AGFORWARD
Agroforestry for Europe

Initial results on studied innovations of agroforestry with high value trees

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1 Context

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

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

This report contributes to the second objective where innovations are being field tested within four agroforestry sectors. Milestone 11, from work-package 3, describes the initial results of ten innovations focussed on agroforestry with high value trees for example the intercropping and grazing of orchards and olive groves and other high value trees (e.g. walnut, pollarded ash, and chestnut). Similar reports exist for agroforestry of high nature and cultural value, agroforestry with arable crops, and agroforestry for livestock systems. The final report on the innovations will appear in Deliverable 3.8.

2 Agroforestry for high value tree systems

Den Herder et al. (2017) calculates the area of agroforestry in the EU27 involving fruit, olive, and nut trees was about 1.05 million hectares corresponding to about 0.2% of the territorial area in the EU (note this does not involve high value timber trees like walnut). The same paper indicates that the largest extent of agroforestry with high value trees can be found in Spain, Italy, Portugal and Greece, Romania, and France. Each of these countries, except Portugal and Romania, is represented in this report. Den Herder et al (2017) indicated that there were about 222,000 ha of intercropped fruit, olive and nut trees, and about 848,000 ha of grazed fruit, olive and nut trees.

The five objectives related to the participative development and research network (PDRN) focused on agroforestry with high value trees are:

i. to identify examples of the best practices, key challenges and innovations to address challenges identified by the stakeholder groups within the PRDN,
ii. to describe and explain the key inputs, outputs and ecosystem services flows for case studies (in association with work-package 6),
iii. to agree within the PRDN, the key innovations or improvements in knowledge needed in order to promote adoption of high value tree systems,
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, and;
v. to provide and promote guidelines for farmers on how to establish economically viable agroforestry practice in high value tree systems.

Research and development protocols focused on agroforestry for high value trees have been produced by nine partners (Table 1). During 2014, each partner established a stakeholder group including farmers and other interested people, who highlighted key challenges for a range of agroforestry practices.

Table 1. Nine partners worked with ten groups focused on agroforestry with high value trees

Acronym	Full name of partner
AFAF	Association Française d'AgroForesterie, France
AFBI	Agri Food and Biosciences Institute, UK
APCA	Assemblée Permanente des Chambres d'Agriculture, France
CRA	Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria, Italy
CRAN	Cranfield University, UK
IDF	Centre National de la Propriete Forestiere, France
TEI	TEI Stereas Elladas, Greece
UEX	Universidad de Extremadura, Spain
USC	University of Santiago de Compostela, Spain

In January 2015, a synthesis report was produced describing the research and development protocols of the ten groups (Pantera et al. 2015) and this addressed objective iii). Between April and May 2016, each of the ten stakeholder group produced a system report on their specific system. A report presenting a summary of the components, structure, ecosystems services, and economic value of selected systems and therefore addressing the second objective, was prepared and is uploaded in the intranet (Deliverable 3.7).

3 Initial results

This report collates and briefly synthesises the initial results from the ten stakeholder groups focused on agroforestry with high value tree systems (Table 2). They are considered under the titles of grazed orchards, olive and orange agroforestry systems, agroforestry with walnut trees, ash pollards, and chestnut agroforestry systems. For each system first the innovation is listed, the site is briefly described followed by the initial results. In this synthesis document, the number of pages per system is restricted to three pages. Please note that the results are provisional and may change with further research.

Table 2. Description of the ten groups focused on agroforestry with high value trees

Category	System	
Grazed orchards	1.	Grazed orchards in England and Wales, UK
	2.	Grazed orchards in Northern Ireland, UK
	3.	Grazed orchards in France
Olives	4.	Intercropping olives and cereals in Greece
	5.	Intercropping olives and vegetables in Greece
	6.	Integration of olives with crops in Italy
Oranges	7.	Intercropping oranges in Crete
Walnut and ash	8.	Grazing and intercropping of plantation trees in Spain
	9.	Bordure trees in South-West France
Chestnuts	10.	Chestnut systems in Galicia, Spain

Grazed orchards

The research on grazed orchards includes an experiment with bush orchards in Northern Ireland, a relatively young orchard in Normandie (planted in 2011) and an orchard with half-standard trees planted in 2001 and pruned to a height of 1.3 m in Herefordshire, England. The initial results indicate that the sheep caused a significant reduction in the apple yields of the bush orchards in Northern Ireland, and there has been some damage to the trees in Normandy. The effect of the sheep on the taller and older trees in England is considered to be minimal. Hence these initial results suggest that apple trees should be of a certain age, for example above 5-15 years, and pruned to a height of about 1.3 m before they grazed by sheep. The initial results demonstrate that grazing can reduce mowing costs. The results from Northern Ireland provide no evidence that grazing reduces the incidence of apple scab.

Intercropping and grazing of olives and oranges

The potential of planting a profitable intercrop between olive trees is still being studied. In 2015, the results from Molos, Greece were dominated by low olive yields due to unfavourable weather during blossoming and the chickpea yields were also low. The olive tree and arable crop interactions from the Chalkidiki site are still being determined, but initial results suggest barley plants can establish well between the olives, although mean crop height within the agroforestry system (72 cm) was less than the 92 cm in a control area. The research in Italy has demonstrated that growing wild asparagus between olives is technically feasible but the asparagus yields between the olive trees was less than when asparagus was grown in the field.

The initial results with the intercropping of oranges with chickpeas, as a leguminous crop, indicate that there may be a benefit in terms of orange yields, although the chickpea yields are lower than those obtained in an open-field.

Intercropping and grazing of high value walnut trees

The first experiment compares the effect of cultivation, grazing, and mowing on walnut trees planted in Spain in 2000. The highest walnut diameter increments were achieved in the cultivation treatment and then within the grazed, and then the mowed plots. However total carbon storage was least in the cultivated treatment. The second experiment compares the effect of intercropping with legumes with mown fertilized and unfertilized grass. The greatest tree diameter increments were achieved with the fertilized grass (e.g. 4.2 mm in one year) than the legumes (3.4 mm) and the unfertilized grass (2.9 mm), and the fertilized grassland also led to the highest levels of carbon sequestration. The highest levels of tree leaf nitrogen were achieved with the fertilized grass and legume treatments. The understorey yield of the legumes and the fertilized grassland (3.6-6.4 t ha^{-1}) were similar and greater than the unfertilized grassland (1.9-3.5 t ha^{-1}).

