Agroforestry for high value tree systems: Guidelines for farmers

Project name	AGFORWARD (613520)
Work-package	3: Agroforestry for High Value Tree Systems
Milestone	Deliverable 3.9 (3.3) Agroforestry for High Value Tree Systems: Guidelines for farmers
Date of report	18 January 2018
Authors	Anastasia Pantera, Paul Burgess, Maria Rosa Mosquera-Losada, Adolfo Rosati, Gerardo Moreno, Jim McAdam, Konstantinos Mantzanas, Nathalie Corroyer, Philippe Van Lerberghe, Nuria Ferreiro-Domingues, Maria Lourdes López, Jose Javier Santiago Freijanes, Antonio Rigueiro-Rodriguez, Juan Luiz Fernandez-Lorenzo, Pilar Gonzalez-Hernandez, Pablo Fraga-Gontan, Miguel Martinez-Cabaleiro, Francesca Chinery, George Eriksson, Erica Pershagen, Cristina Perez-Casenave, Michail Giannitsopoulos, Juliette Colin and Fabien Balaguer
Contact	Anastasia Pantera; pantera@teiste.gr

Contents

1 Context 2
2 Leaflets overview 2
3 A brief description of the innovation leaflets 3
4 A short summary of the main advantages 6
5 Acknowledgements 7
6 References 7

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

1 Context

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

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

This Deliverable 3.9 (3.3) contributes to the second and fourth objectives. It contains a summary and copies of eleven innovation leaflets focused on the use of agroforestry in high value tree systems. The deliverable is connected with work-package 3 in the project. Similar reports exist for agroforestry of high nature and cultural value, agroforestry for arable farmers, and agroforestry for livestock systems.

2 Overview of leaflets

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

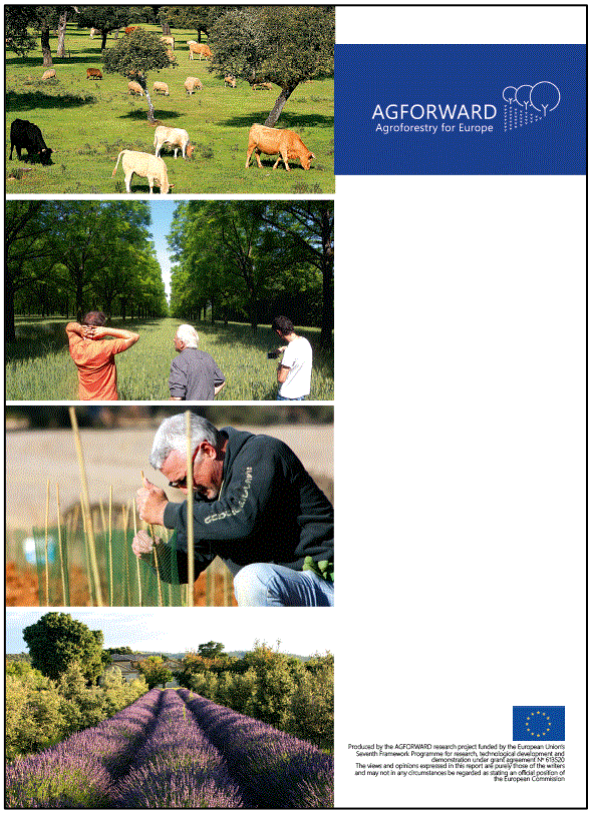


Figure 1. The 11 innovation leaflets focused on agroforestry for high value tree systems were included in a folder with a total of 46 innovation leaflets and 10 best practice leaflets (Balaguer et al. 2017)

Table 1. Overview of the innovation leaflets, the stakeholder groups and the lead organisations

No	Title of leaflet	Stakeholder group	Lead organisation
16	Grazing sheep under walnut trees	Grazing and intercropping of plantation trees in Spain	Universidad de Extremadura, Spain
17	Protecting trees in chestnut stands grazed with Celtic pigs	Chestnut systems in Galicia, Spain	University of Santiago de Compostela, Spain
18	New approaches to producing selected varieties of chestnut		University of Santiago de Compostela (USC), Spain
19	Wild asparagus in olive orchards	Integration of olives with crops in Italy	Consiglio per la Ricerca in Agricoltura e l'Analisi del'Economia Agrarian (CREA), Italy
20	Olive trees intercropped with chickpeas	Intercropping olives and vegetables in Greece	TEI Stereas Elladas
21	Olive trees intercropped with cereals and legumes	Intercropping olives and cereals in Greece	Aristotle University of Thessaloniki, Greece
22	Orange trees intercropped with legumes	Intercropping of oranges on the Greek island of Crete	TEI Stereas Elladas, Department of Forestry & NEM, Karpenissi
23	Apple orchards grazed in France	Grazed orchards in France	Chambre d' agriculture de Seine-Maritime – Cite de l'agriculture chemin de la Breteque, France
24	Economic benefits of grazed apple orchards in England	Grazed orchards in England and Wales, UK	Cranfield University, Bedfordshire, UK
25	Key challenges of orchard grazing	Grazed orchards in Northern Ireland, UK	Agri Food and Biosciences Institute and Queens University of Belfast, N. Ireland
26	Farming with pollards	Bordure trees in South-West France	[1]French Agroforestry Association (AFAF) [2]Institute for Forestry Development (IDF)

3 Overview of the systems

The "Agroforestry with high value tree systems" network focused on agroforestry systems where the farmer or landowner typically starts with a fruit orchard, olive grove or high quality timber plantation. Table 2 summarises the tree species considered including apple, orange and olive trees and hybrid walnut, chestnut and ash. Grass, primarily perennial ryegrass, is the dominant crop in most systems. Other crop species include cereals, vegetables including asparagus, bulbs, mushrooms, and chickpeas. Grass tends to be the dominant understorey crop in Northern Europe whereas a wider range of intercrops are used in the Mediterranean. Grass is particular suited as an understorey crop in Northern Europe because it is a vegetative crop and its yield is less sensitive, than grain crops, to low light levels.

The most common animal is sheep, although pigs are present in the chestnut system in Galicia, Spain. Because of the importance of the tree products, the chosen animals should cause minimal or no damage to the trees. Actually, the choice of animal species and breeds that cause no damage is one of the goals of the research groups in this project. This is also evident by the generally low stock density used in most systems

Table 2. Overview of the high value tree systems studied by the innovation leaflets

Leaflet	Tree component	Crop component	Animal component
16	Hybrid walnut (*Juglans major* x *regia*) Mj209xRa	Grass species	Sheep: Merino breed
17	Chestnut (*Castanea sativa* L.)	*Ulex* sp., *Pteridium* sp. *Rubus* sp., and mushrooms	Pigs: Celtic breed
18	Chestnut		Pigs: Celtic breed
19	Olive (*Olea europea*)	Asparagus (*Asparagus acutifolius*) and bulbs (*Narcissus* and *Tulipa* species)	No animals
20	Olive	Cereals, maize, grape vines, vegetables, grass, and chickpea (*Cicer arietinum*)	Sheep
21	Olive Pear (*Pyrus* sp.), Pines (*Pinus halepensis*)	Wheat and barley	No animals
22	Orange (*Citrus sinensis*)	Vegetables (here chickpea (*Cicer arietinum*)	No animals
23	Apple (*Malus domestica*)	Perennial ryegrass	Sheep: Shropshire breed
24	Apple	Perennial ryegrass (*Lolium perenne*)	Sheep: Shropshire breed
25	Apple cider variety: Coet-de-linge, and dessert variety: Jonagold	Perennial ryegrass	Sheep: mixed breeds including Texel, Belclare, LLeyn and Highlander
26	Ash (*Fraxinus excelsior* L.)	Grass species	Sheep (Lacaunes) or cows (depending on the region)

4 Brief description of the key messages

4.1 Intercropping or grazing in high value timber systems

There is a strong demand for hardwood timber, such as from walnut, and some current plantation systems require high management, fertiliser and energy inputs. Leaflet 16 (Moreno and Lopez 2017) explains that the energy and fertiliser inputs can be reduced by sheep grazing and intercropping with legumes. The reduction in understorey biomass by the use of sheep can reduce fire risk and mowing costs. The sowing of legumes which can fix nitrogen can reduce the need for nitrogen fertilizers and can improve the nitrate losses.

Leaflet 17 (Mosquera Losada et al. 2017) explains how Celtic pigs can graze between stands of chestnut trees in Galicia, Spain without damaging the trees. The main questions involved the productivity of the system, its environmental and economic performance, and management guidelines. Adequate stocking rates and space-distribution of the pigs are important to limit the

damage to the trees. It is a successful combination that preserves biodiversity, increases nutrient cycling and farmers' income.

Leaflet 18 (Fernandez-Lorenzo et al. 2017) describes the production of ink-resistant chestnut varieties that are important for the preservation of chestnut silvopastoral systems. The technology presented can detect early incompatibilities of specific combinations of hybrid clones and varieties; it can minimize infections from the grafting process, is quicker and can produce ink-resistant plants. There is an undergoing research on the production of resistant varieties such as "Loura" and "Parede" which, however, has not been field-tested yet.

