Lessons learnt: Olive agroforestry in Molos, Central Greece

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Specific group	Olive agroforestry in Molos, Central Greece
Deliverable	Contribution to Deliverable 3.8 Lessons learnt from innovations within agroforestry within high value tree systems
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1 Context

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

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

This report contributes to Objective 2, Deliverable 3.8 which is to describe the lessons learnt from innovations within agroforestry with high value tree systems. Within the project, there were ten stakeholder groups focused on such systems (e.g. grazed orchards, intercropped and grazed olive groves and citrus orchards, and high-value walnut and chestnut plantations). This report focuses on a stakeholder group which focussed on olive orchards in Greece.

2 Background

Olive (*Olea europaea*[1]) is probably the most widespread cultivated tree in Greece. It is estimated that olive groves cover 806,600 ha in Greece (Camarsa et al. 2010) with a large proportion (estimated to be 124,311 ha) comprising agroforestry systems with various crops or pasture established in the understory of olive trees (Papanastasis et al. 2009).

Olive trees alone or in orchards are found in all parts of Greece that have a mild Mediterranean climate. The olive tree is considered as one of the least demanding in soil nutrients among the cultivated trees. This is why it is planted in poor, rocky areas with soils mostly derived from hard limestone (e.g. Gomez et al. 2003; Vossen 2007; Duarte et al. 2008). Many olive groves are found on steep mountain slopes that have been terraced with stonewalls to hold the soil. Sometimes other trees such as carobs (mainly in Crete), almonds, walnuts, apricots, fig, poplars, and plums are grown together with the olive trees or along the boundaries of the olive orchards. In the traditional systems, practically all olive trees came from wild plants that were grafted. Edible olives and olive oil are the main products, while secondary products include fodder for animals and firewood. In some places, high quality furniture and handicrafts are made of olive wood.

Olive trees have been grown with: a) animals (sheep, cattle, goats, honey bees, pigs or chickens), b) wheat or other cereals, corn, alfalfa, or grape vines, c) vegetable crops, i.e. melons, beans, onions, or fava beans, or d) wild herbaceous vegetation including some edible plants. Animals grazed on the spontaneous vegetation or on planted crops excluding wheat and barley (Papanastasis et al. 2009).

In the Fthiotida prefecture in Greece, agroforestry is a traditional land use system in which farmers combined olive production with grazing and arable crops (vegetables) on the same plot. In this way they ensured a relatively steady economic return each year irrespective of weather conditions or other type of hazards. The area is dominated by forests (72%), arable land (18.3% cover), and

[1] Scientific names according to Euro+Med (2006-) and Flora Europaea (Tutin et al. 1968-1980)

pastures (8.1%), and settlements and transport infrastructure cover around 1.3% of the land area (ELSTAT 2000). Agricultural systems mostly involve field crop production (58%) but also include vegetables (3%), vines (1%), and tree plantations (27%), operating on small plot units (ELSTAT 2013). Typically, farms are small (average size: < 3 ha) and managed as private enterprises. Land is usually owned or rented by farmers. Many of the olive trees in the prefecture are estimated to be more than 200 years old. It is estimated that there are almost 7,000,000 trees in the prefecture which plays a leading role in edible olives production in the country. Table 1 provides a general description of olives intercropped in Fthiotida, Greece

There is increasing interest in the traditional combination of olive orchards with arable crops (cereals) in the same field in Central Greece (Figures 1, 2, 3 and 4).

2.1 Initial stakeholder meeting

A meeting of the 'Intercropping of olive groves in Greece' stakeholder group was held on 27 June 2014 (Pantera 2014). It was attended by 18 stakeholders and four presenters. Nine described themselves as farmers, one was a manager of a farmers' association, two were educators, one retired, one worker, one economist and three did not identify their occupation. Concerning the age range of the participants, there were two of 20-35 years, one of 35-50 years, and four of 50-65 years. Only one woman attended the meeting.