Bordure trees

The results from the harvest of 325 pollarded ash trees found as bordure trees in the Hautes-Pyrénées is still being studied

Chestnut trees

The results from different forms of protection for chestnut trees in the Galicia region of Spain, the potential to increase mushroom production between chestnuts, and the capacity to create new grafts of Galician chestnuts of high fruit quality are still being determined.

Initial results: Grazed orchards in England and Wales, UK

Reference

Reference: Burgess et al. (2016)

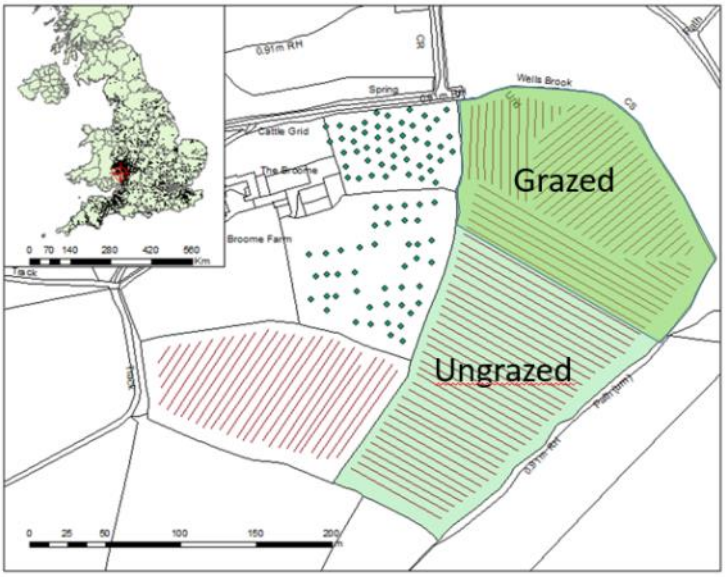
Innovation summary: Grazing sheep in traditional orchards reduce mowing costs and provides grazing for sheep

Images and map of system

Shropshire sheep within the apple orchard in December 2015

An electric fence (left hand side of photo) has been used to divide the orchard into a grazed and ungrazed area (December 2015)

Map of system



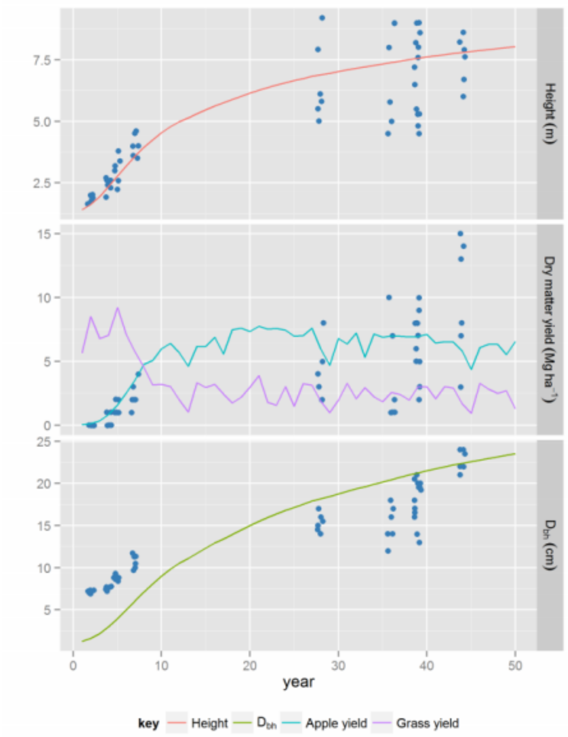
Red lines indicate rows of apple trees in an orchard with half-standard trees. The trial is based in the area highlighted in green which has been split into a grazed and ungrazed area. © Crown Copyright and Database Right 2014. Ordnance Survey. More information about the system can be found here:

Tree component	Understory component
The tree species and variety are apple (*Malus domestica*) 'Harry Master' which were planted in 2001. The intra-row spacing is 3 m and the inter-row is 6 m. Tree density is about 555 trees ha^{-1} A wire surrounding the tree trunk to a height of 50	The crop includes grass species such as perennial ryegrass (*Lolium perenne*). The grass in the ungrazed orchard was mown in April-May and gain in August 2015 to keep down the grass understory. Sheep (Shropshire breed) represent the animal

cm was used to protect trees from rabbits. The side branches of the apple trees have been pruned to a height of 1.3 m. Hence this is an orchard comprising "half-standard" trees; it is not a bush orchard. No fertiliser is applied; the field is limed every five years. The apple trees are not sprayed although a problem with Ermine moth (*Yponomeuta malinellus*) was reported.

component. Typically 40 ewes will be kept with one ram. The ewes will conceive in the autumn ("tupping"), with lambing occuring in the spring. On average, each ewe will have 2 lambs. During the weeks immediately before lambing the sheep will be kept indoors. After lambing, the ewe and the lambs will be moved to a field. The lambs will typically be separated from the ewe in late spring. The typical aim is to fatten the lambs as soon as possible ready for market, and to maintain the weight of the ewes until "tupping". Sheep are given a mineral bolus.

Results and technical assessment



The system report for the grazed apples in England and Wales presents some results from data collected by Vylupek (2010) on apple fresh weight yields, tree age, and tree dimensions. The analysis derived relationships between the number of apples per tree and the cross sectional area of the canopy.

Vylupek (2010) parameterised the Yield-SAFE model to describe the development of apple yields from planting, assuming the site management characteristics. The figure opposite shows the modelled outputs of tree diameter and height, and apple and grass dry matter using Vylupek's calibration of Yield-SAFE. Data for tree diameter, height and apple yields are also shown.

Socio-economic assessment

The remaining of the work in this group will be on a financial and economic analysis. The apple orchard was owned by a local farmer, and the owner of the sheep is his nephew. The apple orchard receives single farm payment. The estimated cost of the electric fencer was £100 (€129) and the estimated cost for the electric fencing was £200 (€258).

A typical annual cost for renting a grass field (known locally as "keep") is about £185 ha^{-1} (€238). A local buyer of apples (Bulmers) is reported to state in their contract that the sheep should be removed 56 days before apple harvest. Hence a key feature of grazing orchards is the requirement for additional areas of grass when the orchard is not available. Grazing orchards was reported by one stakeholder as being "logical but you need additional grassland prior to harvest". Overall the system has the potential to increase profitability over a simple apple orchard. However, a correct management is required to minimise damage in apple trees produced by the sheep.