3.2 Intercropping of olive groves and orange orchards

Are there any opportunities to increase income from an olive grove? This second group of systems referred on the intercropping of olive systems, including two stakeholder groups in Greece (Chakidiki and Molos) and one stakeholder group in Italy. The Italian system was focusing on the use of asparagus, which is not a crop consumed widely in Greece.

Leaflet 19 (Rosati 2017) describes the best practices for growing wild asparagus in an olive orchard. The leaflet argues that intercropping asparagus improve the land productivity of olive production and that it can provide an additional source of revenue for the farmer.

Leaflet 20 (Pantera 2017a) describes research on planting an intercrop of chickpeas in the olive groves of Molos in Greece. The chickpeas had no measurable effect on olive production. Because chickpea is a leguminous crop, it can fix nitrogen reducing the need for nitrogen fertiliser although the need for phosphorus fertilizer may increase.

Similarly Leaflet 21 (Mantzanas 2017) describes that intercropping barley or a mixture of barley and common vetch cereals between olive trees can produce a hay crop for livestock. The results from the experiment in Chalkidiki in Greece were promising showing higher olive production than previously obtained. The yield of the intercrop need not appear to vary with distance from the olive trees.

Orange groves, producing oranges as fruit or for juice production, are common in Western Greece and Crete. The process of grafting new varieties can result in periods of low canopy cover (up to 15 years) before the full development of the new crown. Leaflet 22 (Pantera 2017b) explains that farmers can either enhance their revenue by intercropping vegetables between the orange trees. An alternative are chickpeas which can provide marketable seeds and improve soil fertility by fixing nitrogen in the soil. In Greece, chickpeas can be planted between February and April and if the seeds are not harvested, the crop can also be added to the soil to improve soil chemical and biological properties.

In summary, intercropping of olive and orange trees can increase revenue and improve soil status, and the choice of the intercrop should take into account local market needs.

3.3 Grazed apple orchards

Grazing sheep in apple orchards can reduce mowing cost, provide grazing for the livestock and there is some evidence that some apple pests can be reduced.

Leaflet 23 (Corroyer 2017) explains that there are opportunities for orchard owners to increase farm profitability by grazing apple orchards. Grazing can reduce mowing cost, enhance nutrient cycling, can reduce crop damage from apple scab, sawfly and voles, and increase income by using the grass component to feed the animals. Careful planning and management is needed for the system to be successful. For example lowland sheep breeds are likely to cause less damage than upland breeds, and sheep must be removed from the orchard before apple harvest to avoid faecal contamination of the fruit.

Leaflet 24 (Burgess et al. 2017) describes an unreplicated on-farm demonstration of a grazed and an ungrazed cider apple orchard (with high-stem trees) in England. The Shropshire breed of sheep, which have term “tree friendly', were used for the demonstration. The apples were sold for cider production and hence the pesticide programme was minimal as fruit appearance is not critical. The leaflet explains how a successful grazed orchard system needs an alternative area of grass for period when the sheep cannot be present in the orchard. Establishing a grazed orchard can reduce mowing costs, and although there are increased fencing and sheep movement costs, the capacity to feed the sheep between April and July in the orchard can release other areas of grass for hay or silage production. The leaflet also explains that it is possible to construct agreements that are mutually beneficial to an orchard owner and a sheep farmer, although contract and transportation costs should be minimized.

Leaflet 25 (McAdam 2017) uses results from an experiment in Northern Ireland to explain the impact of sheep grazing on a bush apple orchard (i.e. apple trees with a low canopy height). In this case the sheep (which were of various breeds) ate all the buds and leaves on the apple trees below a height of about 115 cm. This loss of apple tree canopy reduced apple yields by 24-43%. The results demonstrate that sheep grazing is unlikely to be successful in a bush apple orchard.

In summary, farmers with high-stem cider apple trees can reduce mowing costs and secure additional revenue from sheep grazing. However careful and routine management is needed.

3.4 Bordure trees in South West France

Pollarding of ash and willow trees in south-west France can provide an additional source of revenue from firewood, chipped wood, lumber, and fodder. Leaflet 26 (Colin et al. 2017) explains that pollarding can increase the life of old trees and can increase biodiversity. A growing market for ramial chipped wood (RCW), for example for animal bedding, can make pollarding cost-effective.

5 Overview of the main advantages

Each leaflet addresses the effect of grazing or intercropping on the productivity and/or profitability of high value tree systems. The combined production of annual crops with tree crops can provide additional revenue and diversify the range of farm products. Annual revenues provided by, for example a crop (Leaflet 22; Pantera 2017b), can improve farm profitability whilst slowly-maturing trees reach maturity.

Planting leguminous species between trees can reduce nitrogen fertilizer costs and sometimes can enhance tree growth and production (e.g. Leaflet 16, Leaflet 20, Leaflet 21 and Leaflet 22). Intercropping can also enhance carbon sequestration and reduce mowing or cultivation costs. In some conditions, intercropping and grazing can reduce the level of pests (Leaflet 18 and Leaflet 23). The complications of combining the grazing or intercropping of tree crops with pesticide use, means that grazing and intercropping of tree crops is easier in system where there is no or minimal pesticide use.

6 Acknowledgements

The AGFORWARD project (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission. This research has been co-funded by the Hellenic Ministry of Education, Research and Religion, General Secretariat for Research and Technology.

7 References

Balaguer F, Waldie K, Van Leberghe P, Liagre F, Girardin N, Pagella T, Burgess PJ (Eds) (2017). Folder for AGFORWARD Agroforestry Innovation and Best practice Leaflets. 8 November 2017. AGFORWARD project. www.agforward.eu

Burgess P, Chinery F, Eriksson G, Pershagen E, Perez-Casenave C, Giannitsopoulos M, (2017). Agroforestry Innovation leaflet 24: Economic benefits of grazed apple orchards in England. AGFORWARD project. 2 pp. http://www.agforward.eu/index.php/en/Grazed_Orchards.html

Colin J, Van Lerberghe P, Balaguer F (2017). Agroforestry Innovation leaflet No. 26: Farming with pollards. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/bordure-trees-in-france-1375.html

Corroyer N (2017). Agroforestry Innovation leaflet 23: Apple orchards grazed in France. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/grazed-orchards-in-france.html

Fernandez-Lorenzo JL, Rigueiro-Rodriguez A, Ferreiro-Domingues N, Gonzalez-Hernandez P, Fraga-Gontan P, Martinez-Cabaleiro M, Mosquera Losada MR (2017). Agroforestry Innovation leaflet 18: New approaches to producing selected varieties of chestnut. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/chestnut-agroforestry-in-galicia-spain.html

Mantzanas K (2017). Agroforestry Innovation leaflet 21: Olive trees intercropped with cereals and legumes. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html

McAdam J (2017). Agroforestry Innovation leaflet 25: Key challenges of orchard grazing. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/grazed-orchards-in-northern-ireland-uk.html

Moreno G. Lopez ML (2017). Agroforestry Innovation leaflet 16: Grazing sheep under walnut trees, AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/grazing-and-intercropping-of-plantation-trees-in-spain.html

Mosquera Losada MR, Santiago Freijanes JJ, Ferreiro-Domingues N, Rigueiro-Rodriguez A (2017). Agroforestry Innovation leaflet 17: Protecting trees in chestnut stands grazed with Celtic pigs. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/chestnut-agroforestry-in-galicia-spain.html

Pantera A (2017a). Agroforestry Innovation leaflet 20: Olive trees intercropped with chickpeas. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html

Pantera A (2017b). Agroforestry Innovation leaflet 22: Orange trees intercropped with legumes,. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/intercropping-of-orange-groves-in-greece.html

Rosati A (2017). Agroforestry Innovation leaflet 19: Wild asparagus in olive orchards. AGFORWARD project 2 pp. http://www.agforward.eu/index.php/en/intercropping-and-grazing-of-olive-orchards-in-italy.html

Appendix A: The innovation leaflets

Agroforestry Innovation leaflet 16: Grazing sheep under walnut trees (Moreno and Lopez 2017).

Agroforestry Innovation leaflet 17: Protecting trees in chestnut stands grazed with Celtic pigs (Mosquera Losada et al. 2017).

Agroforestry Innovation leaflet 18: New approaches to producing selected varieties of chestnut (Fernandez-Lorenzo et al. 2017).

Agroforestry Innovation leaflet 19: Wild asparagus in olive orchards (Rosati 2017).

Agroforestry Innovation leaflet 20: Olive trees intercropped with chickpeas (Pantera 2017a).

Agroforestry Innovation leaflet 21: Olive trees intercropped with cereals and legumes (Mantzanas 2017).

Agroforestry Innovation leaflet 22: Orange trees intercropped with legumes (Pantera 2017b).

Agroforestry Innovation leaflet 23: Apple orchards grazed in France (Corroyer 2017).

Agroforestry Innovation leaflet 24: Economic benefits of grazed apple orchards in England (Burgess et al. 2017).

