportion of the mature trees are ageing. Hence tree regeneration is a crucial ingredient for the sustainability of these wood-pastures.

Detailed pictures

Map of system



The location of the Breite ancient oak wood-pasture reserve and the place where the plantation activities were conducted (with red circle and square).

Description of tree component	Description of associated component
It is a protected area. 83 oaks (52%) had a diameter of at least 500 cm, 15 trees (9%) had at least 600 cm and 1 tree (0.62%) had over 700 cm. The largest oak had 710 cm girth. Over 20% of the wood-pasture including near half of the large old oaks are threatened by forest succession due to abandonment.	After the collapse of the communism (1989) the grazing intensity dramatically decreased (partly because 70 ha of the site was formally protected) and was completely ceased up to 2006. Several large old oaks were burned by shepherds and visitors. The abandonment of grazing reduced the burning of the large old oaks but triggered a massive regeneration of hornbeam. The formal custodian of the protected area in the period of 2006-2010 employed three rangers which were permanently on the Breite. Twelve large old oak trees with large crown were consolidated in order to prevent their collapse (MET, 2011).

Initial results	
97 wood-pastures surveyed in 2015 and 2016, no evidence was found about the deliberate use of thorny shrubs for protecting young trees. Oak regeneration was associated with thorny shrubs only in those regions of wood-pastures where the grazing intensity dropped temporarily (cca 5-7 years).These areas were always the marginal areas of the wood-pasture. An oak tree regeneration project partly by fencing 2000 naturally grown oak saplings, and by planting and fencing 600 oak saplings originating from acorns collected from the Breite. Furthermore, over 65 ha of dense hornbeam (with a height of at least 1.5 m) were manually removed over three consecutive years. Grazing with 300 sheep and 150 goats were reintroduced to stop the regeneration of hornbeam.	
Scientific conclusions	**Technical recommendations**
Tree regeneration in wood-pastures does not occur with a deliberate purpose in Transylvania. Trees typically regenerate as a consequence of abandonment, which is caused by socio-economic instabilities. The last massive abandonment took place in 1989 and afterwards. Fencing with thorny shrubs as well as artificial (metal) fences in the Breite ancient wood-pasture in 2009 suggests that these methods have a good potential to be efficient. The mortality of the trees is large; in our case 70% of the planted trees dried at the end of the second growing season.	Fencing young tree saplings 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.

Innovations: grazing management and biodiversity of wood-pastures

General view of the system

Oak wood-pasture grazed with buffalo, cattle and sheep.

Detailed pictures

Sheep herd grazing the same wood-pasture shown in the left figure

Map of system

The oak wood-pasture where the study was conducted. The area is grazed with cattle, buffalo and sheep, with about 1 LU per hectare. 40 sampling points were situated across the pasture, with each point being represented by three plots of 1 sq. m each. The 1 m^2 quadrats were situated at 3-5 m distance from each other.

- 10 sampling points were on open pasture surfaces
- 10 sampling points were under sparse tree canopies
- 10 sampling points were under sparse tree canopies and shrubs
- 10 sampling points were situated along the forest edge

Description of tree component

The oak wood-pasture is dominated by oak, with trunk circumferences between 2-3 m. Other tree species (poplar, hornbeam, maple) are less represented. The overall density of trees is about 1/ha^{-1}.

Description of associated component

Pasture grazed by cattle, buffalo and sheep, at about 1 LU per hectare.

Initial results

- 2697 spider specimens (1439 adults), belonging to 140 species from 21 families were identified, with 4 new species for Romanian fauna. Furthermore 190 species of herbaceous plants were identified.
- Trees with shrubs had the highest species richness in both groups while the four microhabitat types has statistically distinct species communities for both groups

Scientific conclusions

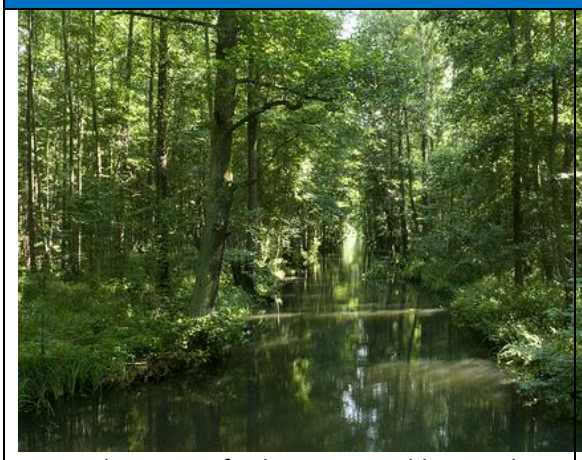
This study showed that sparse trees and shrubs can increase the biodiversity value of even moderately intensively grazed pastures. Furthermore, trees and thorny shrubs provides several ecosystem services which are actively recognized by farmers.