Initial results: Grazed bush orchards in Northern Ireland, UK

Reference

Reference: McAdam and Ward (2016)

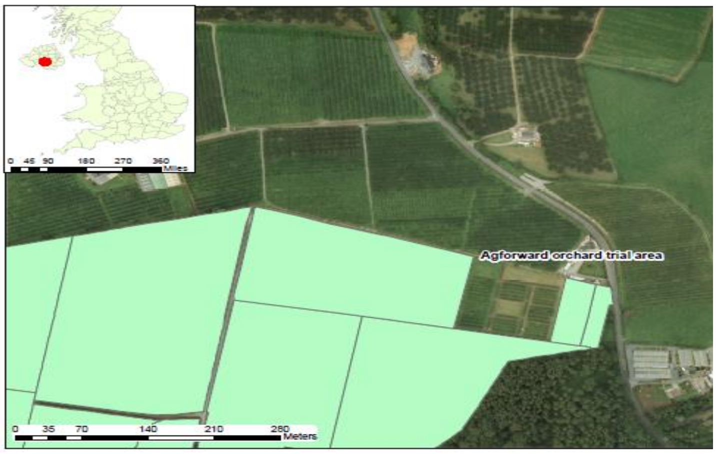
Innovation summary: Grazing bush-apple orchards with sheep could reduce mowing costs but the significant reduction in apple yields means the system is unprofitable.

Images of system

Cider, Coet-de-Linge grazed by sheep

Dessert, Jonagold grazed by sheep

Map of system



Map of orchard trial area (Crown copyright and database rights). More information about the system can be found here

Tree component	Understorey component
Commercial apple trees are a combination of a clonal rootstock to give the tree a particular growth habit, and a clonal scion which will determine harvest fruit variety. The majority of orchards in Northern Ireland are "bush" type systems grown on dwarfing rootstock M9. M9 mature trees grow to 1.8-2.4 m high and have a 2.7 m crown spread (Keepers Nursery). The apple varieties used at this study site are cider "Coet-de-linge" and dessert "Jonagold". Both varieties are normally harvested at the end of October/November.	The crop understory includes a 2m wide grass strip which is mown as for conventional orchard management with a herbicide strip. The area is grazed with sheep LLyn x Texel cross breed.

Initial results

Effect of grazing orchards on sheep

In 2015, the sheep gained weight in grazed orchards and the trees provided shelter to the sheep

Effect of orchard grazing on trees, yield and fruit quality

- All trees in the grazed plots showed signs of tree damage from the sheep. This can be attributed to the trees reducing the amount of grass available
- Monitoring is very important to prevent tree damage but results in higher labour cost
- The lower the tree canopy the greater the overall yield loss
- Leaf scab infections depended on the apple variety. The Coet-de-linge grazed plots recorded a slightly lower percentage of leaf scab in August (8.8%) than the mowed plots (10.2%).
- From post-harvest assessments, grazing had no effect on fruit scab incidences for cider apples
- Grazing appears to increase the size of cider apples.
- Fruit apples from mowed and grazed plots had similar levels of fruit scab
- Percentage of unmarketable apples due to scab was higher in the grazed than in the mowed plots
- Data from this trial confirms the need to maintain a full season pesticide spray programme especially for the control of apple scab with the Jonagold variety.

Results and technical assessment

Grazing management guidelines – lessons to be learnt

- The cider (Coet-de-linge) and dessert (Jonagold) orchard was grazed using LLyn x Texel sheep from 9 May to 22 June 2016.
- Sheep were moved every 10 days to allow fungicide applications for the control of apple scab
- Sheep grazing damage from 2015 had a carry-over effect into 2016 with the lower tier of the trees showing between 40 and 50% reduction in bud formation.
- Sheep grazing caused similar damage in 2016 when fleece caught on the trees and broke small branches, sheep grazed on lower leaf and flower buds and some bark loss was observed. Bark loss was not as extensive as in 2015 as sheep were moved when sward height was *ca.* 10 cm.
- Results show that even with an adequate food supply (grass) the mixed breed sheep grazed on the apple tree.
- Grazing sheep in orchards requires additional infrastructure i.e. fencing and water troughs,
- Labour for stock management i.e. daily grass and stock inspections, movement of sheep to new grass and to facilitate spraying every 10 days. Movement of the sheep is made difficult within an orchard environment.

Fruit quality, quantity and animal production

- Sheep grazing on the lower tree tiers reduced yield by an average of 24% in cider and 43% in the dessert variety over the initial two years of the trial.

The grazing of leaf litter to reduce apple scab infections

- Results from the 2015 trial indicated that sheep did not control apple scab and that they did not graze on the leaves as they fell to the orchard floor as initially expected. Due to the loss of marketable dessert fruit in 2015 the trial received a full fungicide program to control apple scab in 2016.

Harvested cider fruit had no Apple Scab.

- The Jonagold dessert variety had less Apple Scab (2.25%) on the mowed plots than the sheep grazed plots (6.25%).
- Animal production: Most (94.4 %) of sheep lost weight during the trial. The average weight loss was 3.72 kg (5.84%) in cider trees, 2.73 kg (4.34%) Jonagold trees and 3.26 kg (5.40%) for the grass plots.

Improving understanding of the environmental benefits from grazing.

- Sheep grazing reduced mowing by three occasions during May to June 2016.
- Grazing orchards did not remove the need for fungicide applications for the control of apple scab.

Improving understanding of how sheep could improve income

- Fruit production in the grazed treatment was reduced during 2015 and 2016 harvests by an average of 24% for the cider and 43% for the dessert variety.
- From May to June most sheep lost weight when grazing the trial area. On average weight loss for sheep in the cider trees was 5.84 %, dessert 4.34% and grass plots 5.4%.

Socio-economic assessment

The disadvantage of loss of crop far outweighs the advantage of sheep reducing the need to mow in the orchard. Knowledge gained from the trial suggests that grazing mixed sheep breeds in MM106 orchards will not improve income. More successful results may be gained by the use of Shropshire sheep and with older trees with larger rootstocks planted at wider spacing.