Agroforestry Innovation leaflet 25: Key challenges of orchard grazing (McAdam 2017).

Agroforestry Innovation leaflet 26: Farming with pollards (Colin et al. 2017).

Grazing sheep under walnut trees

Producing high quality timber whilst reducing costs

www.agforward.eu

Pasture under hybrid walnut plantationts. *Ref : E. Juarez*

Why introduce livestock?

There is a high demand for hardwood timber, such as hybrid walnut, in the EU. To meet this demand, over the last decade, hardwood plantations have substantially increased production in many Spanish regions. Intensive management is often required to grow these trees in short rotations. Such management comprises irrigation, fertilisation, and chemical weed control. However, this level of management has high economic and environmental costs. Plantation management accounts for more than 45% of the total investment costs. Moreover, these operations can have major environmental impacts, similar to the effects of intensive agriculture systems.

Introducing livestock and sowing legumes can reduce the financial costs of these plantations and optimize their environmental functions. This is known as a silvopastoral system.

Sheep grazing under walnut trees in summer
Ref : G. Moreno

Where and how to plant

Hybrid walnut trees need a rather humid climate, preferably with a moderate dry period (about 3 months without rains) and not too cold (annual mean temperature above 10°C). Some hybrid walnut progenies (e.g. Mj-209xRa; *Juglans major x regia*) show a higher tolerance to warm climates, such as in the Mediterranean areas, than local walnut (*Juglans regia*). Although walnut can grow in a wide variety of soil types, it does best in a deep, well-drained soil, with a loamy texture and neutral or slightly basic pH.

Trees should be planted at a density of 333 trees/ha (5x6 m) and where planting 1-2 year-old trees, saplings should be around 60-100 cm height. Irrigation is needed if summer drought occurs. Fertiliser should be applied in early spring at rates of 40 kg N/ha, 40 kg P_2O_5/ha and 50 kg K_2O/ha.

The trees are very sensitive to weed competition during the first 5 years. Thinning and pruning may be required, depending on tree growth.

How to graze

A stocking rate of 1-2 sheep/ha is recommended in the Mediterranean regions. With summer and winter fodder supplementation livestock can remain in plantations all year. Sheep can be introduced in the first years of plantation as the walnut is not palatable during this period. However, trampling damage should be avoided by using tree protection guards during the first 5-6 years. No damage will be caused after this time as the trees would have gained a sufficient height so that the sheep will no longer be able to reach the crowns.

How to sow legumes

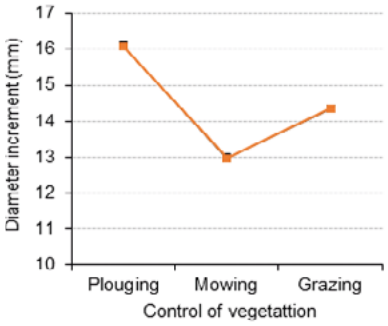
A mix of forage legumes (annual species of *Trifolium spp*., *Medicagospp*. and *Ornithopus spp*.) can be sown at a density of 20 kg seeds/ha to a soil depth of 0.5-1.0 cm. In the first year, pasture should only be grazed after crops maturation to ensure self-seeding in the following years.

AGFORWARD Agroforestry for Europe

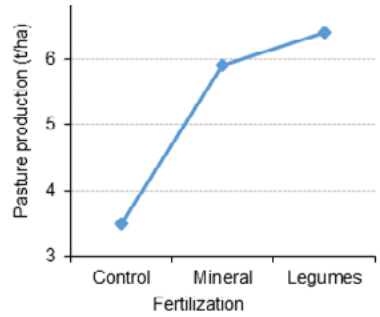
Produced by the AGFORWARD research project funded by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement No 613520

Advantages

The implementation of a silvopastoral system provides short- and medium-term outputs, reducing inputs and, consequently, improving the profitability of the farm while optimising environmental functions. Grazing under walnut plantation reduces fire risk, the competition between trees and weeds, and the financial costs for controlling competition (mowing, herbicides). The sowing of legumes, as an alternative to applying mineral fertilisers, increases available nutrients in soil (especially N), improves pasture production and quality, and optimises the environmental functions of plantations.



Annual increments of walnut stem diameter after 3 years of soil treatments



Pasture production in 2013 two years after sowing

María Lourdes LÓPEZ
Gerardo MORENO
lurdesld@unex.es
Universidad de Extremadura
INDEHESA – Plasencia, Spain
company Bosques Naturales
www.agforward.eu

November 2017

Legume sowing under walnut trees *Ref : TE. Juárez*

How to manage walnut trees

Thinning and pruning must be carried out during tree growth. Pasture and livestock management must include consideration of the need to produce good quality timber. The mixture of self-seeding legume species has a good persistence under shade conditions and with medium grazing pressure (~0.5 LU/ha).

Grazing improved tree growth compared to mowing. In the short term, we did not find any difference among treatments, but with time it is expected that grazing would favour the tree growth more than the other treatments as grazing improved the soil conditions slightly (soil moisture, C and N cycle).

In the second year after sowing, legumes gave a similar yield as the fertilised pasture (5.9-6.4 t/ha) and both these yields were higher than in the plot receiving no fertiliser (3.5 t/ha).

Further information

López-Díaz ML, Rolo V, Moreno G (2013). Manejo silvopastoral para la producción de madera de calidad: bases funcionales, productividad y servicios ambientales. 6º Congreso Forestal Español. Monte: Servicios y desarrollo rural. 10-14 junio 2013 Vitoria-Gasteiz. pp. 1-10.

López-Díaz ML, Moreno G, Bertomeu, M (2014). Pasture management under hardwood plantation: legume implantations vs. mineral fertilization. 2nd European Agrofo restry Conference. Book of Abstracts. In Palma JHN (eds.). 4-6/06 Cottbus, Ger many, pp.10-13.

López-Díaz ML, Bertomeu M, Benítez R, Arenas-Corraliza G, Moreno, G (2016). Carbon sequestration in intensive hardwood plantations: influence of management. 2016. Celebrating 20 years of Agroforestry research in Europe. 3rd European Agroforestry Conference. European Agroforestry Federation. Montpellier, France. 23-25 May 2016. pp. 178-181.

López-Díaz ML, Benítez R, Moreno G (2017). How do management techniques affect car bon stock in intensive hardwood plantations? Forest ecology and management 389: 228-239. http://dx.doi.org/10.1016/j.foreco.2016.11.048. Elsevier.

Protecting trees in chestnut stands grazed with Celtic pigs

Avoiding damage to young and old trees

www.agforward.eu

Pigs in fruit fall season foraging for chestnuts and other feed

Why graze pigs in chestnut stands?

Before ink disease destroyed trees growing below 400 m above sea level, chestnut stands had been the most broadly distributed tree in Galicia (NW Spain). Currently, chestnut stands occupy over 60,000 ha in Galicia, mainly located in the eastern mountainous areas of Ancares-Caurel Natural Park, where close to 100 varieties are still growing and providing chestnut fruits. However, the orography with steep slopes renders the harvest of chestnut fruit unprofitable due to the high labour cost.

In areas that are not profitable to produce chestnut fruit for human consumption, the Celtic breed of pig has recently been introduced to provide an alternative source of income. The high quality of the chestnut fruits as a fodder contributes to the production of premium pig meat, for which there is a large commercial demand in the region.

Tree bark worn by the effect of scratching by Celtic pigs.

Why do chestnut trees need protection?

Pigs can damage mature and even centenary trees found in protected natural parks. It is, therefore, important to evaluate and, where necessary, limit the damage that grazing with pigs can cause.

The type and extent of damage caused by pigs depends on stocking rates and tree age. When adequate animal general stocking rates are maintained damage to trees is usually most significant in areas where the animals spend most of their time.

Animals are usually retained close to places where feed and water are placed, thus creating a gradient of "stocking density" in large plots. We assessed damage to chestnut trees of different diameter size (37-91 cm) and at different distances from the feed and water, both with and without protectors.

Damage caused by biting

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

Advantages

Tree damage was usually restricted to a limited number of trees in the plot. This is probably due to the special flavour of the bark, especially on smaller trees. Direct observation shows that pigs also scratch on specific trees.

Overall damage was negligible as the stocking rate was adequately controlled. Tree damage was lowest on trees located furthest away from feed and water points.

Damage was easily controlled by the protectors consisting of a 5 cm x 5 cm mesh.

Chestnut tree with a protector

María Rosa MOSQUERA-LOSADA, José Javier SANTIAGO FREIJANES, Nuria FERREIRO-DOMINGUEZ, Antonio RIGUEIRO-RODRIGUEZ,
mrosa.mosquera.losada@usc.es
Crop Production and Project Engineering Department. Escuela Politécnica Superior. University of Santiago de Compostela, 27002 Lugo, Spain
www.agforward.eu

November 2017

Management

Adequate stocking rates will limit the general impact of pigs on trees, and protectors can be used when damage to individual trees is observed. Regular movement of available feed and water points can also help to ensure an effective use of plot resources, and also to reduce prolongued damage to trees. In areas where chestnut fruits are profuced for human consumption, Celtic pigs can be introduced after harvesting to consume the remaining fruits as fodder. The potential reduction of future fruit infections, due to the consumption of infested fruit, is a likely benefit of grazing with Celtic pigs.