Participants were asked to complete a survey on the key positive and negative aspects of agroforestry but only eight participants responded. They all answered that were responsible for the management of a farm, but only one characterized it as agroforestry. The stakeholders were all from the area. The group identified examples of interesting or best practices that involved trees intercropped with aromatic/medicinal herbs, leguminous plants for soil amelioration, and higher quality products for human consumption or for feed. Based on the survey, the following positive aspects were identified in order of importance: animal health and welfare, control of manure/noise/odour, animal production, biodiversity and wildlife habitat, landscape aesthetics, general environment and product quality, diversity of products, originality and interest, change in fire risk, soil preservation and flood control, many environmental issues and tourism. Of the negative aspects, the following were identified in order of importance: losses by predation, inspection of animals (sheep), opportunity for hunting, complexity of work and mechanization.

3 Objective, innovation and description

In order to fit in with other activities within work-package 3, it was decided that the study of the olive tree system of Molos would focus on intercropping. Hence a controlled trial was established in an olive orchard, where the olive trees were cultivated for olives and olive oil. Field measurements are described in the research and development protocol (Pantera et al. 2015) and began in April of 2015 and continued until 2017.

4 Experiment on intercropping of olive trees and leguminous crops or cereals

The trial took place in a 2 ha olive orchard located in the area of Molos (38°49'22.58" N, 22°37'22.73" E, 11 m asl), Central Greece. It was different from the Greek olive orchard study in Macedonia because of a focus on the contribution of chickpeas as a nitrogen fixing companion plant, and the determination of the effect on the nitrogen nutrition of the trees and soil chemical and physical properties. The orchard was composed of rows of olive trees (*Olea europaea*) oriented N to S and E to W (Figure 5).

Figures 1 and 2. Looking South-East along the tree rows (left) and some aromatic plants already planted in the orchard (right) (27 March 2015).

Trees in the orchard were at least 60 years old and approximately 5 m in height. The lower edge of the canopy was about 1.6 cm from the ground. The field was not fenced as there was no need for protection. The chickpea was a choice to improve soil chemical properties and, hopefully, nitrogen economy of the tree. Similarly, the introduction of an aromatic herb such as oregano was a popular request to test from the participants of the stakeholders meeting. Further details are given in Table 2.

Table 1. General description of olives intercropped in Greece

General description of the system	
Name of group	Olives intercropped in Molos, Central Greece
Contact	Anastasia Pantera
Work-package	3: Agroforestry for High Value Tree Systems
Associated WP	There are also links with silvoarable systems (work-package 4)
Geographical extent	Olive (*Olea europaea*) is probably the most widespread cultivated tree in Greece. Olive trees alone or in orchards are found in all parts of the country which have a mild Mediterranean climate. It is estimated that olive groves cover an area of 600,000 ha in Greece (Schultz et al. 1987) and a high proportion (124,311 ha) comprises typical agroforestry systems with various crops or pasture established in the understory of olive trees (Papanastasis et al. 2009).
Estimated area	The total area of the research site is about 10 ha however there is no clear estimation of the area occupied by such systems in Greece.
Typical soil types	Luvisols
Description	The olive tree is considered as one of the least demanding in soil nutrients among the cultivated trees. This is why it is planted in poor, rocky areas with soils mostly derived from hard limestone. Olive trees have been grown with: a) animals (sheep, cattle, goats, honey bees, pigs or chickens), b) wheat or other cereals, corn, alfalfa, or grape vines, c) vegetable crops, i.e. melons, beans, onions, or fava beans, or d) wild herbaceous vegetation including some edible plants. Animals grazed on the spontaneous vegetation or on planted crops excluding wheat and barley (Papanastasis et al. 2009).
Tree species	Olive tree (*Olea europaea*); fig trees (*Ficus carica*); grape vine (*Vitis vinifera*) and lemon trees (*Citrus limon*)
Tree products	Edible olives and olive oil, lemons, fig fruits and wood
Crop species	Cereals and other leguminous species
Crop products	Chickpeas, figs, grapes, wine; crops are harvested on an annual base. Time of harvest is crop dependent
Animal species	Sheep
Animal products	Milk and meat production
Other provisioning services	Olive tree pruned for fuelwood production Possibility for intercropping aromatic plants and vegetables
Regulating services	Trees provide a microclimate which protects intercrops from frost and extreme temperatures Trees can promote nutrient cycling and increase carbon storage
Habitat services and biodiversity	Many animal species can use the trees and the edges for habitat resulting in increased biodiversity
Cultural services	The modern silvoarable practice may improve the quality of crop production and reduce the management cost.