Initial results: Grazed orchards in France

Reference

Reference: Corroyer (2016)

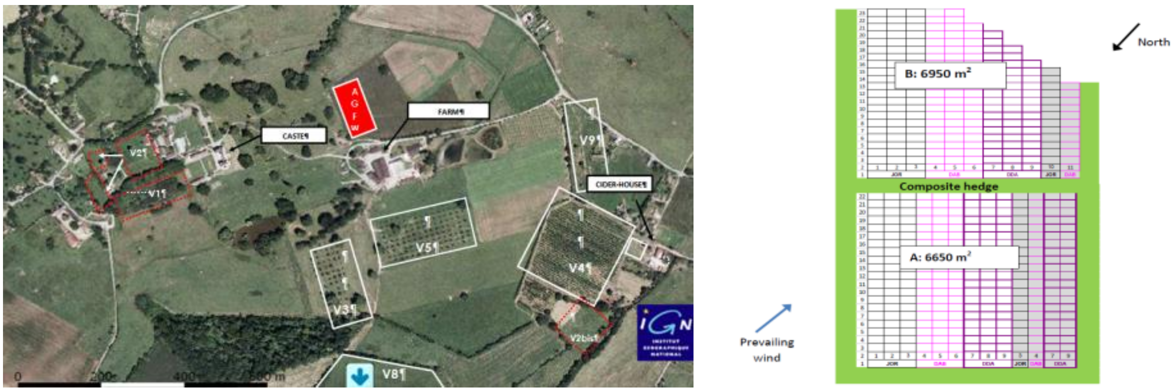
Innovation summary: To produce quantitative information on the effect of sheep grazing on 1) grazing management guidelines, 2) fruit quality and quantity as well as animal production, 3) improved understanding of the environmental benefits from grazing, 4) an improved understanding of how sheep could improve income and reduce costs, 5) the grazing of leaf litter to reduce sawfly, and 6) mineral nutrition and floral diversity.

Images of system

Trees of "Dabinett" in Area B before harvest in October 2015. (Photo by N. Corroyer, 2015)

Sheep in Area B in April 2015. (Photo by H. Jouve, 2015).

Map of system



The orchard for the AGFORWARD trial is indicated in red (Photo by H. Jouve, 2015), left. The two treatment plots (A mowed vs B grazed) in the right picture. More information about the system can be found here.

Tree component	Understory component
Apple (*Malus domestica*) trees varieties are Judor, Dabinett, Douce de l'Avent, rootstock MM 106, at a density 550 trees ha^{-1}. Organic and organic low input with cattle manure as the fertilizer or organic 10/6/2: 100 kg ha^{-1} localised on trees. Different management in the agroforestry vs the reference orchard system.	The crop includes grass species with ryegrass (*Lolium perenne*) sown in spring 2012. Grazing or grazing and mowing depending on the management. No herbicide or crop for the grass. Sheep used as the animal component.

Results 2015 and 2016

Soil results

- The soil analyses showed little difference between the two plots; Part B into which sheep were introduced has somewhat better soil conditions, but this is due to the heterogeneity of the soil
- During the two years, the introduction of sheep in April did not increase nitrogen availability in area B relative to that in area A.

Tree variety

Three varieties were used in this study: 1. Judor, 2. Dabinett, and 3. Douce de l' Avent

Tree density

Commercial cider orchards densities range between 600-1000 tree/ha. In study site A, the density was 790 t/ha whereas in study site B was 550 trees/ha for better aeration and disease control.

Phenology

Full blossom took place 15-20 days later in 2016 as of 2015 due to weather conditions.

Tree growth

Although there was lower growth in area B, the growth was not statistically different. The tendency for lower growth in area B could be associated with competition for nitrogen observed the early years due to the degradation of mulch.

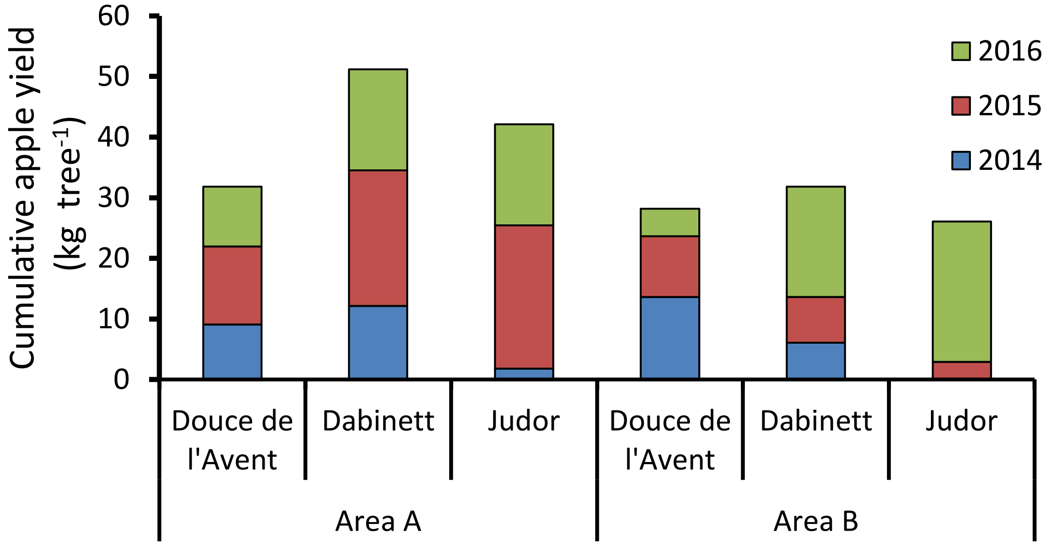
Mineral composition of leaves

- N insufficient in 2015, better in 2016: this improvement is due to the doubling of the fertilizer dose in 2016.
- Mg, Bo: insufficient values for trees nutrition and fructification (Bo) in both areas
- Mn: low value in area A and B.
- K: insufficient value for fruit nutrition in area A in 2015. Amelioration in 2016 but still low.

The presumption is the decomposition of mulch locked up nitrogen and this could have depleted available nitrogen in area B (see tree growth) in 2015. In 2016, the supply of fertilizer allowed an improvement of the contents in 2016. The introduction of sheep did not bring any observable increase in nitrogen availability.

Apple yield

In 2015, the presence of sheep had no impact on apple yields, although a few branches were attacked by sheep at harvest. In 2016, the impact was more substantial and all branches up to a height of 1 m were attacked by the sheep. The measured effect was a 5% decrease in the number of apples in the 2016 harvest.



Cumulative annual apple yields (2014 to 2016) for three apple variety in Area A (not-grazed) and area B (grazed).