Environment

Chestnut trees combined with Celtic pigs can help to preserve biodiversity in chestnuts stands, as the highest number of herbaceous and woody species appear in the understory. Moreover, it increases the rate of nutrient recycling. Pigs consume the understory and produce ammonia in the urine. This probably increases chestnut production as competition with shrubs is reduced.

Further information

Iglesias A, Rigueiro-Rodriguez A, Santiago-Freijanes J, Perez C, Rodriguez I, Carril J, Mosquera-Losada MR (2014). Analysis of a silvopastoral system with animals of the autochthonous swine breed Porco Celta in Galicia (NW Spain). 2nd European Agroforestry Conference, Cottbus, Germany.

Rigueiro-Rodríguez A, Santiago-Freijanes JJ, Ferreiro-Domínguez N, González-Hernández MP, Mosquera-Losada MR (2014). Celtic pig production in chestnut extensive systems in Galicia. 2nd European Agroforestry Conference, Cottbus, Germany.

Santiago-Freijanes JJ, Ferreiro-Domínguez N, Rigueiro-Rodríguez A, Mosquera-Losada, MR (2012). Vegetation dynamics under castaneasativa stand grazed with Celtic pigs. 1st European Conference on Agroforestry, Brussels, Belgium.

New approaches to producing selected varieties of chestnut

Meeting the demands for quality chestnuts

www.agforward.eu

Galician chestnut variety ('Negral') micrografted on a hybrid chestnut resistant to "ink disease" (clone 111) at day 25 after grafting. *Ref: Juan Luis Fernández Lorenzo*

Why do we need new systems for the production of chestnut?

Agroforestry with chestnut *(Castanaea sativa Miller)* is a traditional land use system in the eastern part of the Lugo province in Galicia, North West Spain. 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. However, where high slopes make chestnut harvesting unprofitable, pig grazing does occur during the autumn and winter. Chestnut woodlands are also one of the best habitats for the commercial production of edible mushrooms.

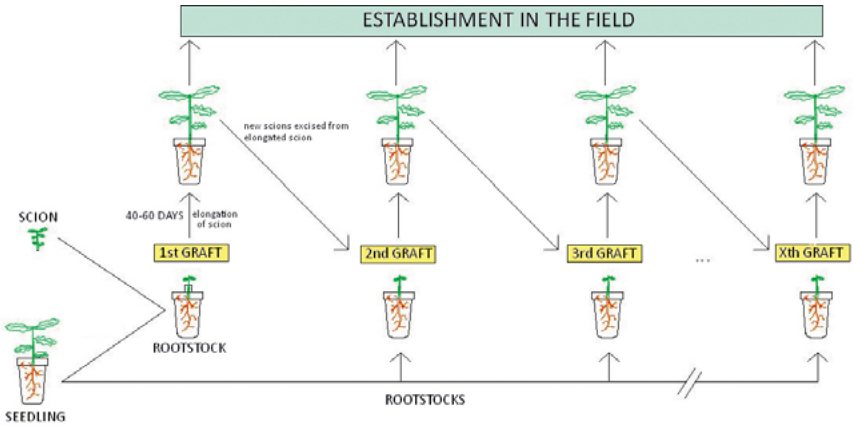
There is an increasing demand from farmers interested in establishing chestnut orchards for commercially attractive varieties. Apart from the environmental benefits of chestnut trees, the profitability of new plantations can be enhanced through understorey management and grazing animals.

The traditional method of grafting varieties on wild chestnut seedlings (used in areas free from ink disease), as well as on hybrids resistant to "ink disease", is inefficient and unable to meet the increasing demand for stock. Varieties grown on their own roots, could potentially avoid the relatively complex process of grafting and help rapid establishment in areas free of "ink disease".

How can the production of quality chestnut be improved?

In vitro culture has an important role to play in developing efficient systems for the production of quality chestnuts. It is an excellent system for early detection of possible incompatibilities. Further, rooting of microcuttings in vitro has a higher rate of success than traditional methods, such as cutting propagation or layering. Aerial grafting in a growth chamber using chestnut seedlings as rootstocks is an alternative method. This method can produce a large number of plants in a significantly shorter time as compared to conventional methods of grafting.

The first step in the process involves the in vitro establishment of suitable hybrid clones to be used as rootstocks and of chestnut varieties. These provide, on the one hand, scions for micrografting and serial grafting and, on the other hand, microcuttings for rooting tests. In parallel, serial grafting on seedlings can provide a constant source of grafted plants for orchards to be established in areas free from "ink disease". Previously grafted plants, maintained in a growth chamber, are the source of new scions in a continuous process of production. In the second step, after a process of acclimatization, micrografted and in vitro self-rooted varieties and plants from serial grafting are established in the field.



Serial grafting in a growth chamber *Ref: Juan Luis Fernández Lorenzo*

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

Advantages

- The use of micrografting permits early detection of possible incompatibilities for specific combinations of hybrid clones and varieties.
- As the process is carried out in sterile (or semi-sterile) conditions, the risks of possible infections derived from the grafting process are minimized.
- The production of grafted plants is much quicker than using conventional methods, and grafting can be done all the year round.
- In varieties showing good rooting ability, production of plants grown on their own roots constitutes a new source of material for planting in areas free from "ink disease".

Variety 'Parede' grafted on seedlings by serial grafting ready for planting in the field. *Ref: Miguel Martínez Cabaleiro*

Juan Luis FERNADEZ-LORENZO, Antonio RIGUEIRO-RODRIGUEZ, Nuria FERREIRO-DOMINGUEZ, Pilar GONZALEZ-HERNANDEZ, Pablo FRAGA-GONTAN, Miguel MARTINEZ-CABALEIRO, María Rosa MOSQUERA-LOSADA
juanluis.fernandez@usc.es
Crop Production and Project Engineering Department. Escuela Politécnica Superior. University of Santiago de Compostela, 27002 Lugo, Spain
www.agforward.eu

November 2017

Grafting of 'Parede' variety on a chestnut seedling in growth chamber. *Ref: Juan Luis Fernández Lorenzo*

In some cases, the introduction and stabilization in vitro of chestnut varieties can take between 1 to 2 years. However, once the material is ready to be used as a source of scions, the process of production of grafted plants is very rapid. The first results show that micrografting success ranges from 40 to 75 %, depending on the variety/hybrid combination. When using wild chestnut seedlings for serial grafting, success is often close to 100 %. The potential for production of grafted chestnuts is extremely high: grafting cycles of 60 days and an average yield of 4 scions per cycle allow a grower to obtain more than 106 grafted plants from one single initial scion after 20 months under growth chamber conditions. In any case, for seedlings to be available for use as rootstocks throughout the year, there is a need for suitable preservation systems for chestnut seeds.

Plants from some varieties, such as "Loura" and "Parede", have been successfully produced from microcuttings, but their performance in the field is not yet known. Field tests of all these materials will identify possible longer term problems, such as delayed incompatibility when using hybrid rootstocks,to reveal. Tests will also reveal whether the low height of the grafting point in micrografting, which will be very near to the soil, could have any influence on the risk of infection by *Phytophthora spp.* which causes "ink disease".

Further information

Cáceres Y, Pulido FJ, Moreno G (2017). Regeneración artificial en dehesas con diferente manejo de ganado: evaluación de la eficiencia y optimización del costo. 7º Congreso Forestal Español, Plasencia, Spain. http://7cfe.congresoforestal.es/sites/default/files/actas/7CFE01-334.pdf

Moreno G, Franco ML (2013). Efecto diferencial de la jara (*Cistus ladanifer*) en la supervivencia de plántulas emergidas y plantadas de encina (*Quercus ilex*). 6º Congreso Forestal Español, June 2013, Vitoria, Spain http://secforestales.org/publicaciones/index.php/congresos/article/viewFile/10451/10355

Pulido F, Alonso S, Castaño FM, Cáceres Y, Moreno G (2016). Can rodent acorn dispersal be manipulated to promote tree regeneration? A test using woody debris as shelter for dispersers and seedlings in grazed oak woodlands. World Congress Silvo-Pastoral Systems (Évora, Portugal).

Rolo V, Plieninger T, Moreno, G (2013). Facilitation of holm oak recruitment through two contrasted shrubs species in Mediterranean grazed woodlands. Journal of Vegetation Science, 24(2): 344-355.

Wild asparagus in olive orchards

Get more income from your orchard

www.agforward.eu

Asparagus in traditional olive grove

Why plant asparagus?

High yielding olive trees need plenty of light and need to be spaced apart. Hence both traditional and super-high-density orchards intercept no more than 50-55% of the sunlight. The rest will fall on the ground and encourage weeds. Why, then, not plant another crop you can sell under the trees, to use that light?

