Lessons learnt: Olive agroforestry in Kassandra, Chalkidiki, Greece

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Work-package	3: Agroforestry for High Value Tree Systems
Specific group	Olives intercropped in Chalkidiki, 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 the second objective. It contributes to Deliverable 3.8 which describes the lessons learnt from the various stakeholder groups within the participative research and development network focused on the use of agroforestry in high value tree systems.

2 High value tree systems and agroforestry practice in Greece

The stakeholder group in Greece, as part of the wider Participative Research and Development Network (PRDN) focused on agroforestry in high value tree systems, has previously addressed the following objectives:

I. To identify examples of the best practices, key topics and innovations. Pantera (2014) reported the results of the initial stakeholder meeting which identified the key benefits of integrating high value olive trees with cereal and legume production as disease and weed control, timber/wood/olives/olive oil quality and production; the key negative aspects were identified as the labour, management costs and mechanisation.

II. to agree and implement within the PRDN an experimental protocol to develop and test proposed innovations at existing experimental plots or through on-farm experiments. This was the focus of the report by Mantzanas et al. (2015a) who identified six technical questions related to crop yields, nutrient use, and the effect of olive trees on crop.

III. to describe an existing farm with olive trees combined with leguminous crops and cereals. This was completed for the site of Kassandra, Chalidiki, Greece by Mantzanas et al. (2015b) in a system report on agroforestry for high value trees in Greece.

It is estimated that olive groves cover an area of 600,000 ha in Greece (Schultz et al. 1987) and that about 124,300 ha have an understorey of various crops or pasture (Papanastasis et al. 2009). According to Schultz et al. (1986) olive (*Olea europea*) is 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. The olive tree is considered as one of cultivated trees with the lowest demand for soil nutrients. This is why it can survive and be productive in poor, rocky areas with soils mostly derived from hard limestone. A large proportion of the olive groves are found on steep mountain slopes which have been terraced with stone walls to hold the soil.

Olive trees are the only tree component in typical olive systems. Quite often other trees are found such as carobs (mainly in Crete), almonds, walnuts, apricots, fig, poplars, and plums. These trees are grown either with the olive trees or along the boundaries of the olive orchards. In the traditional systems, practically all olive trees are formed from grafted wild plants.

Edible olives and olive oil are the main products of olive trees, while secondary products include fodder for animals and firewood. In some places, exquisite 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).

Meetings of the 'Intercropping of olive groves in Greece" stakeholder group were held on 27 June 2014, at which the group identified examples of interesting or best practices that involved the intercropping of olive trees and leguminous crops for animal feeding and soil amelioration or cereals for grain production (Pantera, 2014).

3 Objectives

The aim of the trial was to produce quantitative information about the intercropping of olive trees and leguminous crops or cereals. Key questions included:

- Do we want trees inside the agricultural area or not?
- If we decide to intercrop, which crop species should we use?

A traditional practice included peas, bitter vetch and vetch for feed and wheat.

- How does agroforestry affect crop yield?
- How does agroforestry affect nutrient cycling?
- When is the best time for pruning? Caution must be taken not to transit diseases by the use of the same.

4 Methodology

In order to comply with the initial idea of the work-package 3 for the olive tree system of Chalkidiki, it was decided to focus on an intercropping study. Hence a controlled experiment was established in the premises of the State Agricultural Prison of Kassandra Chalkidiki in December 2014. The olive trees were about 80 years old and were cultivated for olives and olive oil. The physical characteristics of the study site of olives intercropped in Chalkidiki, Greece are shown in Table 1. A description of a specific case study system is provided in Table 2.