Figures 3 and 4. Intercropped area in an olive grove in Molos, Central Greece and the production of olives

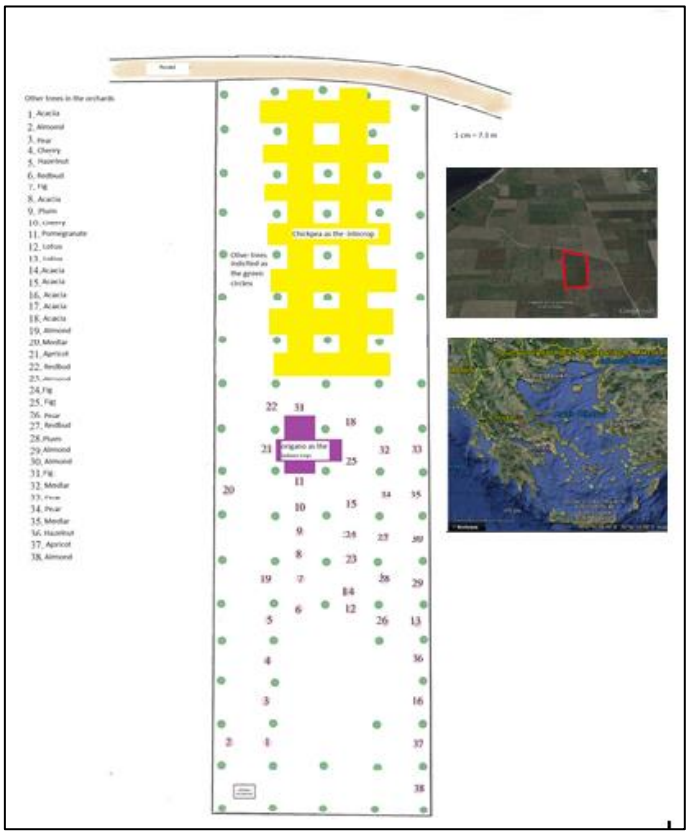

Figure 5. Schematic map of the experiment

Table 2: Description of the system in Molos, Central Greece

Climate characteristics	
Mean monthly temperature	16.5°C
Mean annual precipitation	574 mm
Details of weather station	Hellenic National Meteorological Service, Station of Lamia, data from 1970-1997. There are rarely spring frosts
Soil type	
Soil type	Luvisols
Soil depth	≥ 1 m
Soil texture	SCL Sandy-clay-silt; 59.2% sand, 24.0% silt, 16.8% clay
Soil pH	7.97
Aspect	East
Tree characteristics	
Species and variety	Olive tree (*Olea europaea*), "Kalamon" and "Amfissa" variety
Typical olive production	100 kg tree^{-1}
Date of planting	1950
Spacing	10 m x 10 m
Crop understory characteristics	
Species	Chickpeas (*Cicer arietinum*) and oregano (*Origanum vulgare*)
Management	Conventional arable crop management with ploughing
Typical crop yield	Chickpeas: approx. 2 t ha^{-1}; oregano 970-1800 kg ha^{-1} (Tzouramani et al. 2008)
Fertiliser, pesticide, machinery and labour management	
Fertiliser	None to the trees of the experiment, but there was N fertilisation of the control trees
Pesticides	Copper sprayed
Machinery	Need for tractor access in crop alleys to allow soil preparation
Manure handling	None
Labour	For olive harvest
Fencing	No

5 Experimental design and treatments

Originally the experiment involved three treatments with three replications, namely olive trees + chickpea, olive trees + oregano and olive trees alone as a control (Table 3).

Table 3. Description of the two treatments and the control

Treatment A (Olives + chickpea)	**Treatment B (Olives + oregano)**	**Treatment C (Olives)**
Chickpea (5 m x 60 m)	Oregano	Control

A 0.2 ha area was cultivated by chickpeas and with oregano. Another 0.2 ha of the orchards contained olive trees and other tree species and the rest were only olive trees and these were used as controls. The experimental design is shown in Figure 5. The rows where chickpeas were cultivated were 5 m x 60 m wide. The seed quantities were 80 kg ha^{-1}. In 2015, crop sowing was delayed until the first week of April due to the wet spring period. Oregano was sown in spring 2016. Soil samples were taken at four horizontal directions from the trees (North, South, East, West) at distances of i) half of the crown, ii) at the crown, iii) twice the length of the tree crown, and at the depths of a) 0-10 cm, and b) 10-30 cm. Three trees intercropped and three not intercropped were sampled.