The understorey crop must be adapted to shade. One possible crop is wild asparagus (*Asparagus acutifolius*) which is a culinary speciality in the Mediterranean. The spears can be harvested and sold in local markets. Growing under the trees, the asparagus does not affect the olive yield, while producing an additional crop.

Wild asparagus in super high density olive orchard with plastic mulch

Where and how to plant?

Wild asparagus is a long-lived perennial plant that does not require annual tilling and this means that the olive orchard can be managed with no-till, permanent green cover. Wild asparagus is hardy and tolerates drought, winter cold and rocky soils. Therefore if the growing conditions are right for the olive, the wild asparagus can also thrive.

Few nurseries produce wild asparagus plants, but plants can be produced from seed. Seed can be obtained from the fruits gathered from wild asparagus in the autumn. After harvest, the black and shiny seeds must be stratified[1] in moist sand. Depending on the origin of the seeds it can take up to one year for germination to occur. The seedlings can then be transplanted into containers where they can be grown for another year before transplanting in the field.

Young asparagus plants can be transplanted along rows of olive trees leaving the inter-row free to allow the use of machinery for olive pruning and harvesting. If planting only in the tree rows, the wild asparagus plants are typically planted at about 33 cm spacing along the row. This provides about 4000 to 5000 asparagus plants per hectare. Alternatively if the olives are manually harvested, the asparagus can also be planted in the inter-row area. In this case the wild asparagus can be planted at 33 cm spacing within 1 m rows. This results in about 30000 plants per hectare.

Wild asparagus seeds (left) and fruits (right)

[1] Stratification is the process of putting alternating thin layers of seeds with layers of moist sand in a container with adequate drainage at the bottom. This is usually done outdoors so that the seeds are subjected to the winter cold followed by warm spring temperatures to break seed dormancy.

AGFORWARD Agroforestry for Europe

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

Advantages

Producing a second crop of wild asparagus under olive trees increases the productivity per unit of land, whilst requiring few additional inputs.

The process of weeding, fertilizing and possibly irrigating the asparagus can benefit the olive trees without additional costs.

With increasing volatility in the market prices for olive oil and the uncertainty associated with climate change, crop diversification can protect farmers from extreme crop failures. It is unlikely that both crops will completely fail in the same year.

Asparagus in traditional olive orchard with straw mulch

Adolfo ROSATI
adolfo.rosati@crea.gov.it
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA)
www.agforward.eu

November 2017

This leaflet is produced as part of the AGFORWARD project.

Yields of asparagus

A mature plant of wild asparagus will produce 50-100 g of harvestable spears each spring (March to May depending on local climate). With 5000 plants per hectare (transplanting only along tree rows), the yield can be 250-500 kg per hectare, starting from the second or third year after planting. With 30000 plants per hectare (transplanting in rows 1 m apart also in the olive inter-row space) the yield can be 1500-3000 kg per hectare.

A wild asparagus spear ready for harvest

Disease, pests and weeds

As a wild (non-selected) species, currently wild asparagus suffers from few pests and diseases. Hence it can be grown as an organic crop. However the asparagus beetle can cause some damage, but rarely needs treatment. Weeds can be controlled by carefully managing grazing animals, such as poultry or sheep.

Labour, harvesting and marketing

Wild asparagus cultivation is unlikely to interfere with olive pruning and harvesting, if the olive harvest is carried out by hand or using vibrating combs. The use of harvest "umbrella frames" is particularly suitable since the net is held above the asparagus vegetation.

Wild asparagus is a hardy crop, but it requires high levels of hand-labour particularly to harvest the asparagus spears and to control weeds. Hence although integrating olive trees and asparagus will increase the yield per unit of land, it will also increase the need for labour.

Asparagus spears can fetch high prices in local markets. However, marketing fresh and perishable produce is a difficult task that needs to be carefully evaluated.

Further information

Benincasa P, Tei F, Rosati A (2007). Plant density and genotype effects on wild asparagus (*Aspara gus acutifolius L.*) spear yield and quality. HortScience 42(5):1163–1166.

Rosati A, Concezzi L, Dal Bosco A, Mugnai C, Paoletti A (2012). Video related to the results of a project on Olive, chickens and wild asparagus: www.youtube.com/watch?v=ALw73WwU-r2o/

Rosati A, Castellini C, Dal Bosco A, Mugnai C, Paoletti, A (2012). Manuale per la coltivazione consociata olivo, asparago selvatico, pollo rustico. Edizioni 3A-PTA. Researchgate: 10.13140/RG.2.1.3665.4805.

Rosati A. (2014). Coltivare asparagi selvatici e allevare polli in un piccolo oliveto. Vita in Campagna, 12: 44-48.

Olive trees intercropped with chickpeas

Increasing income from your olive grove

www.agforward.eu

Olives intercropped by chickpeas *Ref : A. Pantera*

Why chickpeas?

Chickpeas (*Cicer arietinum L.*) are valued as a high quality food for humans. They are also an excellent source of protein for animal feed. They are easy to cultivate, requiring little management and, in general, have low treatment costs. They have high monetary value, so a farmer can gain considerable additional income from cultivating chickpeas among trees.

One of the important characteristics of chickpeas is their low water demand. This makes them ideal for intercropping with trees of similar water economy in Mediterranean and other dry ecosystems.

Another important feature of chickpeas is the nitrogen they provide to the soil by the symbiotic relationship of their roots with nitrogen fixing bacteria. This benefits the farmer by reducing the need for expenditure on nitrogen fertilizers, which also protects the soil and water from nitrogen contamination.

Olive production was similar in the plots of mineral fertilization to those intercropped with chickpeas
Ref : Dimitris Kitsikopoulos

Where and how to plant

A trial was conducted in Molos, Central Greece, in a 67 year-old olive grove of "Kalamon" and "Amphissa" varieties. Tree spacing between the trees was 10m. The trial involved three treatments with three replications: olive trees + chickpea, olive trees + oregano and olive trees alone as a control.

A 0.2 ha area was cultivated with chickpeas and a smaller one with oregano. Another 0.2 ha of the orchards contained olive trees and other tree species and the rest only olive trees. This was used as control. The rows where chickpeas were cultivated were 5 m x 60 m wide. A local variety of chickpeas named "Amorgos" was used. This variety was developed by the Hellenic Research Institute and is resistant to fungus infections. The seed quantities were 80 kg/ha. In 2015, crop sowing was delayed until the first week of April due to the wet spring period. Oregano was sown in spring of 2016. The trial was repeated over three years (2015, 2016 and 2017).

The best timing for seeding is between late February and March for lower altitudes. However, at higher altitudes, it can be sown up to late April.

Olive production is expected to be high in the intercropped plots in 2017. *Ref : A. Pantera*

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

Advantages

Pruned branches can be used as fodder and, when the trees have matured, as fuel wood.

Olives and olive oil are traditional products with high economic value. Additional products, such as olive paste, can be produced and sold separately.

Olive trees can reduce local wind speed and protect soils from erosion. The chickpeas contribute to soil nitrogen content and reduce the need for chemical fertilizers. Consequently, they also contribute to reducing chemical contamination in soil and water, such as nitrification.

Chickpeas are sold at the shop of the farmer, contributing additional income
Ref : D. Kitsikopoulos

Anastasia PANTERA
pantera@teiste.gr
Aristotle University of Thessaloniki, Greece
www.agforward.eu

November 2017

Olive oil, edible olives and chickpeas production

In 2015, olive production was low on the farm in Molos due to the unfavourable weather conditions during the blossoming stage. The yield from the olive trees was effectively the same in the olives and chickpeas treatment (which received no fertilizer) and the control olive treatment which received N fertilization.

The level of chickpea production was also very low. Although germination reached approximately 90%, the rain during the spring affected flowering, and there were additional losses due to rodent damage.

However, in 2016, the yield of the chickpeas was very successful with production reaching 2600 kg/ha. Oil production and quality was excellent and it was the same for edible olives. Similar results were reported in another olive grove where the experiment was repeated. Here the farmer reported being pleased with the results: saving money from reduced fertilizer applications, and also earning income from the production of organic chickpeas.

Other species for intercropping: Oregano

Oregano did not do well, but this is maybe due to the late date of establishment and the limited water it received after planting. The plants that survived the first year after establishment are now doing well, but there are too few to draw clear conclusions.

Conclusion

In short, intercropping chickpeas saves money from fertilizer cost but also protects the environment from soil contamination caused by leaching nutrients from fertilizers. It is a win-win situation!

Further information

Duarte F, Jones N, Fleskens L (2008). Traditional olive orchards on sloping land: Sustainability or abandonment? Journal of Environmental Management 89(2): 86-98.
Pantera A (2014). Initial Stakeholder Meeting Report: Intercropping of olive groves in Greece http://agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html?file=files/agforward/documents/WP3_GR_olives_Molos.pdf
Papanastasis VP, Mantzanas K, Dini-Papanastasi O, Ispikoudis I (2009). Traditional agroforestry systems and their evolution in Greece. Agroforestry in Europe. Advances in Agroforestry 6: 89-109.
Vossen P (2007). Olive oil: history, production, and characteristics of the world's classic oils. HortScience 42(5): 1093-1100.