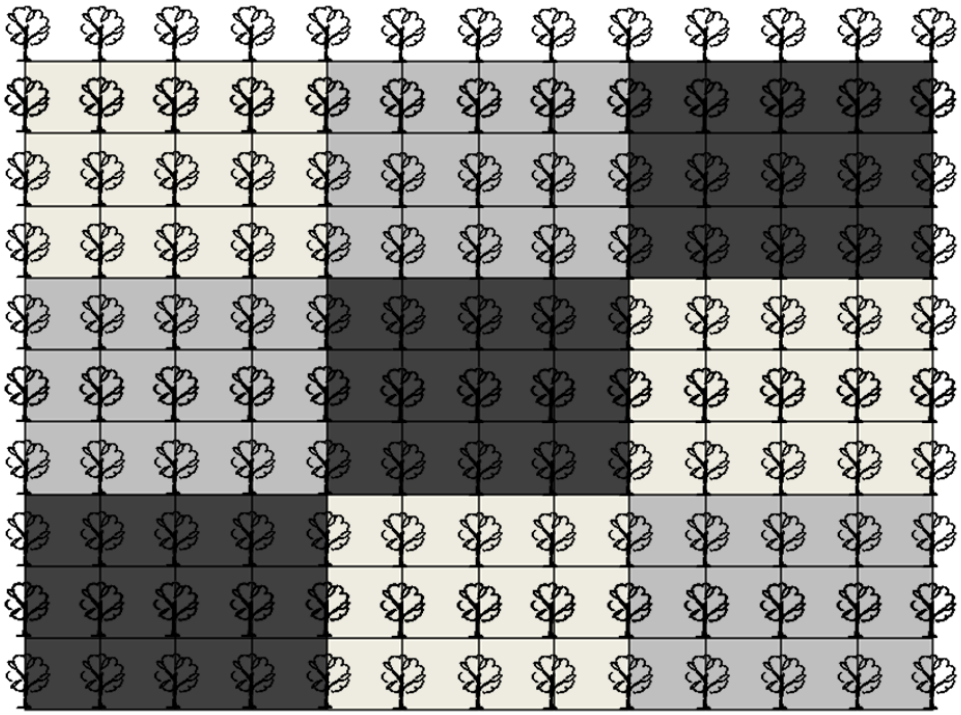
Table 1. General description of the olives intercropped in Kassandra, Chalkidiki

General description of system	
Name of group	Olives intercropped in Kassandra, Chalkidiki, Greece
Contact	Kostas Mantzanas
Work-package	3: Agroforestry for High Value Tree Systems
Associated work-package	None
Geographical extent	According to Schultz et al. (1987) olive (*Olea europea*) is 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. 1986) while a great part of them 124,311 ha forms 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 500 ha.

Typical soil types	Lithosols – Campisols
Description	Olive tree is considered to have a low demand for soil nutrients, and it is planted in poor, rocky areas with soils mostly derived from hard limestone. 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 europea*); pear (*Pyrus sp.*); pines (*Pinus sp.*)
Tree products	Edible olives and olive oil, pear fruits and wood
Crop species	Cereals (mainly wheat and barley), alfalfa, and common vetch
Crop products	Crops can be harvested on an annual basis
Animal species	Sheep and goats
Animal products	Milk and meat production
Other provisioning services	Possibility for intercrops with aromatic plants and vegetables
Regulating services	Trees provide a microclimate which protect from frost and extreme values of temperature Trees can promote nutrient cycling and increase carbon storage
Habitat services and biodiversity	Many animal species can be 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.

Table 2. Description of the specific case study system

Specific description of site	
Area	1.2 ha
Co-ordinates	X450089.747 & Y 4428217.075
Site contact	Kostas Mantzanas
Site contact	Konman@for.auth.gr
Example photograph	

Map of system	

Climate characteristics	
Mean monthly temperature	16.2°C
Mean annual precipitation	602 mm
Details of weather station (and data)	Hellenic National Meteorological Service, Weather station in Kassandra, Chalkidiki- Greece, Data from 1955-1997
Soil type	
Soil type	Lithosols – Campisols
Soil depth	Approximately 0.6 m
Soil texture	SCL Sandy-clay-silt
Additional soil characteristics	pH 8.43, soil OM 8.51% (measured by LOI – Loss On Ignition)
Aspect	North – South
Tree characteristics	
Species and variety	Olive tree (*Olea europea*)
Date of planting	1935
Intra-row spacing	10 m
Inter-row spacing	10 m
Tree protection	None
Crop understory characteristics	
Species	Barley and common vetch
Management	Conventional arable crop management with ploughing
Typical crop yield	Barley: 2.5 t ha^{-1}, barley + common vetch: 2.0 t ha^{-1} (dry matter)
Fertiliser, pesticide, machinery and labour management	

