

LESSONS LEARNT FROM THE INTERCROPPING AND GRAZING OF HIGH VALUE TREE SYSTEMS ACROSS EUROPE

Pantera A^{1*}, Mosquera-Losada MR², Burgess P³, Graves A³, Ferreiro-Domínguez N², Corroyer N⁴, McAdam J⁵, Rosati A⁶, López-Díaz ML⁷, Mantzanas K⁸, Moreno G⁷, Papadopoulos A¹, Papanastasis VP⁸, Van Lerberghe⁹, Giannitsopoulos M⁹

(1) TEI Stereas Elladas, Karpenissi, Greece (2) University of Santiago de Compostela, Department of Crop Production, University Campus, 27002-Lugo, Spain (3) Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK (4) Chambre d'agriculture de Normandie, Chemin de la Bretèque, CS 30059, 76232 Bois Guillaume Cedex, France (5) Agri Food and Biosciences Institute, Newforge Lane, Belfast BT9 5PX, UK (6) Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, centro di ricerca Olivicoltura Frutticoltura Agrumicoltura (CRA – OFA), via Nursina 2, 06049 Spoleto (PG), Italy (7) Forest Research Group (INDEHESA), University of Extremadura. Plasencia 10600, Spain (8) Aristotle University of Thessaloniki, Department of Forestry & Natural Environment, Thessaloniki, Greece (9) Institut pour le Développement Forestier, Auzeville-Tolosane, France

*Corresponding author: pantera@teiste.gr

Abstract

Intercropping or grazing of orchards or groves of fruit trees (e.g. olive, carob, pine-nut, walnut, almond, chestnut, apple, pear), or plantations of trees grown for high value timber (e.g. walnut and wild cherry) can be characterized as a “high-value tree agroforestry systems”. The systems can be combined with agricultural crops such as chickpeas and barley or grass grazed by sheep. The introduction of sheep to apple orchards can minimise the need for mowing and at the same time provide animal feed for sheep production enterprises. Pollarding is still a living practice in France where it is linked to the management of a traditional hedgerow network known as “bocage”. In Spain, hardwood species are commonly grown using rotations of up to 50-60 years, and establishing a legume based mixed pasture understorey and introducing sheep can increase the financial and environmental benefits from such plantations. Chestnut agroforestry is a traditional land use system in Spain after fruit drop. Chickpeas can be a successfully intercropped below orange or olive trees. In addition to chickpeas, olive trees can be intercropped by species such as asparagus and flowers.

Keywords: apple; orange; olive; chestnuts; walnuts

Introduction

Agroforestry is “the deliberate integration of woody vegetation (trees and/or shrubs) as an upper storey on land with pasture (consumed by animals) or an agricultural crop as the lower storey. The woody species can be evenly or unevenly distributed or occur on the plot border. The woody species can deliver forestry or agricultural products or other ecosystem services (i.e.

agroforestry projects, the focus is on integrating trees within arable or livestock systems. There are also reviews of maintenance and improvement of established wood pasture and hedgerow systems of known cultural and biodiversity significance (Moreno et al. 2017). However an alternative approach is to integrate understorey crops or grazing within existing high value tree systems such fruit orchards, olive groves, or high value timber plantations (Rosati et al. 2012; López-Díaz et al. 2013, 2014). Examples of fruit trees include olive, carob, pine-nut, walnut, almond, chestnut, apple and pear. Trees grown for high value timber in Europe include walnut and wild cherry. Olive trees are one of the most important species in the Mediterranean regions (Camarsa et al. 2016) and apple trees are common in Atlantic and Continental regions (Robertson et al. 2012; Lebon 2016). This article provides an overview of the results from the experiments or field trials that were conducted by ten stakeholder groups with high value tree systems, within the AGFORWARD research project.

Materials and methods

Ten stakeholder groups focused on the intercropping or grazing of high value trees covered apple trees (Burgess 2014; Corroyer 2014; McAdam 2014), olive trees (Pantera 2014a, 2014b; Rosati 2014), and orange trees (Pantera 2014c), chestnut (Mosquera-Losada et al. 2014) and walnut trees (Moreno 2014) (Table 1). The stakeholder groups included farmers, breeders, foresters, landowners, and representatives of regional and national associations, agricultural suppliers, extension services, NGOs, policy makers, and scientists. These stakeholder groups cover the North and South Mediterranean, and the North, Central, and Southern Atlantic agroclimatic zones. In the case of olives (Greece and Italy) and apples (UK and France), the same tree species were studied in different areas with opportunities to compare and exchange ideas, information and knowledge between countries. Even though an initial stakeholders' group was created for walnut in Greece and chestnut trees in Switzerland, these did not continue for local logistical reasons. During 2014, each group identified some potential innovations to be tested and during the next three years detailed experimental and/or economic measurements were taken at each site. Farmers could freely suggest potential innovations and research team members contributed only to facilitating the discussion and on the feasibility of the suggested actions. Depending on the site, some innovations were tested experimentally with replicates or by on-farm demonstrations. Additionally, research team members were responsible for gathering data from each site which included site and system characteristic as well as past and present economic information of the system.