Olive trees intercropped with cereals and legumes

A new development for a traditional system
www.agforward.eu

Traditional land use system

Olive (*Olea europea*) is the most widespread cultivated tree in Greece (Schultz et al. 1987). Olive trees alone, or in orchards, are found in all parts of the country that have a mild Mediterranean climate. The olive tree is considered to be one of the least demanding cultivated trees in terms of soil nutrients. For this reason, it is planted in poor, rocky areas with soils mostly derived from hard limestone. In traditional systems, practically all olive trees came from wild plants which were grafted. Edible olives and olive oil are the main products of olive trees, while secondary products include fodder for animals and firewood.

Olive trees intercropped with barley in spring
Ref : Mantzanas 2016

Olive trees intercropped with a mixture of barley and common vetch *Ref : Mantzanas 2015*

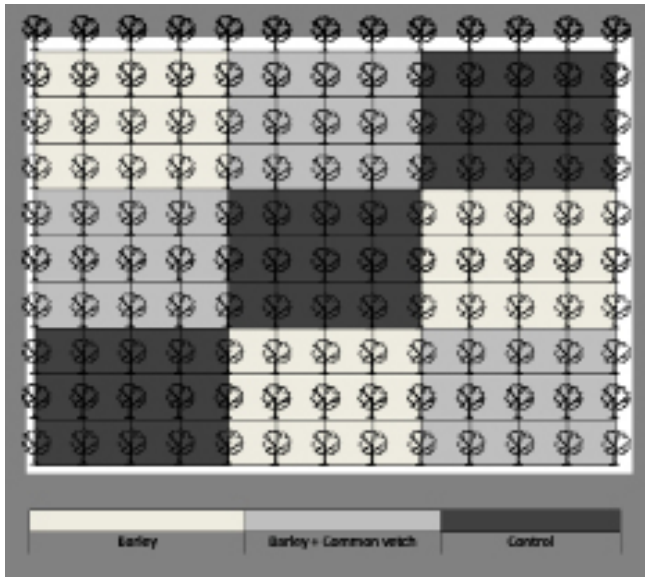
Cropping among trees

A stakeholder group from Kassandreia, Chalkidiki, identified examples of interesting and best practices that involved the intercropping of olive trees and leguminous crops for animal feed and soil amelioration, and/or cereals for grain production (Pantera 2014).

Intercropping can help protect a farmer's income against financial losses due to variable weather conditions. Intercropping is not a new practice, and was widely practised before olive tree orchards were converted to monoculture systems. In order to progress with the initial idea for the olive tree system of Chalkidiki, it was decided to explore the key features of this kind of intercropping system.

System establishment

A controlled experiment was established in the premises of the State Rural Prison in Kassandra Chalkidiki, in December of 2014. It comprised three treatments (olive trees + barley, olive trees + a mixture of barley and common vetch and, as a control, olive trees alone) in three replications in a latin square design. The mixture was harvested for hay and the barley for grain.



The latin square design of the Kassandra experimental area
Ref : Mantzanas 2014

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

Advantages

The intercropping of olive trees and leguminous crops for animal feed and soil amelioration or cereals for grain production could be a valuable addition to the system. It provides new products such as hay and grain for animals, and offers environmental benefits, such as increased biodiversity and soil conservation.

The three year trial demonstrated an impressive growth of olive trees, and higher production of olives to that previously attained.

Impressive growth of the mixture (common vetch + barley) during the spring of second year *Ref : Mantzanas 2016*

Crop yield

The preliminary results for total biomass show that there was no significant difference between the total biomass averages of the samples taken close to the tree or far from the tree. This suggests that the accumulation of the biomass is unaffected by the position relative to the tree. The number of seeds was higher in the samples harvested near the tree, so the tree could have a positive effect on the formation of seeds. Total hay and seed production were higher in the second and third years of the experiment.

Further information

Pantera A (2014). Initial Stakeholder Report – Intercropping of olive groves in Greece. TEI Stereas Elladas, Greece

Schultz AM, Papanastasis VP, Katelman., Tsiouvaras C, Kandrelis S, Nastis A (1987). Agroforestry in Greece. Aristotle University of Thessaloniki, Thessaloniki, Greece

Konstantinos MANTZANAS
konman@for.auth.gr
Aristotle University of Thessaloniki, Greece
www.agforward.eu

November 2017

Orange trees intercropped with legumes

Increasing income from your orange orchard

www.agforward.eu

Orange trees intercropped with vegetables *Ref : Anastasia Pantera*

Why intercropping?

Market-focused farmers manage orange tree (*Citrus sinensis*) varieties by pollarding and crafting. This procedure can take up to 15 years for the tree to reach maturity and attain maximum fruit yields. In the meantime, farmers can take advantage of the wide and open space created by the pollarding, to produce a variety of vegetables and raise a further income to supplement that earned from the orange trees.

Why chickpeas?

Chickpeas (*Cicerarietinum L.*) are valued as a high quality food for humans. They are also an excellent source of protein for animal feed. They are easy to cultivate, requiring little management and, in general, have low treatment costs. They have high monetary value, so a farmer can gain considerable additional income from cultivating chickpeas among trees.

One of the important characteristics of chickpeas is their low water demand. This makes them ideal for intercropping with trees of similar water economy in Mediterranean and other dry ecosystems. Another important feature of chickpeas is the nitrogen they provide to the soil by the symbiotic relationship of their roots with nitrogen fixing bacteria. This benefits the farmer by reducing the need for expenditure on nitrogen fertilizers, which also protects the soil and water from nitrogen contamination.

Where and how to plant

Between 2015-2016, a trial was conducted in Skine, Crete, in an 80 year-old "Valencia" orange grove to investigate the interaction of orange trees with chickpeas. Tree spacing between the trees was 10 m. It involved two treatments. One 0.1 ha area of the grove was cultivated by chickpeas. Another 0.1 ha of the orchard, without chickpeas, was used as a control. The chickpeas were cultivated in 8 m wide rows. The seed quantities were 80 kg/ha. We used a local variety of chickpea named "Amorgos", which was developed by the National Agricultural Research Foundation. It is resistant to fungal infections.

The best time for sowing is between late February and March for lower altitudes. However, at higher altitudes, it can be sown up to late April.

Chickpeas production provide additional income to the farmer whilst enhancing soil nitrogen in an eco-friendly way *Ref : Anastasia Pantera*

There are many compatible crops that can be chosen for intercropping with orange trees. *Ref : Anastasia Pantera*

AGFORWARD Agroforestry for Europe

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

Advantages

- The system can produce orange fruits and orange juice.
- Additional products, such as liqueurs, sweets, marmalades, and dried oranges can be produced and sold separately.
- Orange extracts are used in the pharmaceutical and fragrance sectors, as well as in cooking.
- The chickpeas contribute to soil nitrogen content and reduce the need for chemical fertilizers. Consequently, they can contribute to reducing chemical contamination of soil and soil water (e.g. nitrification).
- The trees reduce local wind speed and protect soils from erosion.
- Pruned branches can be used as fodder and, when the trees have matured, as fuel wood.

Above: Chickpeas can be a profitable choice for the farmer *Ref : Maria Mitsou.*
Below: Once the crown is fully developed, interplanting is no longer possible *Ref : Anastasia Pantera*

Oranges and chickpeas production

In 2015, orange production met the farmer's expectations. The yield from the orange tree was effectively the same in the orange and chickpeas treatment (which received no fertilizer) and in the control orange treatment (which received N fertilizer). The level of chickpea production was poor as low rainfall during the spring affected flowering. In 2016, even though the establishment and yield of the chickpeas was very successful the farmer decided to cultivate the field and incorporate the chickpeas for soil amelioration.

Conclusion

In short, intercropping chickpeas saves money from fertilizer cost but also protects the environment from soil contamination caused by leaching nutrients from fertilizers.

Further information

ELSTAT (2015). Annual Agricultural Statistical Survey of year 2012. Hellenic Statistical Authority, http://www.statistics.gr/en/statistics/agr, visited at 1/16/2016

Fortier S (1940). Orchard Irrigation, USDA Farmer's Bulletin No. 1518

Pantera A (2014). Initial Stakeholder Meeting Report Intercropping of Orange Groves in Greece. 18 November 2014. 7 pp. Available online: http://www.agforward.eu/index.php/en/intercropping-of-orange-groves-in-greece.html

Wheaton TA, Whitney JD, Castle WS, Muraro RP, Browning HW, and Tucker DPH (1995). Citrus Scion and Rootstock, Topping Height, and Tree Spacing Affect Tree Size, Yield, Fruit Quality, and Economic Return. J. Amer. Soc. Hort. Sci. 120(5):861-870.

Anastasia PANTERA
pantera@teiste.gr
TEI StereasElladas, Department of Forestry & N.E.M., 36100 Karpenissi, Greece
www.agforward.eu

November 2017

Apple orchards grazed in France

Increasing the profit from your orchard

www.agforward.eu

Apple grazed orchards in France *Ref : N. Corroyer*

Why graze orchards with sheep?

