Agroforestry for High Value Trees: Synthesis of System Descriptions

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Contents

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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.

Full details of the project can be found on the project website: www.agforward.eu

The second objective is being addressed by four participative development and research networks (PDRN) focused on specific types of agroforestry. One of the networks is focusing on agroforestry with high value trees i.e. trees which provide an annual yield through fruit, olive or nut production, or trees that produce particularly high value timber. Den Herder et al (2016) made an estimate of the area of agroforestry in the EU27 involving fruit, olive, and nut trees (Note that this estimate does not involve high value timber trees like walnut). They calculated that agroforestry involving fruit, olive and nut trees covered about 1.05 million hectares corresponding to about 0.2% of the territorial area in the EU. 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 (2016) 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 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.

The first objective has been completed and the key challenges and innovations identified by 10 stakeholder groups were reported in 2014. 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 (Table 1). This report represents a summary of the components, structure, ecosystems services, and economic value of selected systems and therefore addresses the second objective.

Table 1. Ten system reports focused on agroforestry for high value trees which provide the basis for this report.

Burgess PJ, Upson M, Graves A, Garcia de Jalon S (2016). System Report: Grazed Orchards in England and Wales. April 2016. 23 pp. http://www.agforward.eu/index.php/en/Grazed_Orchards.html

Corroyer N (2016). System Report: Grazed Orchards in France. January 2016. 15 pp. http://www.agforward.eu/index.php/en/grazed-orchards-in-france.html

McAdam J, Ward, F (2015). System Report: Grazed Orchards in Northern Ireland. November 2015. 12 pp. http://www.agforward.eu/index.php/en/grazed-orchards-in-northern-ireland-uk.html

Moreno G, López-Díaz ML, Bertomeu García M (2015). System Report: Silvopastoral Management for Quality Wood Production in Spain. September 2015. 16 pp. http://www.agforward.eu/index.php/en/grazing-and-intercropping-of-plantation-trees-in-spain.html

Fernández Lorenzo JL, Rigueiro Rodríguez A, Ferreiro Domínguez N, González Hernández P, Mosquera Losada MR (2016). System Report: Chestnut Agroforestry in Spain. January 2016. 13 pp. http://www.agforward.eu/index.php/en/chestnut-agroforestry-in-galicia-spain.html

Pantera A, Papadopoulos A, Kitsikopoulos D, Mantzanas K, Papanastasis V, Fotiadis G (2016a). System Report: Olive Agroforestry in Molos, Central Greece. January 2016. 9 pp. http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html

Pantera A, Papadopoulos A, Kasselaki M, Papanastasis V, Mantzanas K, Fotiadis G (2016b). System Report: Agroforestry with Orange Groves in Crete, Greece. January 2016. 9 pp. http://www.agforward.eu/index.php/en/intercropping-of-orange-groves-in-greece.html

Mantzanas K, Papanastasis V, Pantera A, Papadopoulos A (2015). System Report: Olive Agroforestry in Kassandra, Chalkidiki, Greece. December 2015. 8 pp. http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html

Rosati A, Mantovani D (2015). System Report: Intercropping of Olive Orchards in Italy. November 2015. 8 pp. http://www.agforward.eu/index.php/en/intercropping-and-grazing-of-olive-orchards-in-italy.html

van Lerberghe P, Malignier N (2016). System Report: Traditional Pollard Agroforestry in South-West France. May 2016. 11 pp. http://www.agforward.eu/index.php/en/bordure-trees-in-france-1375.html

2 Components of selected systems

Agroforestry systems, managed by humans, can include trees and shrubs, an agricultural crop including pasture, and the livestock. The tree species in the systems reported here include apple (three systems), olives (three systems) with chestnut, walnut, orange and ash in the remaining four systems (Table 2).

Grass, primarily perennial ryegrass, is the dominant crop in most systems (Table 2). Other crop species include cereals, vegetables including asparagus, bulbs, mushrooms, and grapes. 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 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 (Pantera et al. 2015). This is also evident by the generally low stock density used in most systems (Table 3).