Technical recommendations

High level formal institutions such as the CAP should actively and explicitly encourage the maintenance of sparse trees and shrubs on pastures. In this way the integration of food production and biodiversity conservation could be advanced.

4.6 Wet meadows with hedgerows in Germany

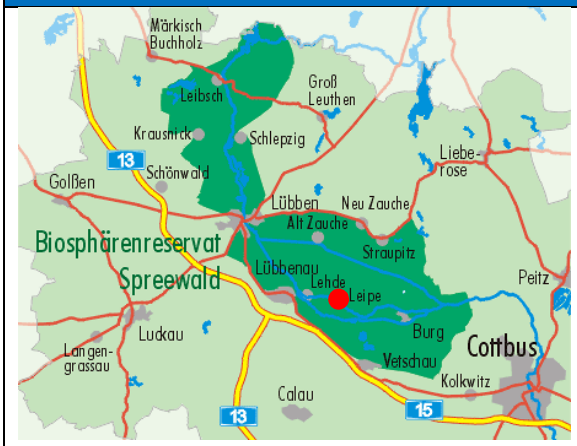
Innovation: best and cost-efficient method for hedgerows rejuvenation



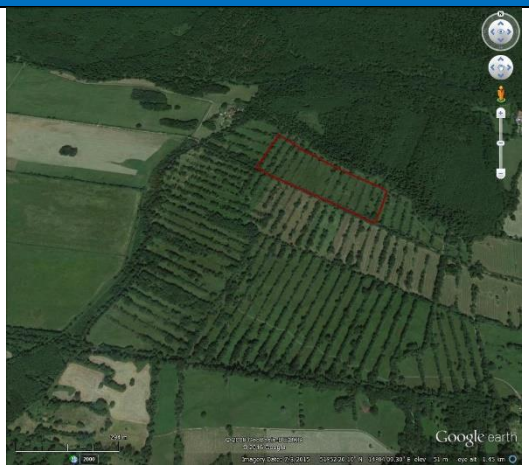
General view of the Spreewald Biosphere Reserve, composed of a dense network of rivers and streams, alluvial meadows and peat covered areas.

View of the Filow area in the Spreewald Biosphere Reserve Source:http://land-entdecken.de/wp-content/uploads/2012/04/Spreewald.jpg

Map of system



A map of the Spreewald Biosphere Reserve (in green) located in Brandenburg, Germany. The location of the research area near Leipe is marked by a red dot.
Source: www.spreewaldportal.de/images/spreewald-karte.png



Map of the Filow area and the research area investigated in this study delineated by a red line.

Description of tree component

Tree species that can be found are black alder (*Alnus glutinosa* (L.) Gaertn.), black poplar (*Populusnigra* L.), bird cherry or hackberry (*Prunus padus* L.), English oak (*Quercus robur* L), willow (*Salix* spp). Shrubs predominantly include glossy buckthorn (*Frangula alnus* Mill.), common buckthorn (*Rhamnus cathartica* L), buckthorn (*Rhamnus alaternus* L.), wild rose (*Rosa canina* L.), blackberry (*Rubus sectio Rubus*). The hedgerow in the research area covers about 20% of the area.

Description of associated components

The grass consists of native grasses such as meadow soft grass (*Holcus lanatus*), lesser pond-sedge *Carex acutiformis*), creeping buttercup (*Ranunculus repens*), rabbitfoot clover (*Trifolium arvense*), *bitter dog* (*Rumex obtusifolius*), and reed sweet-grass (*Glyceria maxima*) (LUA 2004; LUGV 2011). The grass is mowed and subsequently incinerated. The yield of the grassland in the Filow area was estimated at 6.9 t DM ha^{-1} yr^{-1} (LUGV 2011).