Impact on trees
About 30% of the apple trees were attacked in September 2016. The assumed reason is that the grazing time was too long and/or a lack of food supplements (mineral salts). After this observation, the sheep were removed from area B
Impact on sawfly
No individuals have been captured in either plot.
Impact on scab
Part A was more infested than Part B. This cannot be correlated to the presence of sheep that were introduced in the orchard in April and are therefore has not yet taken action on litter decomposition of leaves. More research on this is needed. In 2017 no scab infection on both plots is noted.
Impact on voles:
It appears that the presence of sheep lowered the number of vole holes.

Results and technical assessment

- Permanent grazing with 2 ewes was insufficient for 2016: and hence the number of ewes was increased to 4 from April to September
- Sheep damages on trees: 13% of trees with pieces of bark peeled off in September 2016
- Suppression of flowers and fruits eaten by sheep on low branches: Estimated at 12% on Judor.
- Reduction of mechanized equipment for mowing: 50 %
- No economic valuation of sheep meat: No breeding
- Reduction of mowing costs: 50 %
- For scab: the same inoculum in the two plots at the harvest 2016: Management with RimPro
- For sawfly: no sawfly in the two plots in 2016: Management with Rebell® trap
- Slight improvement in potassium and phosphorus content of apple leaf in plot with sheep: 2 hypotheses: organic fertilization and / or inflows by sheep; to be checked in 2017.

Socio-economic assessment

Sheep grazing in apple orchards can have a positive effect of apple production if performed with caution and under good management; if not then apple yield reductions may occur.

Initial results: Intercropping olives and cereals in Greece

Reference

Reference: Mantzanas et al. (2016)

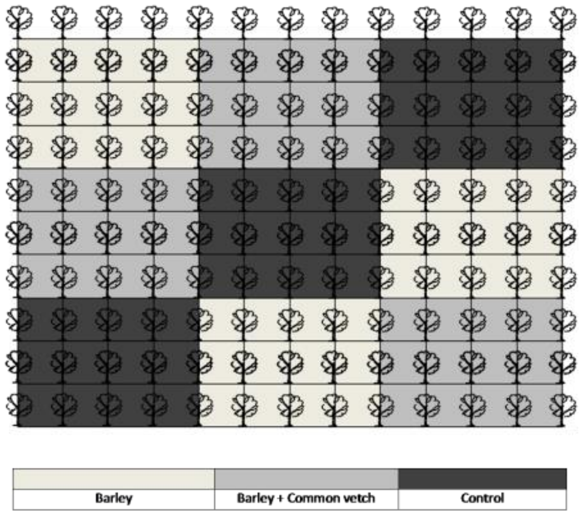
Innovation summary: To identify examples of best practices that involve the intercropping of olive trees with leguminous crops for animal feed and soil amelioration or cereals

Images of system

Experimental plots in Chalkidiki, Macedonia (credit: K. Mantzanas).

Olive groves in Macedonia (Credit: K. Mantzanas)

Map of system



The design involves three treatments in three replications in a Latin square design, namely olive trees + barley, olive trees + a mixture of barley and common vetch, and olive trees alone as a control. The distance between the trees is 10 m. So, each treatment covers 0.12 ha and the total area is 1.08 ha. Olive trees were pruned in February of 2015. More information about the system can be found here.

Tree component	Understory component
The olive (*Olea europea*) tree is considered to have a low demand for soil nutrients, and it is planted in poor, rocky areas with soils mostly derived from hard limestone. Trees in the experimental plot were planted in 1935 at spacing 10 m x 10 m. No protection is applied.	Barley and common vetch are used in this experiment with conventional arable crop management with ploughing. Fertilizers applied were 130 kg ha^{-1} (24-10-0, N-P-K) for the barley treatment and 120 kg ha^{-1} (0-46-0, N-P-K) for the barley + common vetch treatment.

Initial results

Barley and common vetch results

The effect of distance from the tree on total biomass production was not significant at the 5% level, but it was significant at the 10% level ($p = 0.088$). There was a significant effect of distance ($p = 0.011$*) on the number of seeds, with higher seed numbers at the edge of the tree.

Mean height of the common vetch was the only parameter to vary significantly with distance from the tree ($p = 0.043$*). The common vetch was higher for samples taken between the rows of trees. Although the effect was not statistically significant, the barley was also higher between the trees than at the edge of the trees.

Barley results compared to monoculture

The agroforestry treatment, compared to the monoculture treatment, has a significant effect on the density of barley ($p < 0.001$), barley height ($p< 0.001$), the number of heads ($p = 0.007$**), and the number of tillers ($p = 0.04$).

Soil results

No significant differences were found in the soil parameters.

Results and technical assessment

- The intercropping of olive trees with barley and common vetch had positive effect on system productivity.
- The biomass of the crop seems to have been unaffected by location relative to the olive trees.
- The number of seeds is higher in the samples harvested at the edge of the tree. The tree could have a positive effect on the formation of seeds.
- Early crop seeding (before the end of November) resulting in higher production

Socio-economic assessment

The interaction between the understory crops and the olive trees will be assessed after future harvests.

Initial results: Intercropping olives and vegetables in Greece

Reference

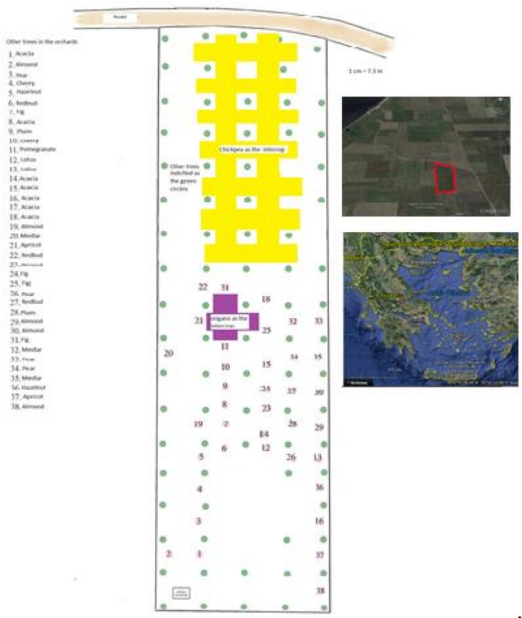
Reference:	Pantera et al. (2016a)
Innovation summary:	To identify examples of interesting or best practices that involve the intercropping of olive trees and vegetables or aromatic/medicinal herbs to gain production and soil amelioration

Images of system

Intercropped area in an olive grove (A. Pantera).

Olives production (D. Kitsikopoulos)

Map of system



Schematic map of the experiment. More information about the system can be found here.