Table 2. Components of ten agroforestry systems with high value trees

System	Tree component	Crop component	Animal component
Grazed orchard in England and Wales, UK	Apple (*Malus domestica*)	Perennial ryegrass (*Lolium perenne*)	Sheep: Shropshire breed
Grazed orchard in Northern Ireland, UK	Apple cider variety: Coet-de-linge, and dessert variety: Jonagold	Perennial ryegrass	Sheep: mixed breeds including Texel, Belclare, LLeyn and Highlander
Grazed orchards in France	Apple	Perennial ryegrass	Sheep: Shropshire breed
Traditional wood pasture in France	Ash (*Fraxinus excelsior* L.)	Grass species	Sheep (Lacaunes) or cows (depending on the region)
Intercropping of olive groves, Molos, Greece	Olive (*Olea europea*)	Cereals, maize, grape vines, vegetables, grass, and chickpea (*Cicer arietinum*)	Sheep
Intercropping of olive groves, Kassandreia, Greece	Olive (*Olea europea*), Pear (*Pyrus* sp.), Pines (*Pinus halepensis*)	Wheat and barley	No animals
Intercropping of orange groves, Greece	Orange (*Citrus sinensis*)	Vegetables (here chickpea (*Cicer arietinum*)	No animals
Intercropping in olive orchards, Italy	Olive	Asparagus (*Asparagus acutifolius*) and bulbs (*Narcissus* and *Tulipa* species	No animals
Grazing walnut timber plantations in Spain	Hybrid walnut (*Juglans major* x *regia*) Mj209xRa	Grass species	Sheep: Merina breed
Chestnut agroforestry in Galicia, Spain	Chestnut (*Castanea sativa* L.)	*Ulex* sp., *Pteridium* sp. *Rubus* sp., and mushrooms	Pigs: Celtic breed

3 Structure of selected systems

The tree provides the most important crop within most of "Agroforestry with high value tree species" systems e.g. in most cases the farmer will be starting with either an apple orchard, an olive or orange grove, or a plantation of walnut trees. The canopy of many of these trees are actively managed, e.g. the farmer may prune apple trees to allow air movement and maximise fruit production or prune walnut trees to maximise the volume of knot-free timber. These processes can

affect the amount of light reaching the ground. The height of the trees in these systems range from 2 m to 12 m (Table 3).

Table 3. Structure of the high value tree agroforestry systems. Strata are defined in terms of the number of vertical (V) and horizontal (H) strata.

System	Strata	Spatial arrangements	Temporal arrangement	Tree spacing	Tree height	Tree density	Stocking density
Grazed orchard in England and Wales, UK	2 V	Traditional orchard with trees in rows	Sheep are removed 56 days before apple harvest	6 m x 3 m	6-7 m	500 ha^{-1}	20 sheep ha^{-1}
Grazed orchard in Northern Ireland, UK	2 V	Bush orchards in linear rows with windbreaks	Short-term grazing on small plots; sheep start in May, removed in June, and introduced in Nov – Dec*	Cider variety 5 m x 2 m Dessert variety 4 m x 1.5 m	2-2.5 m	Cider: 900 ha^{-1} Dessert: 1485 ha^{-1}	Over the season would be 12-15 sheep ha^{-1}
Grazed orchards in France	2 V	«bush» orchards in linear rows	Sheep introducing in April & removed in mid-November	a: 5-5.5 m b: 2-2.5	5 m	600-1000 ha^{-1}	4 sheep ha^{-1}
Traditional wood pasture in France	Multiple H & V	Boundary (Hedges around fields)	Sheep introduced in April				Not specified
Intercropping of olive groves, Molos, Greece	2 V	Linear rows of trees and in-between intercrops	Intercropping only in spring-summer, sheep from March to November*	10 m x 10 m	~ 5 m	120 ha^{-1}	Not specified
Intercropping of olive groves, Kassandreia, Greece	2 V	Scattered and in some cases linear rows of trees	Intercropping only in spring-summer, sheep & goat grazing from March- November*	10 m x 10 m	~ 8 m	100 ha^{-1}	-
Intercropping of orange groves	2 V	Scattered and in some cases linear rows of trees	Intercropping only in spring-early summer	10 m x 10 m	~ 5 m	100 ha^{-1}	-
Intercropping in olive orchards in Italy	2 V and 1 H	Intercrops between linear rows of olive trees: traditional spacing	Intercropping with permanent evergreen (asparagus) or with fall-to-spring vegetation (bulbs) crops	5 m x 4 m	5 m	500 ha^{-1}	
		Super-high density		4 m x 1.5 m	2.5 m	1666 ha^{-1}	
Grazing walnut in Spain	2V	Linear rows of trees	Year-round grazing except the lambing period	6 m x 5 m	~ 12 m	333 ha^{-1}	1
Chestnut agroforestry in Galicia, Spain	2H and 1V	Scattered trees with full canopy cover	April- December	No specific	na	TBI	1.5
	2H		Whole year around	TBC	….		-
							-

*: Depending on weather conditions

Most of the systems are composed of two vertical strata of vegetation (Table 3). This is in contrast with some tropical systems (where light receipts are high) which may have four or more vertical layers. In the olive grove and the chestnut orchard system, the understorey (asparagus and mushroom respectively) are considered to be shade tolerant species. This practice could be of wider interest as these marketable products may enhance farmers' income.