Initial results

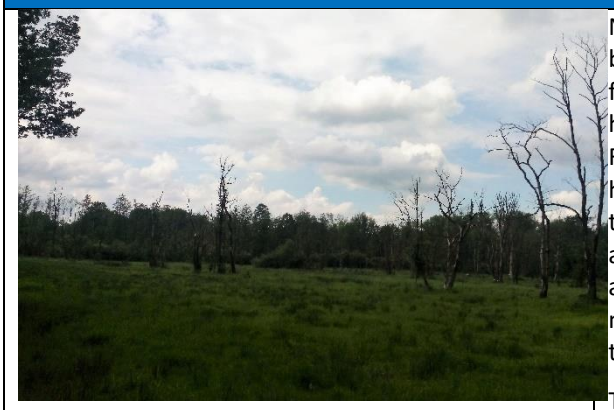
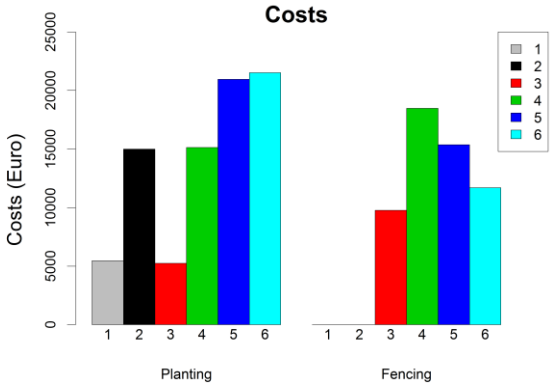


Photo of the degraded tree rows which have a priority for rejuvenation.

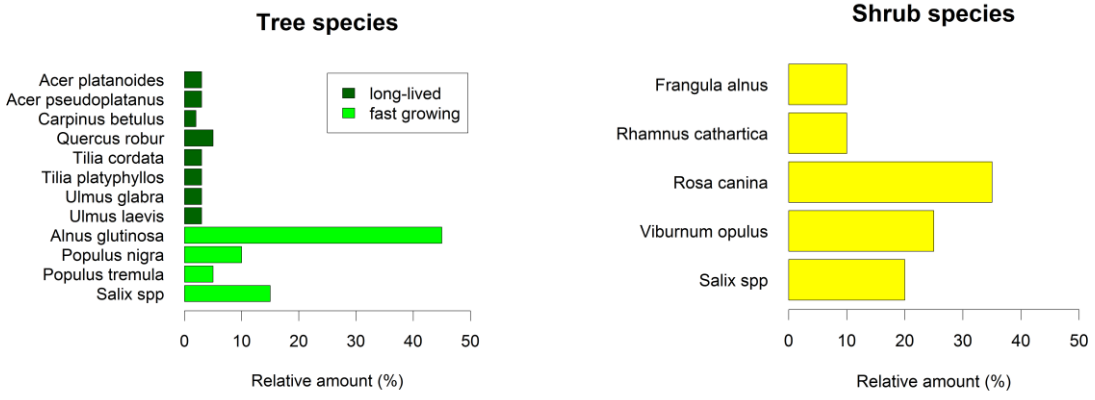


Costs of planting of hedgerows with total length of 1140 m and fencing of hedgerows with total length of 1550 m, submitted by local companies, the names of which are not disclosed for anonymity reasons.

No benefits from wood harvesting can be obtained because the wood has no economic value (top left figure). On the contrary, costs are incured related with harvesting and removing the wood from the field. From the costs regarding machinery usage, the highest values were calculated for the use of large tractor and caterpillar. The fixed and variable cost amounted to 45 and 46 € $hour^{-1}$ for the former and 66 and 46 € $hour^{-1}$ for the latter. The use of heavy machinery is generally problematic in the field due to the risk of compaction.

The first rejuvenation activites were planned for five hedgerows in total, with 60% rejuvenation of three hedgerows and a complete rejuvenation of two hedgerows. Hence, the costs of planting hegerows with total length of 1140 m and fencing hedgerows with total length of 1550 m were obtained from local companies (bottom left figure). The prices differed depending on the planned activities, such as maintenance of trees and replacement of trees that did not survive. In general, the planting constitued the main cost, but fencing costs were also high. Fencing was mandatory due to risk of damage for the newly planted trees by wild animals. Company number five was found most suitable to conduct both activites. For selection of the firm important criteria were experience in similar projects and knowlegde of the area.