Tree component	Understory component
Olive (*Olea europea*) tree is considered to have a low demand for soil nutrients, and it is planted in poor, rocky areas with soils mostly derived from hard limestone. Trees in the experimental plot were of varieties “Kalamon” and “Amfissa”.	Chickpeas (*Cicer arietinum*) and oregano (*Origanum vulgare*) established with conventional arable crop management with ploughing.

Planted in 1950 at spacing 10 m x 10 m. No protection is applied.	

Initial results

Olive production

Olive production was the same in the plot that chickpeas were planted with the plot that received chemical N fertilizer. The same results were found the second year of the experiment.

Chickpeas production

In the first year of the experiment chickpeas production was poor. Even though the seeds established well (93%) and grew vigorously, final yields were poor due to the unfavourable spring weather (continuous rain) and rodent damage.

Chickpeas production was satisfactory in the second year (2016).

Results and technical assessment

Chickpeas represented an additional income to the farmer. Additionally, the farmer saved money by non-fertilizing the grove but having the same olive production. It also contributed to the lower chemical inputs to the system.

Planting in early spring is important. No watering is needed for the chickpeas. Oregano was planted in a small plot but it established well even if the production was low.

Socio-economic assessment

Intercropping with N-fixing plants represent an interesting option. More information will be collected during the remainder of the experiment.

Initial results: Integration of olives with crops in Italy

Reference

Reference: Rosati and Mantovani (2016)

Innovation summary: 1) To develop best practices for growing wild asparagus and flowers in the olive orchard, 2) assess the technical feasibility and the economic profitability of the asparagus intercrop, and 3) evaluate production and water conservation.

Images of system

Olive-asparagus-bulb system with high-density olive orchard system (Picture A. Rosati).

Olive-asparagus-bulbs system in open field control plot (Picture A. Rosati)

Map of system

Colle Cecco experimental farm: a map of the three systems 1) Super-High-Density olive orchard-asparagus-bulbs, 2) asparagus-bulbs system in an open field, 3) Traditional olive orchard-asparagus-bulbs system. More information about the system can be found here:

Tree component	Understory component

Olea europea, multiple varieties established in 2007. The super-high density system had intra row spacing of 4 m whereas the traditional system 5 m. Super-high density system has intra-row spacing 1.5 m; traditional system 3.5 m. The systems are fenced by wire mesh for protection. Fertilizers composed of 100 kg N ha^{-1} (as ammonium sulphate).	*Asparagus acutifolius, Narcisus* L. *var.* Tete à Tete, Johann Strauss, King Alfred, Ziva Paper withe, and Poeticus Recurvus *Tulipa kaufmanniana* R. Var. Giuseppe Verdi. Wild asparagus were established in 2014. The bulbs were established in 2015 at 1300 kg ha^{-1} a^{-1} .

Initial results

Initial results indicate that photosynthetic rates of the wild asparagus, previously unknown, appear to be similar to those of cultivated asparagus. The wild asparagus appears to have high tolerance of high temperatures, with an optimal temperature of about 30°C and positive photosynthesis up to 45°C.

The light transmitted through the olive trees and available to the asparagus, was about 40% in the traditional orchard and about 46% in the super-high density stand. This was due to the hedge-like shape of the super-high-density systems where the small trees do not intercept most of the light incident over the inter-row during the most sunlit hours of the day, unlike the trees in the traditional systems where the much bigger trees have an almost complete canopy cover. In fact, the spatial variation in the super-high-density treatment was much greater with the proportion of transmitted light ranging from 24% under the tree rows, to 62% between the rows (the range was only 36-50% in the traditional system).

Asparagus production was greater in the open field control than within the olive orchards and it is proposed that this is related to light availability. Hence it is proposed that within an olive orchard, positioning the wild asparagus where light availability is greatest is likely to result in higher yields.

Results and technical assessment

The greater spatial variability in the solar radiation receipts within a super high density olive orchard, compared to a traditional orchard, means that it is best to plant asparagus in the middle of the inter-row as asparagus growth will be limited in the dense shade under tree lines.

As a drought-resistant plant, wild asparagus can be grown under the olive orchard with no additional water.

Growing wild asparagus in olive orchards appears technically possible. In super high density orchards, planting wild asparagus in the middle of the inter-row will maximise asparagus yield but the impact on machinery use for weed control and olive harvest still needs to be evaluated. Planting asparagus along the tree row results in lower yields but is likely to result in fewer mechanisation constraints.

Socio-economic assessment

Yield could not be evaluated yet because asparagus spears cannot be harvested before the plant is at least 2-3 years of age. Preliminary data has been collected in spring 2016 from plants that were 2 years old. The yields and the labour requirements for planting and harvesting the asparagus are still being evaluated.

Initial measurements suggest that shade may increase the edible proportion of the spears.

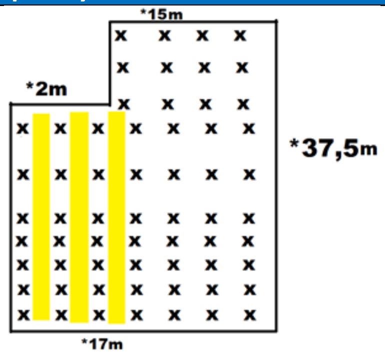
Initial results: Intercropping oranges in Crete

Reference	
Reference:	Pantera et al. (2016b)
Innovation summary:	A legume intercrop can improve soil health and produce food or animal feed

Images of system


Orange trees intercropped with vegetables (right) and leguminous plants (right) (Photo A. Pantera)

Map of system



A 0.2 ha area has been intercropped with chickpeas and potatoes. Each yellow line includes two rows of chickpeas.

Another 0.2 ha of the orchard contains orange trees and other tree species, and the rest are only orange trees and will be used as control. Experimental design with the chickpeas highlighted in yellow.

The trial is located in Western Crete (Google maps). More information about the system can be found here:

Tree component	Understory component
Orange (*Citrus sinensis*) represents the tree component. Local farmers have switched to different varieties, from local types to "Californian" and lately to the "faloforo" and "merlin" types. Presently "valencia" is the predominant variety mainly used for juice. The harvest season for "Valencia" oranges lasts typically from March to July-August. Orange trees for juice production are a cultivar combining a clonal rootstock to give the tree a particular growth habit, and a clonal scion that determines fruit quality.	Chickpeas (*Cicer arietinum*) and potatoes (*Solanum tuberosum*)

Initial Results

Initial results indicate that orange production was higher in the intercropped site than in the control site. Chickpeas production was lower in the intercropped site and this was attributed to tree shading. However this low production can provide an income to the farmer.