The traditional olive and chestnut system comprises trees that have naturally seeded or which have been established in an apparently random way. The pollarded trees are confined to hedgerows (Table 3). The trees in the remaining systems are primarily planted in rows to facilitate the use of machinery. There has been a tendency to increase the tree planting density and the tree spacing is typically narrower in modern than traditional systems (Table 3). Increased tree densities can result in greater fruit or olive yields and the density of tree planting is one of the innovations mentioned by stakeholders (Pantera et al. 2015).

The temporal arrangement of the agroforestry systems can be characterized as coincident (i.e. grazed walnuts), intermittent (i.e. livestock grazing) and concomitant (all other systems) (Table 3). In some silvopastoral systems the sheep are either removed during the winter; in the agrosilvopastoral olive grove in Molos, Greece the sheep are introduced after the crop component is harvested. By contrast the sheep within the walnut plantations in Spain are allowed to graze all year-round. Each of the systems can be characterized as continuous in that they follow an annual cycle of cropping or grazing.

4 Ecosystem services of selected systems

Relative to a monoculture crop, all agroforestry systems enhance biodiversity, which in turn provides numerous ecosystem services that can benefit human well-being (Table 4). Ecosystem services can be categorised in to provisioning, regulating, cultural and supporting services. Each of the 10 agroforestry systems provides either a primary (olives, apples, nuts, vegetables) or secondary food product (meat and dairy products). Each of the system can also provide fuel wood. Some of the systems also provide timber or, in the case of olive trees, wood for artefacts.

Agroforestry provides a number of regulating ecosystem services (Table 4). In many cases the trees provide shade; the reduction of temperatures can be particularly important in Mediterranean areas. The regulation of water quality and the sequestration of carbon are amongst the most frequently mentioned ecosystem services (Table 4). Other regulating services include disease regulation and pest control, which are both issues of concern to the stakeholders (Pantera et al. 2015). All agroforestry systems provide a variety of cultural and supporting services (Table 4). It is assumed that this includes traditional cultural heritage, aesthetic, educational and employment opportunities with each system. As mentioned by Isted (2005), traditional agroforestry systems contribute to the culture and heritage of many European areas. It is also assumed that the orange and olive trees intercropped in Mediterranean, and the chestnut agroforestry in Spain provide opportunities for recreation and inspiration.

5 Economic value of selected systems

Agroforestry systems and practices need to be financially viable and socially acceptable to practitioners (Graves et al. 2007). The level of labour required to maintain the systems range from

high (grazed orchards, olive tree intercropping, grazed or intercropped walnut plantations) to low (pollarded boundary trees and chestnut systems) (Table 5). The level of mechanisation in most systems is moderate to high; some of the fruit crops require regular application of agrochemicals. Many of the systems involve both high levels of inputs and outputs (Table 5), which suggests that agroforestry can maximise land productivity. With the exception of the pollard boundary trees, each of the systems has been designed for commercial production (Table 5).

Table 4. Ecosystem services of agroforestry systems with high value trees

	Provisioning				Regulating					Cultural					
System	Food	Fuel wood	Timber	Artifacts from olive wood	Shelter or shade for animals	Microclimate for crops	Disease regulation	Water purification	Carbon storage	Traditional cultural heritage	Recreation	Aesthetic	Education	Employment opportunity	Inspiration
Grazed orchard in England and Wales	Apple, cider, meat	✓			✓		?		✓	✓		✓	✓	✓	
Grazed orchard in Northern Ireland	Apples, cider, meat	✓			✓		?		✓	✓		✓	✓	✓	
Grazed orchards	Apple, cider, meat, dairy products	✓			✓		?		✓	✓		✓	✓	✓	
Pollard boundary trees in France	Meat, dairy products				✓			✓	✓	✓		✓	✓	✓	
Intercropping of olive groves, Molos in Greece	olives, olive oil, herbs, vegetables, meat, dairy product	✓		✓					✓	✓	✓	✓	✓	✓	✓
Intercropping of olive groves, Kassandreia, Greece	olives, olive oil, vegetables, meat, dairy	✓		✓				✓	✓	✓	✓	✓	✓	✓	✓
Intercropping of oranges, Greece	oranges, herbs	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Intercropping in olive orchards, Italy	olives, olive oil, asparagus, flowers	✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓
Grazing walnut timber plantations, Spain	walnuts, meat, dairy products	✓			✓		✓	✓	✓	✓		✓	✓	✓	
Chestnut agroforestry in Galicia, Spain	chestnuts, meat, dairy products	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
	chestnuts, mushrooms	✓	✓			✓		✓	✓	✓	✓	✓	✓	✓	✓

All systems were considered to provide supporting services such as primary production, nutrient cycling, and soil protection from erosion.

Table 5 Economic values associated with agroforestry with high value trees. The goals of the systems are indicated as commercial (C), intermediate (I), or subsistence (S).

