System Report: Agroforestry with Orange Groves in Crete, Greece

Project name	AGFORWARD (613520)
Work-package	3: Agroforestry for High Value Trees
Specific group	Intercropping of Orange Groves in Greece
Deliverable	Contribution to Deliverable 3.7 (3.1): Detailed system description of a case study system
Date of report	20 January 2016
Authors	Anastasia Pantera, Andreas Papadopoulos, Maria Kasselaki, Vassilios Papanastasis, Konstantinos Mantzanas, George Fotiadis
Contact	pantera@teiste.gr
Reviewed	Paul Burgess (7 April 2016)

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.

This report contributes to Objective 2, Deliverable 3.7: "Detailed system description of case study agroforestry systems". The detailed system description includes the key inputs, flows, and outputs of the key ecosystem services of the studied system. It covers the agroecology of the site (climate, soil), the components (tree species, crop system, livestock, management system) and key ecosystem services (provisioning, regulating and cultural) and the associated economic values. The data included in this report will also inform the modelling activities which help to address Objective 3.

2 Background

Out of the global annual production of 80 million tonnes of citrus fruit, 19 million tonnes come from the Mediterranean and 1.1 million tonnes from Greece. Greek production of citrus fruit originates from an area of about 50,000 ha (500,000 stremma). Of this, there are about 38,780 ha of oranges (ELSTAT, 2015), with the rest being tangerines, lemons and grapefruits. In Crete, citrus cultivation covers 4500 ha, comprising 3300 ha of oranges, 340 ha of tangerines, about 300 ha of lemons and 70 ha of grapefruits. Greece is the 17th of the 121 orange producing countries contributing 805,500 tonnes to the world total of 71.3 million tonnes (FAOSTAT 2013).

In the past, farmers in the Chania area of Crete cultivated crops between citrus trees after pollarding. They also used cypress trees as windbreaks to protect the citrus trees from wind. However most farmers have removed the cypress trees from the windbreaks, uprooted the citrus trees and replaced them with avocado monocultures for higher profit. Only a few farmers still use the agroforestry practice of growing citrus trees with intercrops. This practice can ensure an economic return each year, typically from vegetable intercrops, until the tree canopy fully develops. After full canopy development the inter-rows are sometimes used for poultry production.

Meetings of the "Intercropping of Orange Groves in Greece" stakeholder group were held on 2 August 2014, at which the group identified examples of interesting or best practices that involved the intercropping of orange trees for increased income and soil amelioration (Pantera 2014).

3 Update on field measurements

The objective of the trial was to produce quantitative information about the intercropping of orange trees with leguminous crops (chickpeas) or cereals. Vegetables (potatoes, watermelons and beans) are used as intercrops. Field measurements began in late June 2015 and continue to be conducted by the farmer. Originally the amount of chickpeas produced in the trials was measured. In

September and October 2015, the amount of oranges produced in the different sites was also measured.

4 Description of system

The physical characteristics of the study site are shown in Table 1. The system is focused on widely spaced orange trees that are 80 years old.

Table 1. General description of the orange grove

General description of system	
Name of group	Intercropping of orange groves in Greece
Contact	Anastasia Pantera and Maria Kasselaki
Work-package	3: High value trees
Associated WP	Use of agricultural crop
Geographical extent	Intercropped orange groves are found in Greece, India with leguminous species (Lachungpa, 2004), USA with Lima beans (Fortier, 1940), Brazil with vegetables or cotton (Smith et al. 1995).
Estimated area	38,780 ha of orange groves (ELSTAT, 2015)
Typical soil types	Luvisols
Description	Orange groves are found in many areas of Greece. Citrus groves of orange, tangerine and lemon trees are a characteristic land use system in Chania, Crete, Greece. In the past, farmers used to cultivate crops in between citrus trees but also after pollarding them to change variety. They also used cypress trees as hedgerows to protect citrus trees from winds (as windbreaks). However nowadays many farmers have removed cypress trees from the hedgerows or have uprooted the citrus trees and switched to avocado monoculture for higher profit. Only a few farmers still practice agroforestry as citrus trees typically with vegetable intercrops ensuring a steady economic return each year until the tree crown fully develops and prevent any further intercropping. Poultry production is sometimes practised after crown development.
Tree species	Orange (*Citrus sinensis*[1])
Tree products	Oranges for direct consumption and the production of orange juice. The present selling price for producers ranges from 0.17 to 0.20 euros per kilo, which is considered insufficient to cover cultivation expenses. Capital controls in Greece, due to the economic crisis, have negatively affected fruit exports including oranges. Greece is the 17th out of 121 orange producing countries contributing by 805,500 tonnes to the world total of 71.3 million tonnes (FAOSTAT 2013).
Crop species	Chickpeas (*Cicer arietinum*) and potatoes (*Solanum tuberosum*)
Crop products	Chickpeas and potatoes
Other provisioning services	Possibility of using tree pruned branches as fodder, and eventually tree wood as fuel wood.