Technical assessment

A leguminous crop can be interplanted between rows of orange trees.

Socio-economic assessment

The intercropping with nitrogen fixing crop can positively influence orange production enhancing the farmer's income.

Initial results: Grazing and intercropping of plantation trees in Spain

Reference

Reference: Moreno et al. (2016)

Innovation summary: 1) To determine the productive and ecological consequences of managing walnut plantations with grazing compared to intensive management (tillage and chemical inputs), and 2) the use of different fodder legume species and varieties to improve nitrogen nutrition of the trees.

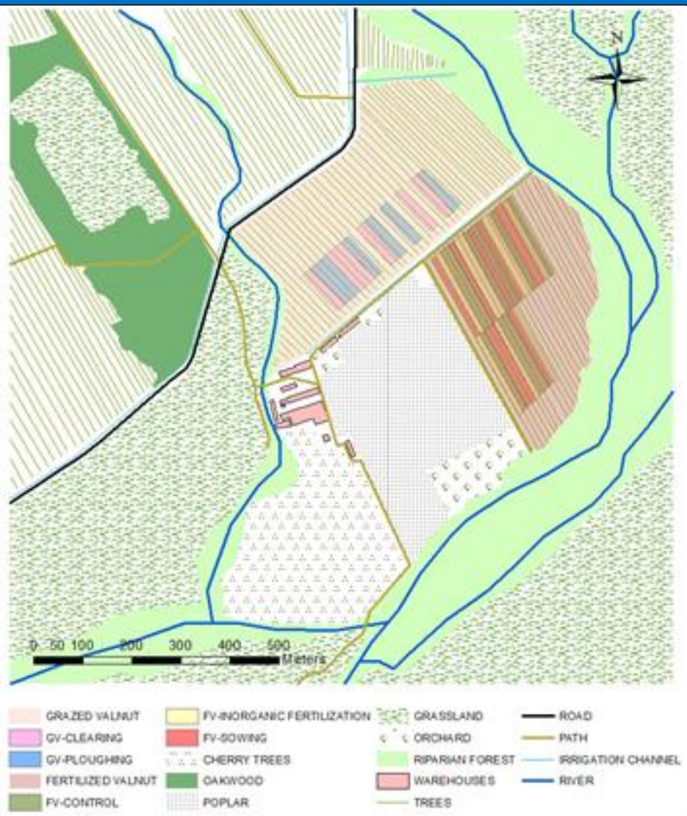
Images of system

Sheep grazing with high value timber trees

Forage legumes sown among hybrid walnuts

Silvopastoral experimental site in Central Spain (province of Cáceres; 40^{o} 6’ 34’’N - 5^{o} 21’ 53’’ W). View in February

Map of system



Map of the experimental area

Fertilized walnut experiment

Three treatments are compared (with nine 12 x 50 m replicate plots):

1. Legume sowing
2. Mineral-fertilized native grasses
3. Unfertilized native grasses

Grazed walnut experiment

Three treatments are compared (with nine 12 x 50 m replicate plots):

1. Grazing
2. Ploughing
3. Mowing

More information about the system can be found here.

Tree component	Understory component
The tree species was Hybrid walnut (*Juglans major* x *nigra* mj 209xra), planted in 2000 at intra-raw spacing 5 m and inter-raw 6 m. No tree protection is applied. *Inorganic fertilization:* application of 40 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} only for mineral fertilizer and legume sown treatments of the experiment I.	Fertilized walnut (experiment 1): native grasses except in sown plots with legumes; the three treatments managed by grazing in late spring. Grazed walnut: native grasses managed by ploughing, clearing (mowing) and grazing depending on treatments. Animal component is sheep (Merina). On average, each ewe will have about 1 lamb. Three lambs every two years. During the weeks immediately before lambing the sheep are often kept indoors. After lambing, the ewe and the lambs will be moved to a field. The lambs will typically be separated from the ewe in late spring. The typical aim is to fatten the lambs as soon as possible ready for market, and to maintain the weight of the ewes until "tupping".

Initial results

Soil nutrients

- In the fertilized walnut experiment, legume sowing resulted in the largest values of P, N and K.
- In the grazed walnut experiment, mowing and grazing increased P availability however, ploughing improved soil available Ca and N.

Soil moisture

- In the fertilised walnut experiment, in the summer-autumn of 2013, the lowest soil moisture contents were found in the legume sowing and inorganic fertiliser plots than the control.
- In the grazed walnut experiment, in April, May and June in 2013, the highest soil moisture was found in the ploughed treatment, however in the summer and autumn, the highest soil moisture was found in the grazed treatment.

Nitrate leaching

- In the fertilised walnut experiment, highest levels of soil nitrate were found in the legume treatment than the control and fertilised treatments.
- In the grazed walnut experiment, the nitrate concentration at 30 cm depth was greatest in the ploughing treatment, than the mowing or grazed treatments, presumably because of nitrogen mineralisation form the herbaceous vegetation.

Tree leaf nutrients

- In the fertilised walnut experiment, tree leaf nitrogen levels were generally higher in the legume and fertiliser treatments than the control.
- In the grazed walnut experiment, the tree leaf nitrogen levels were generally higher in the ploughed treatment than the mowed plots. The value in the grazed plots varied substantially with year and this was related to the grass growth.

Tree diameter increment

- In the fertilised walnut experiment, inorganic fertilization resulted in the greatest tree diameter increment followed by legume sowing. It is proposed that high levels of pasture production need not lead to poor tree growth.
- In the grazed walnut experiment, ploughing and grazing resulted in a greater walnut tree diameter increment than no grazing.

Pasture production

- Pasture production was improved by inorganic fertilization and legume sowing compared to the control.

Root length

- Pasture roots occurred at depth under grazing and below the tree.
- Inorganic fertilization and legume sowing had a positive effect on pasture roots length, mostly at 40-70 cm depth.

Potential of carbon storage

- The largest reservoir of carbon occurred in the soil followed by the tree. In the tree, 60% of the carbon was sequestered in the aerial part and 40% in the roots.
- In the experiment, the percentage of carbon stored in the fine roots was between 0.6 and 0.8% of the total C.