- Sheep can reduce the cost of grass mowing in orchards
- Sheep can promote nutrient retention and cycling within the orchard
- Sheep can eat fallen leaves (a refuge for apple scab spores) and fruits (a refuge for pests such as sawfly and-codling moth) which should result in reduced need for pesticide applications
- Sheep could reduce vole populations (which can damage trees)
- Grass can be used to maintain ewes or fatten lambs, which can increase farm income

Sheep grazing apple orchards in April 2015
Ref : N. Corroyer

How do you manage a grazing apple orchard?

- Selection of sheep breeds: preference should be given to lowland sheep breeds, such as Shropshire, with behavioural characteristics that minimise tree damage.
- It is important to regularly monitor grass height and sheep behaviour to minimise the sheep grazing the trees. The sheep should be removed immediately if there is evidence of significant tree damage.
- Fencing is needed to keep sheep in the orchard.
- When spraying with organic products, sheep can be moved to another part of the orchard during spraying.
- Sheep must be removed from the orchard before apple harvest to avoid possible contamination of the fruit by the faeces. Hence the sheep need access to another pasture plot in addition to the orchard.

Sheep grazing in July 2016

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

Advantages

Does grazing reduce apple scab infection?
Grazing in orchards could reduce apple scab infections, but the two year study in Normandie needs to be continued to determine the response.

Does grazing reduce vole populations?
Grazing in orchards appear to reduce the number of voles holes in the soil, but the long-term response still needs to be determined.

Impact of sheep on trees: attacked branches up to a height of 1 m *Ref : N. Corroyer*

Nathalie CORROYER
nathalie.corroyer@normandie.cham-bagri.fr
Chambre d'agriculture de Seine-Maritime - *Cité de l'agriculture chemin de la Bretèque - CS 30059*
76232 BOIS GUILLAUME CEDEX
www.agforward.eu

November 2017

Sheep grazing in orchards need to be well organized and continuously monitored

Based on our experiments, it was found that:

Grass management

- Results from Normandie in 2016 indicate that a density of more than 4 ewes/ha is needed to maintain the low sward height required for apple harvest.
- A stocking rate of four ewes per hectare in 2016 reduced the need for mowing the grass sward below the apple trees from four cuts to two cuts.

Value of sheep

- In the case study, the focus was on the maintenance of ewes. In other systems, the orchard may be stocked with fattening lambs which may provide additional income.

Apple yields

- A lack of management, in 2016, led to sheep removing pieces of bark from 30% of the apple trees. There was no long-term damage to the trees in 2017 as a paste [badigeon in French] was applied to areas of damage.
- In 2016, grazing by sheep was estimated to cause a 5% reduction in the number of flowers and apple fruits.
- There was less scab inoculum in the grazed, rather than the ungrazed, orchard in 2016 after two years of grazing. In 2017 there was no scab in both the grazed and ungrazed plots which received the same sprays as indicated by the RimPro decision support software.
- No sawflies were observed in either plot in 2016, when Rebell® traps were used.
- There was a slight increase in the potassium and phosphorus content of apples leaves in the plot with sheep, possibly due to additional fertilization.
- The number of soil holes formed by voles was greater in the ungrazed than the grazed plots in 2017. There were half the number of vole holes in the ground in the plot with sheep, compared to ungrazed areas, in 2016.

Further information

Corroyer N, Upson M (2015). Research and Development protocol for Grazed Orchards in France. Available at: http://www.agforward.eu/index.php/en/grazed-orchards-in-france.html

CTPC (1993). Culture du Pommier à Cidre. Librarire Agricole de la Maison Rustique, 24pp.

Economic benefits of grazed apple orchards in England

Grazing under half-standard or standard trees
www.agforward.eu

Shropshire ewes and lambs in a traditional cider apple orchard in Herefordshire, England (March 2017)

Why graze orchards with sheep?

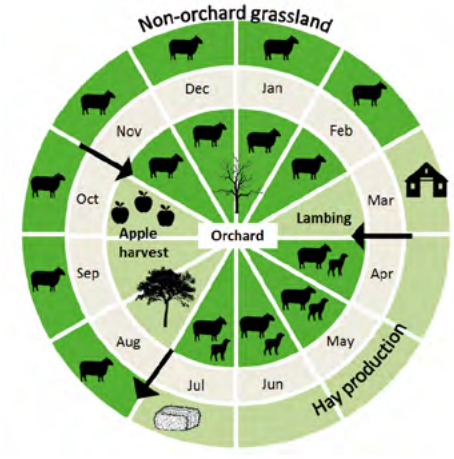
Orchard grazing can offer financial and environmental benefits. The experience of stakeholders in the AGFORWARD project is that some lowland sheep breeds (e.g. Shropshire) can successfully graze on orchards which have been pruned to a height of 1-2 m without noticeable losses in apple yields. Sheep producers can profit from an additional source of grass in the orchards, and the release of grazed land for hay production. Orchard owners can profit from reduced mowing costs, increased nitrogen cycling and a rent from the sheep owner. There can also be societal benefits in terms of employment and plant biodiversity.

Electric fencing was used in the trial to separate the grazed and ungrazed parts of the orchard.

Cider apple orchards and sheep

Cider apple orchards have significant economic, biodiversity, and societal benefits. (Robertson et al. 2012) Cider apples are sold for their juice rather than their appearance and therefore the pesticide regime can be less intensive than that required for dessert apples.This reduction in agrochemical use provides opportunities for integrating sheep. In the UK, about a third of the cider apple orchards are comprised of "standard" or "half-standard" trees, which have been pruned to a height of 2 m and 1-2 m respectively. This pruning allows the yields from apple trees to be maintained when the grass understorey is grazed by "tree-friendly" sheep. In England, orchard owners commonly use Shropshire sheep because, if managed correctly, they cause minimal levels of bark damage.

A key feature of grazed orchard systems is that it is necessary for the sheep to be absent from the orchard for 60 days before apple harvest (generally from August to October) to minimise faecal contamination of the fruit. Hence, a sheep producer must have access to separate non-orchard grassland where the sheep can be kept at this time. Thus, a grazed orchard system involves sheep, apple trees, the grass understorey, and an area of separate non-orchard grasslandfor supplementary grazing.



Annual cycle of sheep production showing the location ■ and movement ← of sheep between an orchard (inner circle) and an area of non-orchard grassland (outer circle). Sheep must be absent from the orchard for 60 days before apple harvest, and need to be kept on the non-orchard grassland at this time. The sheep may use both the orchard and non-orchard grassland from November to February before being housed indoors for lambing. In April, the ewes and lambs can use the orchard until August and the grassland area can be used for hay production. The cycle then starts again.

AGFORWARD Agroforestry for Europe

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

Advantages

- For orchard owners: sheep in orchards can reduce mowing costs and land rents can provide another source of income
- Sheep grazing can also increase nitrogen recycling within the orchard and could reduce orchard fertilisation costs.
- For a sheep farmer: apple orchards provide additional grass and thereby an opportunity to use other grass fields for hay or silage production

Apple orchard with electric fencing

Paul BURGESS
with Francesca CHINERY, George ERIKSSON, Erica PERSHAGEN, Cristina PÉREZ-CASENAVE, and Michail GIANNITSOPOULOS
P.Burgess@cranfield.ac.uk
Cranfield University, Bedfordshire, MK43 0AL, UK
www.agforward.eu

November 2017

Assessment of financial benefits

The gross margin of separately managing a cider apple orchard and a grass field with 10 sheep was compared with a grazed orchard system. The analysis assumes that both the grazing land and orchard land are available on the same farm. Although the actual margins depend on the assumptions made, the table below highlights some key considerations. The grazed orchard analysis assumed that sheep had no effect on the yield or quality of the cider apples, but the reduction in grass mowing from three to one increased the apple gross margin by €55 (€560 rather than €505). The gross margin from sheep production was assumed to be the same (€365), except for the need to make the orchard stock proof (-€65) and the increased transportation of sheep (-€45). The greatest benefit from grazing the orchard (April to July) was that the non-orchard grass area could be used to produce a valuable crop of hay (+€290). Overall the grazed orchard system increased the margin from €870 to €1105, a benefit of €235.

	Ungrazed orchard and grass field managed separately	Grazed orchard and grass field managed together
Apple gross margin	€505	€560
Sheep gross margin	€365	€365
Stock-proofing the orchard		-€65
Increased sheep movement cost		-€45
Hay production gross margin		€290
Overall gross margin for 2 ha	**€870**	**€1105**

Indicative annual gross margins for the separate management of 1 ha of cider apple trees and a 1 ha grassland area with 10 sheep compared to those for 1 ha of a grazed orchard with a 1 ha grassland area. Values are based on the assumption that £1 is equivalent to €1.1. (Burgess et al. 2017)

Opportunity for joint agreements

It is also possible to construct arrangements where orchard grazing provides a profit for both the orchard owner and the sheep farmer. However, the maximisation of the financial benefit in such agreements requires the minimisation of contract and transport costs.