The proportion of tree and shrub specied to be planted, selected based on the species already present in the field (with main species *Alnus glutinosa*), are shown in the figure below. Each sixth tree should be long lived. The distance within rows was set to 1 m for trees und 0.5 m for shrubs and between rows was set to 2-2.5 m. According to local regulations only native species should be used and maintenance measures can only take place between 01.10 and 28.02.



Relative proportion of tree species (long-lived amount to 25% and fast growing comprise 75% of the total

<table>
<tr><td colspan="2">area with trees) and shrub species to be planted in the selected hedgerows in the research area.</td></tr>
<tr><th>Scientific conclusions</th><th>Technical recommendations</th></tr>
<tr><td>In recent years, the regeneration of hedgerows in the area was inhibited, as a consequence of extreme weather events (for example, the flood events in 2010 and 2013) and a lack of management. The main reason for the severe degradation of hedgerow structures was found in the extreme events. Hence, leaving the system on its own for recovery is not likely to restore the historical look that has been developed with human intervention and has been typical for this area in the past decades.

Degraded trees adversely affect the aesthetics of the area and may reduce its value as an important touristic destination in the long term. A rejuvenation strategy should take into account the limitations of the regulations in the nature protection area and aim to restore the historical look of the system in order to preserve and enhance its value as a habitat for biodiversity and a region of cultural significance.</td><td>General recommendations can be summarized as follows:
➢ Only native tree and shrub species should be used for hedgerow replanting. Important species in the area are Alnus glutinosa, Quercus robur, Ulmus laevis.
➢ According to local regulations maintening measures can only take place between 01.10 and 28.02.
➢ Single Quercus spp. in the area should not be harvested.
➢ Heavy machinery is to be used with caution due to increased risk of compaction.
➢ A portion of dead wood should be kept at site for its ecological value.
➢ Fencing cannot be avoided in the first five years after planting, due to the risk of damage by wild animals.
➢ As the area is important touristic destination, it is important to avoid a severe disturbance of the landscape with large scale activities, but rather gradually harvesting and replacing tree rows. Only when the row is degraded, it is advisable that the whole row is harvested. Otherwise harvesting and replanting 1/3 to 2/3 of the row would be considered sufficient.</td></tr>
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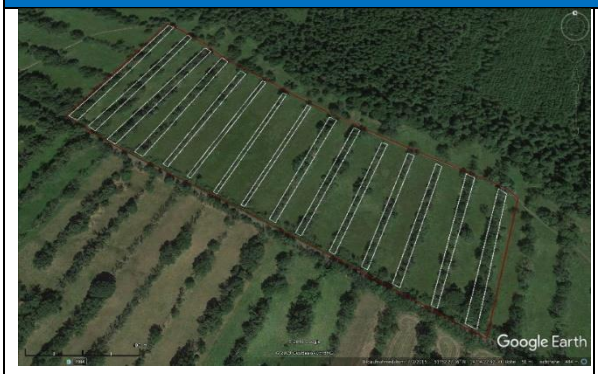
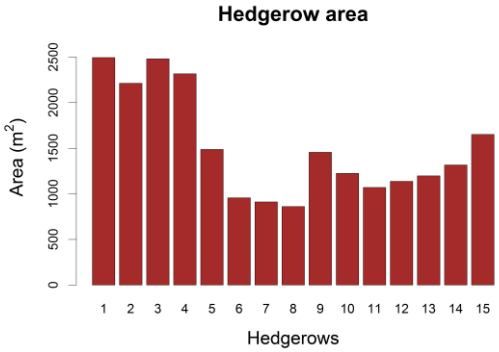
Innovation: Valuing hedgerow biomass



Map of the research area delineated by a red line. White lines delineate the hedgerow area.