Fertiliser	Barley treatment: 130 kg ha^{-1} (24-10-0, N-P-K) and barley + common vetch treatment: 120 $kgha^{-1}$ (0-46-0, N-P-K)
Pesticides	None
Machinery	Need for tractor access in crop alleys to allow soil preparation
Manure handling	None
Labour	For olive harvest
Fencing	Yes

At the beginning of the experiment crop sowing took place on 23 December 2014, relatively late for the area due to the very rainy autumn period. However, due to normal spring no particular problems were observed.

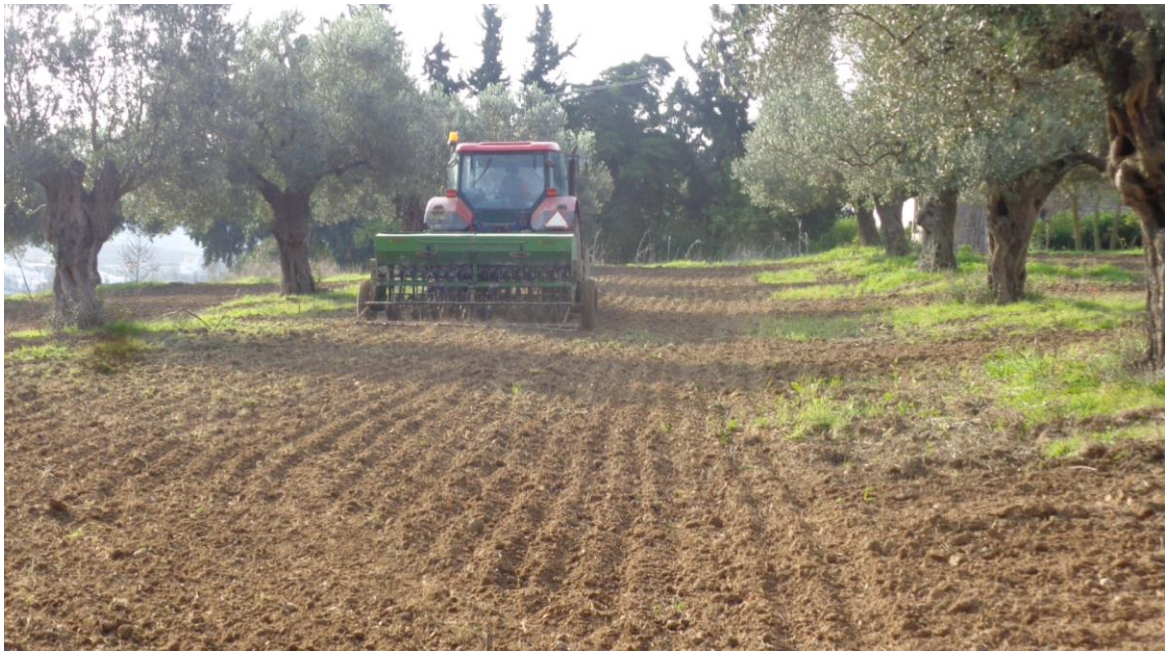


Figure 1. Crop sowing in agroforestry plot (December 2014)

Regarding the agroforestry plot measurements took place at the edge of tree canopy (2 m from the trunk) and at the middle of cropped area (5 m from the trunk). Measurements included the biomass production for the mixture of barley and common vetch treatments (during May), density of barley and common vetch (sampling time depends on the year; with appearance of new plants), number of tillers in barley (during February), mean height of barley and common vetch (before harvesting), number of heads and number of seeds per head in barley (before harvesting).