Table 1: Components of selected High Value tree agroforestry systems

System	Tree component	Crop/understorey component	Animal component
Grazed orchards in England, UK	Apple (<i>Malus domestica</i> L.)	Perennial ryegrass (<i>Lolium perenne</i> L.)	Sheep: Shropshire breed
Grazed orchards 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
Intercropping of olive groves, Molos, Greece	Olive (<i>Olea europea</i>)	Cereals, maize, grape vines, vegetables, grass, and chickpea (<i>Cicer arietinum</i>)	Sheep
Intercropping of olive groves, Kassandraia, Greece	Olive (<i>Olea europea</i> L.), Pear (<i>Pyrus</i> sp.), Pines (<i>Pinus halepensis</i> Mill.)	Wheat and barley	No animals
Intercropping in olive orchards, Italy	Olive	Asparagus (<i>Asparagus acutifolius</i> L.) and bulbs (<i>Narcissus</i> and <i>Tulipa</i> species)	No animals
Intercropping of orange groves, Greece	Orange (<i>Citrus sinensis</i> L.)	Vegetables (here chickpea (<i>Cicer arietinum</i> L.))	No animals
Grazing walnut timber plantations in Spain	Hybrid walnut (<i>Juglans major x regia</i>) Mj209xRa	Grass species	Sheep: Merina breed
Chestnut agroforestry in Galicia, Spain	Chestnut (<i>Castanea sativa</i> L.)	<i>Ulex</i> sp., <i>Pteridium</i> sp. <i>Rubus</i> sp., and mushrooms	Pigs: Celtic breed

Results and discussion

The main results are described in terms of two main types of intervention: i) intercropping, and ii) grazing.

Timber from species such as walnut, wild cherry and chestnut and fruit from olive and orange trees can produce high revenues, but some production systems involve substantial energy,

water, and agrochemical inputs. The experimental work demonstrated that there are benefits from planting a nitrogen-fixing intercrop, such as chickpeas or alfalfa, rather than investing substantial energy in regular cultivation between the trees. For example, sowing rich-legume pasture in the alleys could roughly double the stocking rate without compromise the tree growth. As an overall conclusion, managing of Mediterranean hybrid walnuts and wild cherry timber plantation under silvopastoral schemes seem a feasible way to reduce the high economical maintenance costs of these plantations and the ecological risks, without compromising their productivity. Similar promising results on the positive effect of the legumes to the walnut overstory were reported by Homar et al. (2014).

As mentioned above, grazing may be beneficial from an environmental and an economic perspective. This is also evidenced from a “chestnut grazed by pig” system in Galicia, Spain. With proper management this system is productive and has many environmental and economic profits, preserving biodiversity, increasing nutrient cycling and enhancing farmer’s income. In specific, adequate stocking rates and space-distribution of the pigs are important to limit any damage to the trees.

Olive is one of the most popular and characteristic trees in the Mediterranean. Based on the results from the three stakeholders groups in Greece and Italy, intercropping can be a successful choice to enhance the farmer’s income while producing multiple products and reducing the need for chemical fertilizers. The choice of the intercrop species is an important parameter in the management scheme of such a system. For example, chickpeas successfully complement olive cultivation, as, besides being a leguminous species that enhances soil nitrogen level, it is also a low water demanding species. Similar results were obtained from a trial in the island of Crete, Greece, where orange trees were intercropped with a leguminous crop. As Greece produces over 0.8 million tonnes of oranges annually (1.1% of total global production), this combination can be a profitable choice for the farmer and the environment. Actually, intercropping with a leguminous species not only enhances soil nitrogen levels, but also increases income to the farmer by the extra product (e.g. chickpeas). There is a plethora of species for intercropping olive groves. For example, in Italy, olives were successfully intercropped with wild asparagus plants and flowers such as narcissus and tulips.

The focus with the apple systems in France and the UK was on the grazing of orchards using sheep. The experiments comparing orchards where the understorey was either grazed or mown demonstrated that orchard grazing can be profitable and productive but it is not suitable for all orchards. Grazing was most successful where the lower branches of the apple trees have already been pruned to a height of at least 1.2 m (to minimise yield loss from the browsing sheep). In these systems tree height is of great importance and should represent an important parameter in the management of such system. Grazing is also likely to be more successful where the apple trees receive a minimal spray programme e.g. grazing is easier in an organic than an intensively-sprayed system. The other two important issues are selection of an appropriate “lowland” sheep breed and regular monitoring of the sheep, the surface height and quality of pasture, and the status of the trees.

Of the numerous traditional agroforestry systems in Europe, “bocage” is one of the popular in South-West France. It represents an excellent example of the wisdom acquired through time where farmers gained as many products as possible by this system such as wood (mostly fire-wood) from the branches of the pollarded trees and dairy products from the livestock grazed.