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

	Multiple products such as liqueurs, sweets, marmalades, and dried oranges are produced and sold separately. Extracts used in pharmaceutical and fragrance sector as well as in cooking and nutrition in general. Provide employment to rural areas, reduces urbanization.
Regulating services	The trees reduce local wind speed and protect soils from erosion The chickpeas contribute to soil nitrogen content and reduce the demand for chemical fertilizers.
Habitat services and biodiversity	Multiple crops enhance biodiversity.
Cultural services	It is a traditional system. Every year numerous folklore festivals are organised promoting oranges and relevant old traditions.
Key references	See end of report

Table 2. Description of the specific case study system

Site characteristics	
Area: Co-ordinates: Site contact: Site contact email address	0.2 ha 35°25'50.31"N; 23°54'54.42 "E; 102 m a.s.l. Maria Kasselaki, Anastasia Pantera kasselakis.skines@gmail.com pantera@teiste.gr
Example photograph	 Figure 1. Intercropping of oranges near Chania, Crete

Figure 2. Intercropping between oranges near Chania in Crete

Map of system

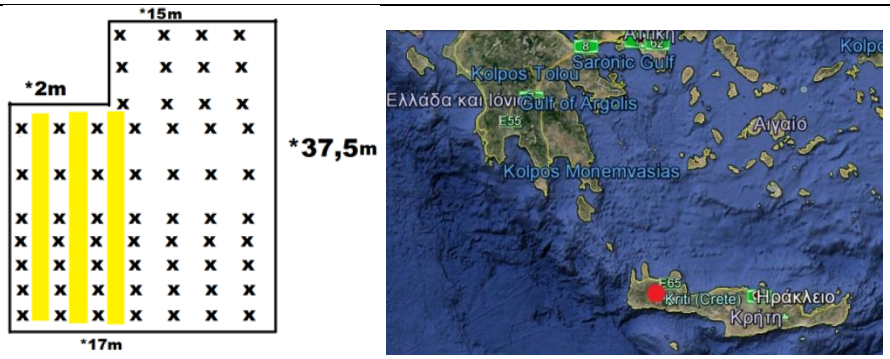

Figure 3. A map of the orange orchard site. A 0.2 ha area was intercropped with chickpeas and potatoes. Each yellow line includes two rows of chickpeas. Another 0.2 ha of the orchard contains orange trees and other tree species, and the rest are only orange trees and will be used as control. Experimental design with the chickpeas highlighted in yellow. The trial is located in Western Crete (Google maps).

Possible modelling scenarios	
Comparison	Technical and economic analysis of intercropping vs not intercropping
Climate characteristics	
Mean monthly temperature	18.8°C
Mean annual precipitation	622 mm
Details of weather station (and data)	Chania Meteorological Station (35°30′N, 24°02′E, 62 m), period 1961-1994.
Soil type	
Soil type	Luvisol
Soil depth	< 1 m
Soil texture	Sand 59.2%, silt 24.0%, clay 16.8%
Additional soil characteristics	pH 6.52 (slightly acid), total $CaCO_3$:0.88 (low), Organic matter content: 2.41%; electric conductivity 0.245 (low), Nitrogen (nitrate) 0.25 mg kg^{-1}, P: 0.80 mg kg^{-1}, K: 100 mg kg^{-1}, Ca: 409 mg kg^{-1}; Mg:

	72 mg kg^{-1}, Fe: 15 mg kg^{-1}, Zn: 1.70 mg kg^{-1}, Mn: 3.33 mg kg^{-1}, Cu: 3.07 mg kg^{-1}
Aspect	South
Tree characteristics	
Species and variety	Orange (*Citrus sinensis*) Valencia
Date of planning	80 years ago
Intra-row spacing	10 m
Inter-row spacing	10 m
Typical orange yield	25 t ha^{-1}
Typical increase in tree biomass	To be confirmed
Crop/Understorey characteristics	
Species	Chickpeas (*Cicer arietinum* var Amorgos), Potatoes (*Solanum tuberosum*)
Management	Conventional management with mowing, fertilization and pesticide spraying
Typical crop yield	Chickpeas approximately 2 t ha^{-1}, potatoes 40-50 t ha^{-1}
Financial and economic characteristics	
Indicative costs	One 50 kg bag of chickpeas costs about 100 euros Seed rate is about 150 kg ha^{-1} One 25 kg bag potatoes costs about 26 euros Seed rate is about 2.0-2.5 t ha^{-1}