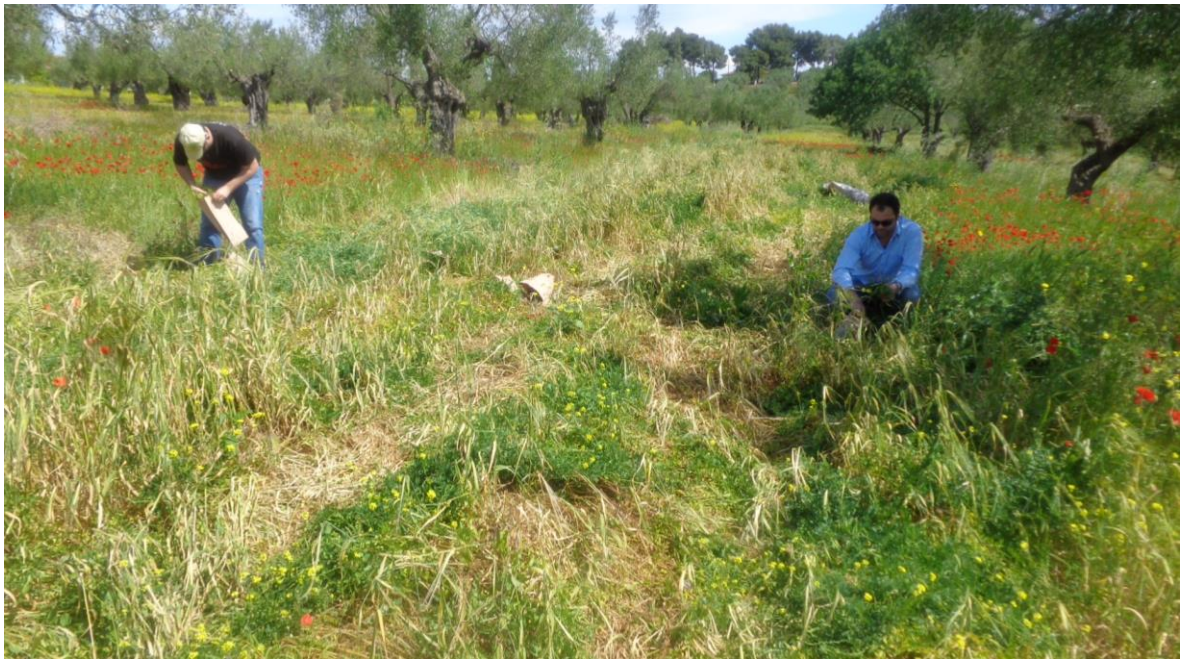


Figure 2. Measurements in the agroforestry plot in May 2017

A monoculture plot sowed with barley (close to agroforestry plot) was used through the experiment as a reference plot. Measurements took place at the same time within the agroforestry plot and included density of barley, number of tillers, mean height and number of heads.

5 Results

5.1 Tree component

The olive trees could produce edible olives and olive oil. The age of olive trees was about 80 years at the beginning of the experiment. The diameter at breast height was 0.65 m and the tree high was 6 m while the canopy diameter was close to 4.5 m. The trees were well managed and pruned for high production. Understory treatments such as sowing of barley and the mixture of barley and common vetch and fertilizer application had positive effects on olive trees that were apparent after the second year of the experiment. The leaves were greener and the branches were stronger. The annual production was expected to be the highest for the last decade according to the farm agronomist.

5.2 Barley and common vetch

The results for first year are shown in Tables 3 and 4. An analysis of variance showed that the effect of distance from the tree on total biomass production was not significant at the 5% level, but it was significant at the 10% level ($p = 0.088$) (Table 3). An analysis of variance showed that there was a significant effect of distance ($p = 0.011$*) on the number of seeds, with higher seed numbers at the edge of the tree.