6 Results

6.1 Tree and crop production

The measurements taken and the results in term of production are presented in Table 4.

Table 4. Results from the trial in 2015, 2016, and 2017

Measurements	2015	2016	2017
Olive production with intercrop	0.5 t/ha	1.5 t/ha	2.75 t/ha
Olive production without intercrop: seeding took place the first week of April	0.5 t/ha	1.5 t/ha	2.75 t/ha
Olive oil	40 l /ha	180 l/ha	305 l/ha
Chickpea production	0 t/ha	1.3 t/ha	1.45 t/ha
Oregano production	None	100 roots	Oregano did well even if there are no official results
Comments	Chickpeas production was poor. Even though the seeds established well (93%) and grew vigorously, final yields were poor due to the unfavourable spring weather (continuous rain) and rodent damage.	Chickpeas production was satisfactory. 200 kg of olives were stored and processed for edible olives. 2800 kg of olives were used for the production of 370 l of extra virgin oil of high quality (0.3-0.4 acidity). Oregano plants did not grow well.	It was an average year for olive production but it was better than the previous two for the specific orchard. Overall production was 5.5 t (compared to the 3 t in 2016). 900 kg were stored to be proceeded for edible olives. 4600 kg were processed to produce 500 kg of extra virgin oil of high quality (0.3-0.4 acidity)
Tree damage from machinery	None		None
Dates of field operations	Seeding: 4 April 2015 Weeding: 9 May and 29 June 2015		Seeding: 24 March (Figure 6) Weeding
Labour inputs	1400 € ha^{-1} (for seeding, weeding, watering etc)		Same as previously
Transport costs	350 € ha^{-1} (includes transportation to the field for all tasks by the farmer)		Same as previously
Pruning costs	450 € ha^{-1}		

6.2 Soil analyses results

We performed an Analysis of Covariance on the plot constructed in the area of Molos. The dependent variables (N, P, pH, soil organic matter) were transformed logarithmically to achieve normality. Each log transformed variable was run through an ANCOVA test. There were three fixed factors: (i) Cardinal direction, (ii) depth, (iii) existence of co-cultivation with chickpea, and one covariate, the distance from the tree. Only the significant differences are presented below.

Nitrogen: the mean N (%) at a shallow depth was significantly larger than that in the deeper soil ($F = 25.481$, $p = 0.000$). No other difference was found.

Phosphorus: the mean P (ppm) at the shallow depth was significantly larger than the one in the deeper soil ($F = 4.012$, $p = 0.047$). The mean P (ppm) in the area with no intercrop was significantly greater than that in the area with chickpeas ($F = 18.574$, $p < 0.001$). The mean P (ppm) at a shallow low depth was significantly greater than that in the deeper soil ($F = 52.119$, $p < 0.001$).

Figure 6. Chickpeas were sown in the trial at Molos, after ploughing, on 24 March 2017

pH: the mean pH in the area with no intercrop was significantly less than that in the area with co-cultivation ($F = 7.817$, $p = 0.006$).

Organic matter: the only difference found was that the organic matter declines as the distance from the tree increased.

7 Conclusions – lesson learnt

As shown in Table 4, olive production was the same in the intercropped with chickpeas plot as in the plot with only olive trees and receiving fertilization. From the soil analyses it was clear that, even if the soil nitrogen content was not statistical different in the two plots, the intercropped with chickpeas had a lower phosphorus content, suggesting a need to apply phosphorus fertilizer. One explanation of this is that nitrogen-fixation has high phosphorus demands for ATP formation. The farmer also noticed that, even if 2017 was not a productive year in general for the area, his production and quality of olive production was high.

The following lessons learnt can be drawn from the three year trial:

1. Chickpeas represented an additional income to the farmer.
2. Additionally, the farmer saved money because it was unnecessary to fertilizing the grove whilst still achieving the same levels of olive production. There were also lower chemical inputs to the system.
3. Planting in early spring is important to minimize the irrigation requirements for the chickpeas.
4. Oregano was planted in a small plot but it established well even if the production was low.
5. Intercropping with N-fixing plants represents an interesting option in olive orchards.

8 Acknowledgements

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