5 Description of the tree component

5.1 Variety

Local farmers have switched from local to different orange varieties such as “Californian” types and lately to “faloforo” and “merlin”. Presently “valencia” is the predominant variety mainly used for juice. It is favored for the rich orange color and flavor (Kimball et al. 2004). The harvest season for “Valencia” oranges lasts typically from March to the beginning of August. Orange trees for juice production are a cultivar combining a clonal rootstock to give the tree a particular growth habit, and a clonal scion that determines fruit quality.

5.2 Tree density and height

Most commercial orange orchards tend to be planted at densities of about 300-400 trees per hectare with a spacing 5 m x 5 m or 7.7 m x 5 m (Nanos, 2011). Due to the dense crowns this density limits intercropping. However, during the transition time from one variety to another performed by pollarding, there is the opportunity to cultivate a vegetable crop between the rows. Also, in traditional systems tree density is low with the trees being planted at densities of 10 m x 10 m. Tree height reaches 8 m.

5.3 Relationships between orange yield, and tree size, age and density

According to Wheaton et al. (1995), yield increases with increasing tree density during the early years of planting. However growth rate diminishes substantially above 1000 trees/ha and yield is independent of density at tree maturity. Tree spacing is considered to have only minor effects on fruit quality. Wheaton et al. (1995) also reports planting densities in the range of 350 to 1000 trees/ha in Florida, using lower densities for more vigorous combinations.

6 Trial design

6.1 Conceptual design and treatments

The trial design comprises three treatments (Table 3). These are: i) orange trees + chickpea, ii) orange trees + potatoes, and iii) orange trees alone as a control. There is no replication. The distance between the trees is 2 m.

Table 3. Description of the three treatments

Treatment	Tree species	Understorey crop
1	Orange	Chickpea
2	Orange	Potato
3	Orange	Control

Crop sowing was delayed due to the very rainy spring period and took place in the first week of April 2015 and will be repeated in spring 2016 and 2017.

7 Measurements

The planned measurements to be taken in the two treatments are described below (Table 4).

Table 4. Planned measurements at the site

Agroforestry component	Measurements	
Tree characteristics	• Trees canopy inside each experimental plot. • Two diameters of tree canopy in a cross form will be measured for each tree in m. • Tree breast height diameter • Leaves examined for their nutrient content (Five measurements are to be taken per tree) • The height to the base of the tree canopy (All measurements will be repeated at the beginning and at the end of the trial) • Weight and condition of the orange crop with intercrop • Weight and condition of the orange crop w/o intercrop	To be included To be included To be included To be included To be included 6 t ha^{-1} 5 t ha^{-1}
Crop characteristics	• Total crop: chickpea with orange[1] • Chickpea without oranges • Potato yield will be measured at the end of the growing season (Crop sampling plots will include plots in close proximity to the tree canopy and in the center between the tree rows).	800 kg ha^{-1} 1300 kg ha^{-1}
Soil characteristics	Soil texture Soil pH Total $CaCO_3$ Organic matter Electrical conductivity Nitrogen (nitrate)	Sand 59.2%, silt 24.0%, clay 16.8% 6.52 (slightly acid) 0.88 % (low) 2.41% 0.245 dS m^{-1} 0.25 mg kg^{-1}

	Phosphorus, P Potassium, K Calcium, Ca Magnesium, Mg Iron, Fe Zinc, Zn Manganese, Mn Copper, Cu	0.80 mg kg^{-1} 100 mg kg^{-1} 409 mg kg^{-1} 72 mg kg^{-1} 15 mg kg^{-1} 1.70 mg kg^{-1} 3.33 mg kg^{-1} 3.07 mg kg^{-1}
Management characteristics	Tree damage from machinery operations Labour inputs Dates of any field operations such as topping, spraying and mowing Costs of sprays used Cost of pruning Record of the dates, quantity, and types of fertilizer	None 60 euros 15 November 2015 60 euros 120 euros 100 euros for fertilizers

[1]Note that 2015 had a humid spring with high rainfall that negatively affected flowering and seed formation in chickpeas.

8 Acknowledgements

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