Figure 3. The mixture of barley and common vetch treatment (May 2017)

Table 3. Effect of distance from tree on various crop parameters in the barley + common vetch plot (values in brackets are standard deviations)

Category	Mean	Position "A" at the edge of the trees	position "K" between the rows of trees
Mean total biomass (t ha^{-1})		6.5 (± 2.1)	7.8 (± 1.1)
Number of seeds per head	18.0 (± 5.0)	18.7 (± 4.8)	17.5 (± 5.0)
Density of barley (plants per 0.25 m^2)	10.44 (± 2.04)	10.1 (± 2.1)	11.0 (± 1.9)
Density of vetch (plants per 0.25 m^2)	7.56 (± 1.5)	7.3 (± 1.5)	8.1 (± 1.2)
Number of tillers (per 0.25 m^2)	45.3 (± 8.9)	43.2 (± 9.2)	49.3 (± 6.7)
Barley height (m)	0.74 (± 0.13)	0.71 (± 0.1)	0.81 (± 0.1)
Common vetch height (m)	0.73 (± 0.09)	0.70 (± 0.07)	0.78 (± 0.1)
Number of heads (per 0.25 m^2)	33.3 (± 8.7)	31.3 (± 9.1)	37.1 (± 6.4)

Measurements of density, height, the number of tillers and number of heads were completed within an area of 0.25 m^2. An analysis of variance showed that the mean height of the common vetch was the only parameter that significantly varied according to the relative position to the tree ($p = 0.043^*$). The common vetch was higher for samples taken between the rows of trees, perhaps indicating possible competition between the crop and the olive trees. Although the effect was not statistically significant, the barley was also higher between the trees than at the edge of the trees.

Figure 4. Barley treatment in June of 2016 (before harvest)

During the following two years of the experiment, the mean total biomass of the mixture was statistically similar at the edge of tree canopy and in the middle of cropped area. Among the above parameters only the number of seeds per head was higher at the edge of tree canopy than in the middle of cropped area suggesting an adaptation of plants to the stress caused by tree canopy.

5.3 Intercropped barley compared to the monoculture

Measurements on the barley were also taken with areas of 0.25 m^2. The analysis of variance showed that the agroforestry treatment, compared to the monoculture treatment, has a significant effect on the density of barley ($p < 0.001$), barley height ($p< 0.001$), the number of heads ($p = 0.007$**), and the number of tillers ($p = 0.04$).

Table 4. Effect of barley parameters in the agroforestry and monoculture areas (values in brackets are standard deviations)

Category	Agroforestry system	Monoculture
Density of barley (plants per 0.25 m^2)	18.4 (±5.1)	10.7 (± 1.0)
Height of barley (cm)	72.2 (± 8.0)	91.7 (± 12.1)
Number of tillers (per 0.25 m^2)	80.1 (± 20.1)	97.7 (± 9.1)
Number of heads (per 0.25 m^2)	69.8 (± 19.0)	91.3 (± 6.4)

For each parameter, higher means were obtained in the monoculture rather than the agroforestry treatment. The cultivation of barley in the presence of olive trees led to a slower development rate than in a plot without trees. Similar results were also observed in the following two years when the crop sowing took place earlier than in the first year (mid-November). Higher densities of barley in the agroforestry plot related to monoculture suggests an adaptation of barley plants to the negative effects of olive trees. The total grain production of agroforestry plot was 2.7 t/ha, compared to 3.0 t/ha in the monoculture.

6 Summary of lessons learnt

- The intercropping of olive trees with cereals (barley) and leguminous crops (common vetch) had positive effect on overall system productivity due to soil cultivation, nitrogen fixation and nutrient input by fertilization.
- The production of the barley, in both the agroforestry and reference plots, was enhanced by early crop sowing (before the end of November).
- The standard of farm management seems to be high because of the guidelines set by the agronomist of the farm (the specific farm belongs to the State Prison of Kassandra).
- This trial provides an excellent demonstration for the whole area of Kassandra peninsula of the intercropping olive trees with cereals and legumes.
- Intercropping needs experienced or well-trained farmers in order to achieve the best results.
- Seminars for intercropping and modern agroforestry practices with olive trees should be organized not only in Chalkidiki area but in the whole country.

7 Acknowledgements

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