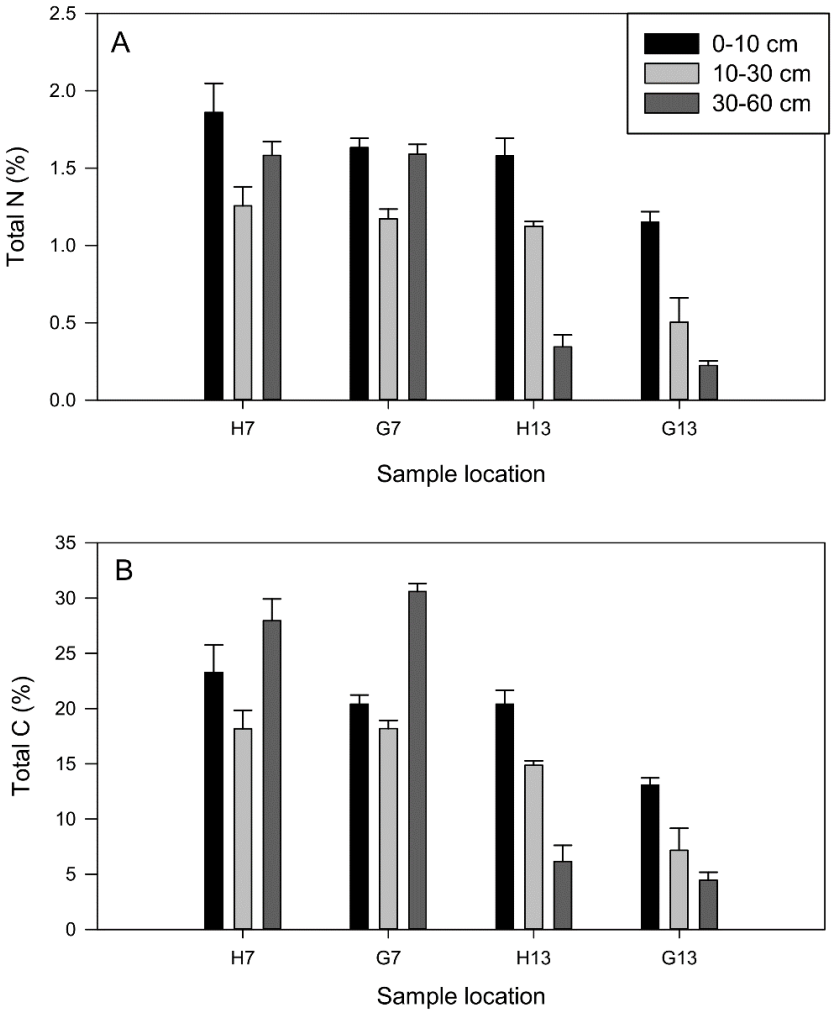
Area occupied by hedgerows in the research field.

Initial results

The area of hedgerows based on aerial photo amounted to ~24% of the research area (top left figure). The pattern of hedgerow area follows the hydrology of the area, where flooding conditions in recent years in the middle of the research area (hedgerows 6-8) have led to severe degradation of the hedgerows and loss of biomass (bottom left figure).

To estimate the effect of trees on soil, samples were collected in 2016 within the tree rows (H7 and H13) and in the middle between the rows (G7 and G13) at depths of 0-10, 10-30, and 30-60 cm. According to the initial results soil carbon and nitrogen values within the tree rows (H7 and H13) were higher than under grass (G7 and G13) (see the figure below). In addition, in the previously flooded location (H7 and G7), the highest C values were measured for soil depth of 30-60 cm, while at the drier location (H13 and G13), C values decreased with depth.

The system is characterized by a very high heterogeneity. Biomass assessment measurements are planned to take place in 5 sections in each row. The length and width of the hedgerow will be measured as well as the diameter and height of each tree species for each section. The severely degraded rows 6-8 will not be measured.



Soil carbon and nitrogen measured under hedgerows (H) and under grass (G)

Scientific conclusions	Technical recommendations
Soil carbon under trees was measured to be higher than under grass. Consequently, degradation of trees will lead to a loss of carbon stored in their biomass and in soil. In addition to providing market goods from agricultural activities and being an important touristic destination of high recreational value, wetlands have an important function as CO_2 sink and climate protection. In general, in Spreewald a change in the hydrology, especialy regarding a reduction of the groundwater table is expected, which could results in a loss of vegetation and habitat, and reduce the touristic value of the area. Trees are important to regulate the local hydrology and their management should be adapted to the changing conditions in the area.	When harvested in a sustainable way hedgerow biomass could become a source of funding for maintaining the hedgerows. This remains to be examinated and recomendations regarding tree biomass will be made after data has been collected and analysed.

5 Acknowledgements

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