System Report:
Intercropping of Olive Orchards in Italy

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Work-package	3: Agroforestry for High Value Trees
Specific group	Intercropping of Olive Orchards in Italy
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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 modeling activities which help to address Objective 3.

2 Background

In Italy over one million ha of olive (*Olea europea*) orchards risk large scale abandonment, since the removal of trees is prohibited, the olive oil price is relatively low, and the de-coupling of subsidies from production have made harvesting unnecessary. The economic gain could be improved by intercropping olive trees with other viable crops grown beneath the canopy (Rosati et al. 2012, Daoui and Fatemi, 2014). This may provide additional income, and promotion of the advantages of agroforestry practices may increase farmer interest in olive groves (Tsonkova et al. 2012, Pisanelli et al. 2014). However, selection of appropriate species and management practices are important if the efficiency of and ecosystem service provision from agroforestry are to be maximized (Tsonkova et al. 2012).

Wild asparagus (*Asparagus acutifolius*) holds particularly high potential as a new crop, in combination with the olive tree (Mantovani and Rosati 2014). Since the plant naturally grows in abandoned olive orchards, and the market for its spears is already established, its cultivation appears profitable. To optimize the land use and further diversify the outputs, other crops could be added to asparagus production in olive orchards. Bulb crops appear to be an interesting alternative to arable crops, since they are perennials like the asparagus (i.e. no cultivation is required), but they produce vegetation in winter and spring, leaving the soil bare during the summer and the olive harvest time in the autumn.

3 Update on field measurements

Field measurements described in the research and development protocol (Rosati and Mantovani, 2015) began at the end of 2014, and will continue till the end of 2016.

Photosynthetic characterization of wild asparagus has been completed. This includes light and CO_2 response curves for full and partial light treatments and temperature response curves. The effect of water stress on photosynthesis has been measured and a scientific article is being prepared.

The level of photosynthetically active radiation (PAR) transmitted through traditional and super-high-density (i.e. small trees planted in a hedgerow) olive orchards was measured along transects from the row to the inter-row. The biomass growth and characterization of the wild asparagus in the different treatments has been established and soil water content have been monitored. The above data will be used for modeling wild asparagus growth and development in order to help identify the best planting positions, to explain tree-crop interactions, and to explain the possible advantages and disadvantages of agroforestry combinations.

Bulb performance under olive orchards is currently being described in terms of compatibility of bulb management practices with olive management practices.

4 Description of system

Table 1 provides a general description of the agroforestry system for intercropping of olive orchards in Italy. A description of a specific case study system is provided in Table 2.

Table 1. General description of the agroforestry system for intercropping of olive orchards

General description of system	
Name of group	Intercropping of Olive Orchards in Italy
Contact	Adolfo Rosati, Dario Mantovani, CRA, Spoleto, Italy adolfo.rosati@entecra.it
Work-package	3: Agroforestry for High Value Trees
Geographical extent	Naturally occurring wild asparagus are typically present and often exploited in all but the intensively cultivated olive orchards in Italy (and in the Mediterranean), which could be equivalent to the greatest part of one million (Italy) or five million (EU) hectares of olives. However asparagus plants are usually only sparingly present and in low numbers per hectare, and typically are not cultivated.
Estimated area	Since the start of the project, a few dozen farmers have been asking questions and planting wild asparagus plants under their olive orchards in Italy. Probably many more farmers have done so, even if without contacting us, based on published work. The total area cultivated with wild asparagus is probably still negligible at the national level.
Description	Growing understory crops in an olive orchard was a common practice before agricultural intensification; however the cultivation of the wild asparagus in the olive orchard is novel. The wild asparagus plants are established along the row at a spacing of about 40 cm within the row. Asparagus is a perennial plant; the edible spears are collected every year, in spring whereas the ferns are photosynthetically active for several years. If well managed, the wild asparagus vegetation does not impair field practices in the olive orchard such as harvesting and pruning.
Tree species	Olive tree (*Olea europaea* L.)
Tree products	Olive oil
Crop species	Wild asparagus (and cut flowers)
Crop products	Wild asparagus spears (and cut flowers)
Regulating services	The trees can provide shade for asparagus and mitigate high temperatures and water stress in summer. As a perennial understory crop, asparagus can prevent soil erosion (olive trees are often grown on slopes).

	The agroforestry system can also provide wild edible greens and fodder. The understory crops, especially bulbs, when cultivated in the orchard, can add landscape value (cultural), pest and disease control (regulation) through increased biodiversity, and improve water-use-efficiency (regulation) via intensifying vegetation (i.e. more efficient use of water through spatial root and canopy vegetation) and via reducing the proportion of evaporation from the soil vs. transpiration through the plant.
Habitat services and biodiversity	Increased biodiversity and positive effect on wildlife as compared with the olive orchard.
Key references	See end of report