Further information

Robertson H, Marshall D, Slingsby E, Newman G (2012). Economic, biodiversity, resource protection and social values of orchards: a study of six orchards by the Herefordshire Orchards Community Evaluation Project. Natural England Commissioned Reports, Number 090.

Shropshire Sheep Breeders' Association (2008). Two Crops from One Acre: A Comprehensive Guide to using Shropshire Sheep for Grazing Tree Plantations.

Burgess PJ, Chinery F, Eriksson G, Pershagen E, Pérez-Casenave C, Lopez Bernal A, Upson A, Garcia de Jalon S, Giannitsopoulos M, Graves A (2017). Lessons learnt – Grazed orchards in England and Wales. AGFORWARD project. 21 pp.

Key challenges of orchard grazing

Issues to consider before introducing sheep
www.agforward.eu

Why should you plan carefully?

The potential benefits from grazing apple orchards with sheep include a reduction in mowing costs and an additional source of grass for the sheep. The sheep can promote nutrient cycling and can benefit from the shelter in winter.

However, introducing sheep to an orchard is not suitable in all cases and sometimes it is the wrong thing to do. This leaflet describes some of the issues to consider before introducing sheep.

The low branches of bush apple trees are susceptible to grazing damage

Sheep grazing a bush apple orchard in Northern Ireland. *Ref: F. Ward*

What should be considered?

Four things to consider in the management of a grazed orchard system are:

i) market for the apples
ii) apple tree structure
iii) sheep breed
iv) manager

A successful grazed orchard system requires each of these components to be correct.

Market for the apples: because the quality requirements for dessert apples are typically higher than for cider apples, dessert apples often receive high levels of agrochemicals to control pests and diseases. Each time the apples are sprayed, it is necessary to restrict the movement of the sheep; hence grazing management can be more difficult with dessert, rather than cider, apple production.

Apple tree structure: apple growth can be managed to vary the height from the ground to the lowest leaves in the canopy. The traditional way of managing apples was to create "standard" trees so that there were no side branches on the lowest 2 m of the trunks. A "half-standard" tree has a trunk of 1-2 m high, and the branch-free trunks of a "bush"apple tree can be less than 1 m tall (Robertson et al. 2012).

Sheep breed: the behaviour of sheep breeds can vary substantially. Some lowland breeds are relatively sedentary whereas some upland breeds can behave like goats, readily getting up on their two hind legs to reach browse. Selecting the appropriate sheep breed and stocking rate can be important to minimise tree damage.

Manager: a successful grazed orchard system requires a manager or a management arrangement that pays attention to the health of the apple trees and the daily monitoring of the sheep and the availability of grass. Successful management of such complex integrated systems can be labour and knowledge intensive.

AGFORWARD Agroforestry for Europe

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

Advantages

The grazing of apple orchards with sheep can be successful providing financial and environmental benefits. However, the introduction of the wrong sheep breed in low-canopy apple orchards can also cause long term economic damage. Hence careful planning is needed.

Sheep can damage the bark below a height of about 1.2 m

Jim McADAM
jim.mcadam@afbini.gov.uk
Agri Food and Biosciences Institute and Queens University of Belfast Newforge Lane, Belfast BT95PX N. Ireland
www.agforward.eu

November 2017

Grazing a bush apple orchard

A replicated experiment was established in Northern Ireland to determine the effect of sheep grazing on a "bush" orchard planted in 1998.

Apple trees: there were cider apple (Coet-de-linge) and dessert apple (Jonagold) plots each split into a grazing or mowing treatment. Before grazing, the lowest leaves in the canopy were 76cm above the ground.

Sheep: the sheep were a mix of breeds including Texel, Belclare, LLeyn and Highlander. These sheep breeds were not specifically selected to minimise tree damage.

The stocking rate was set at 3-5 sheep per 0.33-0.42 hectares (i.e. 7-15 sheep per hectare) for 50-57 grazing days from April to mid-June.

Effect on apple yield

Sheep grazing in the bush apple orchard increased the height of the lowest part of leaf canopy to 109 cm. There was a 24% reduction in the apple yield of the cider apple variety Coet-de-linge and a 43% reduction in the apple yield of the dessert variety Jonagold over 2015 and 2016. Whilst there was no damage from mechanical mowing, grazing caused damage to trees in the following ways:

- Sheep fleeces caught in the trees caused damage to small branches and twigs.
- Sheep ate all buds and leaves on the apple trees below a height of about 115 cm.
- Even with ample grass, large areas of bark from the tree trunks and lower limbs were removed by the sheep.

Experimental bush apple orchard plots in Northern Ireland before grazing

Further information

McAdam J, Ward F (2016). System report: Grazed Orchards in Northern Ireland. http://www.agforward.eu/index.php/en/grazed-orchards-in-northern-ireland-uk.html

Robertson H, Marshall D, Slingsby E, Newman G (2012). Economic, biodiversity, resource protection and social values of orchards: a study of six orchards by the Herefordshire Orchards Community Evaluation Project. Natural England Commissioned Reports, Number 090. http://publications.naturalengland.org.uk/publication/1289011

Farming with pollards

A productive way of pruning
www.agforward.eu

Fuel-wood from pollarded ash trees *Ref : D. Mansion*

Why pollard trees?

Pollarding trees optimises renewable biomass production and facilitates local production of firewood, ramial chipped wood (RCW), lumber and fodder. Harvest occurs over decades, depending on the chosen frequency of pruning and utilization. Many tree varieties can be pollarded to provide a range of products. Pollarded trees have an increased lifespan. As their growth is limited, they better resist wind and drought, and this may be of particular benefit in global warming conditions. Old pollards use compartmentation to ensure living cells are protected from diseases and dead cells in the middle of the trunk. The tree trunks, and even the roots, are also great biodiversity habitats for flora and fauna.

Where and how to pollard trees

Pollarding trees is a traditional and widespread practice found throughout the world. The technique involves reducing the height of the tree without reducing the tree bole. Pruning can be done every 6 to 15 years depending on the tree growth.

Pruning is best done with a chainsaw when there is no sap rise, and as soon as the tree reaches the desired block height. It is often done in winter. However, pollarding can also be carried out in summer in order to provide fresh fodder to cattle when there is drought and grass shortage. Pollards have a longer vegetation growing season, and for three years after pollarding can produce juvenile leaves late in the season, wich are richer in nitrogen and more edible than that available from non-pollarded trees. Harvested leaves can be dried to provide fodder throughout winter. Larger branches can be processed into logs and smaller ones can be crushed to produce RCW or chips, to be used as mulch or as litter for livestock farming.

Sheep like to eat the leaves of ash trees
Ref : P. Van Lerberghe

Ramial chipped wood is produced by crushing pollards branches *Ref : D. Mansion*

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

Advantages

Non-pollarded trees can only be harvested once after decades of growth. By contrast, pollarded trees can be harvested regularly over a prolonged period resulting in a range of economic products. This increases the resilience and stability of the system. Bulky trees can be pollarded instead of being cut down or removed. This same technique provides an opportunity to maintain a high number of trees by optimising space, as is the case with living hedges made of short pollards. This agroforestry system minimizes light competition from the tree and can alter the seasonal distribution of leaf growth

An old ash tree can produce up to 4 m³ of logs
Ref: P. Van Lerberghe

Juliette COLIN[1], Philippe VAN LERBERGHE[2], Fabien BALAGUER[1]
fabien.balaguer@agroforesterie.fr
[1]French Agroforestry Association (AFAF)
[2]Institute for Forestry Development (IDF)
www.agforward.eu

November 2017

Large pollards of fast growing trees, such as willows or ash trees, can produce up to 90 kg of fresh branch biomass over the year following pruning. Branch woody biomass production is often far higher than trunk biomass production (between 5 to 20 times higher). A study showed that over a production cycle of 100 years, pollarded ash trees can produce between 1300 to 1700 kg of dry biomass (i.e. trunk and branches). Pollard biomass productivity depends on the tree species and its suitability to the environment, the health of the tree stand, and the maintenance regime. Labour demands can be fairly limited.

On the basis of the market demand for RCW along (around 50€ per cubic metre in 2017 in some regions of France) pollarding can be profitable although this depends on the location of the pollards, the availability of wood chippers and the available labour force. It is also important to recognise their value in terms of biodiversity and cultural ecosystem services.

Studies have been made on wood chips used as cattle litter. The first results are very positive, and show that dried wood chips can reduce disease levels over winter. They are stable and very absorbent (1 m³ absorbs about 350 litters of urine), and their use can lead to a reduction in incidences of mastitis and lameness. No case of intestinal occlusion or respiratory complications was reported. Owners of wood chip can use this to replace straw litter, which is an important in zones with limited straw resources. Used wood chip litter provides a very good compost similar to humus.

Further information

Mansion D (2015). Les trognes: L'arbre paysan aux milles usages (Editions OUEST-FRANCE).

Serre B (2012). Litière en plaquettes de bois La litière. Chambre d'Agriculture du Cantal.