Conclusion

The intercropping of high value tree systems can help to reduce cultivation costs, while the use of understorey nitrogen-fixing crops can reduce fertiliser needs for the tree crop and maintain or increase tree yields. However it is noted that additional phosphorus may be required in some soil types. The grazing of high-stem orchards and timber plantations, typically with sheep, can reduce mowing costs and provide an additional source of revenue.

Acknowledgment

We are thankful for the responses from a range of stakeholders who spared their time in meetings during 2014. The AGFORWARD project (Grant Agreement N° 613520) was co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food. This research has been co-funded by the Hellenic Ministry of Education, Research and Religion, General Secretariat for Research and Technology.

References

- Burgess PJ (2014) Initial stakeholder meeting report: grazed orchards in the UK. http://www.agforward.eu/index.php/en/Grazed_Orchards.html (accessed 23/04/2018).
- Camarsa G, Gardner S, Jones W, Eldridge J, Hudson T, Thorpe E, O'Hara E (2016) LIFE among the olives: Good practice in improving environmental performance in the olive oil sector. LIFE report available on line: <http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/oliveoil.pdf> (accessed 23/04/2018).
- Corroyer N (2014) Initial stakeholder meeting report: grazed orchards in France. <http://www.agforward.eu/index.php/en/grazed-orchards-in-france.html> (accessed 23/04/2018).
- Homar-Sánchez C, Urbán-Martínez I, Rigueiro-Rodríguez A, Mosquera-Losada MR (2014) *Juglans* growth under ploughing and *Vicia villosa* sowing understory management. 2nd European Agroforestry Conference, Cottbus, Germany.
- Lebon G. SVPC (2016) Observatoire économique cidricole: couts de production 11 P. Chambre d'agriculture de Normandie, 6 rue des Roquemonts – 14000 Caen France.
- 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. Vitoria-Gasteiz, Spain.
- López-Díaz ML, Moreno G, Bertomeu M (2014) Pasture management under hardwood plantation: legume implantations vs. mineral fertilization. 2nd European Agroforestry Conference, Cottbus, Germany.
- McAdam J (2014) Initial stakeholder meeting report: grazed orchards in Northern Ireland, UK. <http://www.agforward.eu/index.php/en/grazed-orchards-in-northern-ireland-uk.html> (accessed 23/04/2018).
- Moreno G (2014) Initial stakeholder meeting report: grazing and intercropping of plantation trees in Spain. <http://www.agforward.eu/index.php/en/grazing-and-intercropping-of-plantation-trees-in-spain.html> (accessed 23/04/2018).
- Moreno G, Aviron S, Berg S, Crous-Duran J, Franca A, García de Jalón S, Hartel T, Mirck J, Pantera A, Palma JHN, Paulo JA, Re GA, Sanna F, Thenail C, Varga A, Viaud V, Burgess PJ (2017) Agroforestry systems of high nature and cultural value in Europe: provision of commercial goods and other ecosystem services. *Agroforestry Systems* (2017). <https://doi.org/10.1007/s10457-017-0126-1> (accessed 23/04/2018).
- Mosquera Losada MR, Ferreiro-Domínguez N, Fernández Lorenzo JL, González-Hernández P, Rigueiro Rodríguez A (2014) Initial stakeholder meeting report: chestnut agroforestry in Galicia, Spain. [file:///C:/Users/Nuria/Downloads/WP3_ES_chestnut%20\(3\).pdf](file:///C:/Users/Nuria/Downloads/WP3_ES_chestnut%20(3).pdf) (accessed 23/04/2018).
- Mosquera-Losada MR, Santiago-Freijanes JJ, Rois M, Moreno G, Pisanelli A, Lamersdorf N, den Herder M, Burgess PJ, Fernandez-Lorenzo JL, Gonzalez-Hernandez P, Rigueiro-Rodríguez A (2016) CAP and agroforestry practices in Europe. 3rd European Agroforestry Conference, Montpellier, France.
- Pantera A (2014a) Initial stakeholder meeting report: intercropping of olive groves in Greece (Kassandra). <http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html> (accessed 23/04/2018).
- Pantera A (2014b) Initial stakeholder meeting report: intercropping of olive groves in Greece (Molos). <http://www.agforward.eu/index.php/en/intercropping-of-olive-groves-in-greece.html> (accessed 23/04/2018).
- Pantera A (2014c) Initial stakeholder meeting report: intercropping of orange groves in Greece <http://www.agforward.eu/index.php/en/intercropping-of-orange-groves-in-greece.html> (accessed 23/04/2018).
- 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 (accessed 23/04/2018).
- Rosati A, Castellini C, Dal Bosco A, Mugnai C, Paoletti A, Caporali S (2012). Olive agroforestry: an inverse approach to agroforestry. 1st European Agroforestry Conference, Brussels, Belgium.
- Rosati A (2014). Initial stakeholder meeting report intercropping and grazing of olive orchards in Italy <http://www.agforward.eu/index.php/en/intercropping-and-grazing-of-olive-orchards-in-italy.html> (accessed 23/04/2018).