System	Labour	Mechanization level	Inputs	Outputs	Goal
Grazed orchard in England and Wales	High: Sheep may reduce mowing costs; but labour needed to manage sheep	Medium; Mowing can be reduced by use of sheep	Case study system does not use fungicide for scab control	12-50 t/year/ha apple) About 20 ewes per hectare with 2 lambs produced per ewe	C
Grazed orchard in Northern Ireland	High (mowing, spraying, pruning, harvesting, sheep herding)	High: mowing for grass and chemicals for pest control	High use of pesticides	30-45 t ha^{-1} apple	C
Grazed orchards in France	High (mowing, spraying, pruning, harvesting, sheep herding)	High: mowing for grass and chemicals for pest control	Low in pesticides & fertilizers (cattle manure), reduced mowing	25-35 t/year apple	C
Pollarded boundary trees in France	Low (pollarding, sheep herding)	Low (tree pollarding)	Low	Medium (cheese)	S – I
Intercropping of olive groves, Molos, Greece	High (pruning, spraying, ploughing, cultivation & planting, harvesting, sheep herding)	High: pruning, cultivation for intercrops and chemicals for pest control	Low (chemicals – Cu-for olive pests once a year, N fertilisation)	Olive production approx. 2.3 t/ha, chickpeas: 2 t/ha oregano: 0.97-1.8 t/ha	C & S
Intercropping of olive groves, Kassandreia, Greece	High (pruning, spraying, ploughing, cultivation & planting, harvesting,)	High: pruning, cultivation for intercrops and chemicals for pest control	High (pesticides, N fertilisation)	Olive production approx. 2.3 t/ha, chickpeas: 2 t/ha	C & S
Intercropping of orange groves, Greece	High (pruning, spraying, cultivation & planting, harvesting)	High: pruning, cultivation for intercrops and chemicals for pest control	High (pesticides, N fertilisation)	Orange production approx. 25 t/ha, chickpeas: 2 t/ha	C & S
Intercropping in olive orchards, Italy	High (pruning, spraying, cultivation & planting, harvesting)	High: harvesting, cultivation for intercrops and chemicals for pest control	Medium (N P K fertilisation + pest control (Peacock eye disease and olive fly)	Olive production approx. 6-12 t/ha, asparagus 0.5 t/ha	C & S
Non-grazed walnut timber plantations, Spain	High (ploughing, spraying, pruning, harvesting)	High: mowing for grass, chemicals for pest control, fertilization	High (energy, pesticides & fertilizers)	High (timber)	C
Grazed walnut timber plantations	High (pruning, harvesting, sheep herding)	Low: fertilization	Low (fertilizers)	High (timber, meat and cheese)	C
Chestnut agroforestry in Galicia, Spain	Low	none	none	High	C
	Low	none	none	0.2 t ha^{-1} mushroom production	C

6 Conclusion

Agroforestry with high value trees, as the name implies, are dominated by the use of tree species which provide either an annual crop (apples, olives, oranges) or high quality timber (walnut and chestnut). The space between the trees is then used for intercrops or for grazed grass. Many of the systems have been traditionally practiced and they provide a wide range of provisioning, regulating, and cultural ecosystem services.

7 Acknowledgements

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8 References

den Herder M, Moreno G, Mosquera-Losada RM, Palma JHN, Sidiropoulou A, Santiago Freijanes JJ, Crous-Duran J, Paulo JA, Tomé M, Pantera A, Papanastasis VP, Mantzanas K, Pachana P, Andreas Papadopoulos A, Plieninger T, Burgess PJ (2016). Current extent and stratification of agroforestry in the European Union. Paper submitted to Agriculture, Ecosystems and Environment.

Graves AR, Burgess PJ, Palma JHN, Herzog F, Moreno G, Bertomeu M, Dupraz C, Liagre F, Keesman K, van der Werf W, Koeffeman de Nooy A, van den Briel JP (2007). Development and application of bio-economic modelling to compare silvoarable, arable and forestry systems in three European countries. Ecological Engineering. 29: 434-449.

Isted R (2005). Wood pasture and parkland; overlooked jewels of the English countryside. In: Mosquera-Losada MR, McAdam J, Rigueiro-Rodriguez A (Eds). Silvopastoralism and Sustainable Land Management. Wallingford, UK: CABI.

Pantera A, Burgess PJ, Corroyer N, Ferreiro-Domínguez N, Fernández Lorenzo JL, González-Hernández P, Graves AR, McAdam J, Moreno G, Mosquera Losada MR, Rigueiro Rodríguez A, Rosati A, Upson M (2015). Innovations to be examined for Agroforestry for High Value Tree Systems. Milestone 3.2 (MS 9) for EU FP7 Research Project: AGFORWARD 613520. 14 pp. http://www.agforward.eu/index.php/en/agroforestry-innovations-to-be-examined-for-high-value-tree-systems.html