Results and technical assessment

Managed grazing, rather than ploughing, is an alternative practice to control the herbaceous understory of timber plantations in a Mediterranean climate. It can allow satisfactory tree growth and enhance soil carbon sequestration, soil fertility and control of nutrient leaching. Grazing at a common stocking rate of up to 4 sheep ha^{-1} was insufficient to control the herbaceous understory in late spring and a higher stocking rate of up to 10 sheep ha^{-1} may be needed at this time. However tree-understory competition for water and nutrients can negatively affect tree growth and a combination of mechanical clearing with grazing deserves further study.

Improving soil cover with sown forage legumes under walnut plantations has mostly positive effects on soil quality and tree performance and growth compared to unfertilized/unmanaged plantations. Carbon sequestration is also reinforced. The sowing of forage legume species under walnut plantations increased the nitrogen, phosphorous and potassium availability for trees. Forage yield and tree growth also were increased compared to unfertilized plantations but the increments in tree growth remained below those of trees that received mineral fertilizer.

Socio-economic assessment

Grazing managed for the control of herbaceous understory seems a cost-effective management practice. The growth of mature trees (> 10 years old) was barely affected by different management practices used to control herbaceous understory and grazing saved important costs for the timber company and produced additional incomes (not evaluated) to the livestock farmer.

Sowing legumes as a forage source beneath walnut plantations reduced tree growth relative to that achieved with mineral fertilizers. Nevertheless the increase quality and yield of underneath pasture could bring additional income (not evaluated) for associated livestock farmers. This together with the reduced fertiliser costs and reduced mechanical labour for weed control could make sown legumes a cost-effective and environmental-friendly practice to manage high-quality timber plantation.

Initial results: Bordure trees in South-West France

Reference

Reference: van Lerberghe and Malignier (2016)

Innovation summary: 1) To produce quantitative and qualitative information about branches biomass production of pollarded ashes, 2) determine the productive consequences and economic benefits of pollarding old trees, and 3) develop a simple mathematical model that could help increase farmers' income: an allometric equation to predict branches biomass.

Images of the system

Glacial valley of Louron in the municipality of Mont, near the Lake Génos-Loudenvielle in the Hautes-Pyrénées (Picture P. Van Lerberghe).

Sheep grazing in ashes (*Fraxinus excelsior L.*) planted on hedges (Picture P. Van Lerberghe)

Map of system

The numbered blocks correspond to tree rows where all the trees have been inventoried and measured. More information about the system can be found here.

Tree component	Understory component
Ashes (*Fraxinus excelsior L.*) are planted on hedges around the fields. It's a traditional way to delimit plots, to bring shadow and fodder to livestock and to restrict erosion. Trees are pollarded to increase	Grassland is composed of *Lolium perenne*, *Poa pratensis and Festuca rubra.* Sheep grazing in the area may be lambs which are being fattened or ewes that need to maintain body weight until the

the quantity of wood production during a short-term rotation. The cutting tree height depends on the region. Grazing is a mean to maintain a short sward and to provide fodder for sheep. Other species include *Populus nigra italica Populus, Quercus petraea, Q. pyrenaica, Q. pedunculata, Prunus avium, Tilia cordata, Alnus glutinosa, Salix, Acer* and *Fagus sylvatica. Castanea sativa* can be pollarded in this way, however, ash is the key species.	next lambing season. Traditionally, ewes will conceive in the autumn with lambing occurring in the spring. During the weeks immediately before lambing, the sheep are often kept indoors. After lambing, ewes and lambs will be let free in the large wood pastures. The sheep will go back indoors to be milked each morning and evening. Farmers make cheese every morning.

Initial results

So far, the research has cut down 16 trees and prepared 16 slices of each trunk and 166 slices of branches in order to study their age and biomass characteristics. Their green biomass weight (just cut on the field) have been compared with their weight after being dried. These measures can be used to find the percentage of water loss of these different parts of ashes and their density.

The next stage is to determine the age of each tree and each of its branches (as they were frequently cut, being pollard trees), and establish the growth curves of height and diameter of these trees. This may be used to determine the best pollarding frequency to optimise biomass production (number of branches).

Results and technical assessment

No results are available yet.

Socio-economic assessment

Their biomass growth curves, correlated with the number of their branches will indicate how ash pollard should be pruned to optimize biomass production for firewood and sheep fodder.

Initial results: Chestnut systems in Galicia, Spain

Reference

Reference: Fernández Lorenzo et al. (2016).

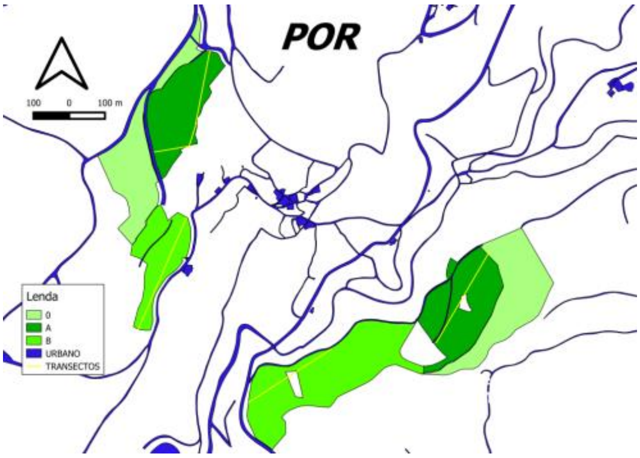
Innovation summary: A system for both chestnuts, mushrooms and animal production (pigs)

Images of system




Example photographs of chestnut trees (Photo M.R. Mosquera)

Map of system



Location of the chestnut agroforestry sites (left) and layout of one of the chestnut agroforestry sites (right). More information about the system can be found here.

Tree component	Understory component
The tree species is chestnut (*Castanea sativa* L.). Although chestnut groves are rarely intercropped (due to the low understorey production) or grazed (due to the fear of tree damage), the groves create a fine-grained mosaic of land uses including cropland and forests. Chestnut woodlands are also one of the best habitats for the commercial production of edible mushrooms.	The understory is composed mainly by *Ulex* sp., *Pteridium* sp. *and Rubus* spp. The animal species used is free ranging pigs (celtic pig). Pigs graze in the 50 year old stand from April to September and from October to December in the old stands. They are killed when they reach 100 kg weight. Mushrooms are *Boletus edulis*.

Initial Results

The mushroom established well but the 2016 climatic conditions were not favourable for production. More results will be expected in 2017.

Results and technical assessment

No final results yet.

Socio-economic assessment

This type of system can increase rural employment.

4 Acknowledgements

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