Table 2. Description of the specific case study system

Specific description of site	
Area	The field trial includes two olive treatments (traditional and super-high-density orchards), plus the control (asparagus in open field). For the pot experiment two treatments (full and partial light availability) are being considered, both at full water availability and under water stress. Potted plants are kept under semi-controlled environmental conditions. The total area for all experiments is about 500 m^2.
Address and co-ordinates	Colle Cecco, Castel Ritaldi (PG), Italy: 42°48'34.4"N 12°39'39.7"E
Site contact	Adolfo Rosati
Site contact email	adolfo.rosati@entecra.it
Example photographs	

Figure 1. Olive-asparagus-bulb system with high density olive orchard system

Figure 2. Olive-asparagus-bulb system with traditional olive orchard system

Figure 3. Olive-asparagus-bulbs system in open field

Aerial photograph of system

Figure 4. Colle Cecco experimental farm: a map of the three systems 1) Super-High-Density olive orchard-asparagus-bulbs, 2) asparagus-bulbs system in an open field, 3) Traditional olive orchard-asparagus-bulbs system.

Possible modelling scenarios	
Comparison	Technical analysis of the asparagus-bulbs system in open field vs. olive-asparagus-bulbs system in olive orchard with i) super-igh-density system and ii) traditional system
Climate characteristics	
Mean monthly temperature	12.6 °C
Mean annual precipitation	870 mm
Details of weather station	Data from 1976-2006 from the meteorological station at Perugia
Soil type	
Soil type	Calcareous marl/marlstone
Soil depth	>120 cm
Soil texture	Silty clay
Tree characteristics	
Species and variety	*Olea europea,* multiple varieties
Date of planting	Established in 2007
Intra-row spacing	Super-high density system 4 m; traditional system 5 m
Inter-row spacing	Super-high density system 1.5 m; traditional system 3.5 m
Tree protection	The systems are fenced by wire mesh
Typical increase in tree biomass	Currently being measured

Crop/understory characteristics	
Species	*Asparagus acutifolius,* *Narcisus* L. *var.* Tete à Tete, Johann Strauss, King Alfred, Ziva Paper withe, and Poeticus Recurvus *Tulipa kaufmanniana* R. Var. Giuseppe Verdi
Management	Wild asparagus were established in 2014 Bulbs were established in 2015
Typical in open field	1300 kg ha^{-1} a^{-1} (Benincasa et al. 2007)
Fertilizer, pesticide, machinery and labour management	
Fertilizer	100 kg N ha^{-1} (as ammonium sulphate)
Pesticides	None
Machinery	Tractor (at planting time) and weed whacker afterwards.
Financial and economic characteristics	
Costs	Some figures on harvest man-hours and price per kg of spears, provided in Benincasa et al. 2007. Costs for olive growing and harvest, well established in the literature, both for traditional and super-high density orchards.

5 Description of tree component

In Italy, olive trees are grown mostly in traditional orchard systems, with tree density varying from 100-200 trees per hectare, to 300-500 trees per hectare in more recent, intensive orchards. A new super-high density system with 1000-2000 small trees planted in a hedge has been proposed in the last two decades and has been increasingly adopted, first in Spain and then in Italy and Portugal. Although this system still represents a small proportion of the total area, it is possible that it will be adopted on a much wider area, due to its advantages in terms of the mechanisation of harvest using straddle machines (as used for grapes with small modifications), thus reducing hand labour and costs. Few varieties are suitable for such systems but some are being developed. In this trial, therefore, this super-high-density treatment has been included since it could represent a significant model of olive growing in the future and it is already adopted over more than 80,000 hectares worldwide.

6 Trial design and treatments

The idea developed here was to test the cultivation of a wild asparagus species as an understory crop under the olive trees, as an additional source of income for the farmers. It was important to test the intercropping under representative olive growing conditions. Therefore the olive-asparagus trials were designed and implemented in both a traditional orchard with large trees and uniform canopy cover, and in a super-high density orchard with trees with an inter-row spacing of 4 m and an intra-row spacing of 1.5.

The asparagus were planted along the tree rows. In between the rows bulb crops were also planted with the idea that the vegetative period of bulb growth (autumn to spring) would occur after harvest and before the pruning of the olive orchard.

7 Preliminary results

Initial results indicate that photosynthetic rates of the wild asparagus, previously unknown, appear to be similar to those of cultivated asparagus. The wild asparagus appears to have high tolerance of high temperatures, with an optimal temperature of about 30°C and positive photosynthesis up to 45°C.

The light transmitted through the olive trees and available to the asparagus, was about 40% in the traditional orchard and about 46% in the super-high density. This was due to the hedge-like shape of the super-high-density systems where the small trees do not intercept most of the light incident over the inter-row during the most sunlit hours of the day, unlike the trees in the traditional systems where the much bigger trees have an almost complete canopy cover. In fact, the spatial variation in the super-high-density treatment was much greater with the proportion of transmitted light ranging from 24% under the tree rows, to 62% between the rows (the range was only 36-50% in the traditional system).

Asparagus productivity was greater in the open field control than within the olive orchards indicating that the effect of greater light availability was more important that the effect of higher temperatures and evapotranspiration. Thus within an olive orchard, positioning the wild asparagus where light availability is greatest is likely to result in highest yields.

8 References

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