Research and Development Protocol for Timber Trees intercropped with Cereals in Italy

Project name	AGFORWARD (613520)
Work-package	4: Agroforestry for Arable Farmers
Specific group	Timber Trees intecropped with cereals in Italy
Milestone	Milestone 16 (4.3) Part of experimental protocol for WP4
Date of report	2 April 2015
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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 the initial research and development protocol (Milestone 16 (4.3)) for the participative research and development network focused on the use of agroforestry on arable farms.

2 Background

Poplar hybrids and species has been intensively managed in Italy for timber production mostly in monoculture plantations, but often in intercropping systems (intercropping of arable crops in between young tree rows) and in linear plantations along field edges, drainage canals and streams (Eichhorn et al. 2006). However the growing of poplar in all of these systems is currently declining because of a stagnating domestic timber market (Minotta et al. 2015). Urgent environmental concerns, such as sequestration of carbon sequestration, provision of bioenergy, and soil erosion control, could open new opportunities for poplar silvoarable systems and linear planting (Dalla Valle 2011; Correale et al. 2011; Veneto Agricoltura 2002). In some circumstances there may be options for phytoremediation (Bianconi et al. 2011). Furthermore, the current agricultural policy of the European Union could create new opportunities for the establishment and management of timber trees in agricultural areas, reversing the decline of trees outside forest characterizing the deployment of modern intensive agriculture in the last decades (Eichhorn et al., 2006). The new rural development plans (2014-20) are currently being implemented with possible direct measures for establishing new agroforestry systems, and the inclusion of agroforestry in the ecological focus areas (Pisanelli et al. 2014).

The Casaria farm, in the Veneto region, covers about 65 ha. In 2013, an agroforestry system occupying about 15 ha was established by planting poplar cuttings and oak seedlings along field edges and drainage ditches. The farm owner decided to establish the agroforestry system using the public subsidy of the regional rural development plans (2007-2013), Measure 222 “New establishment of agroforestry systems”. Hybrid poplar I214 (*P. x canadensis*) was chosen because it is adapted to local site conditions, it has a history of being grown in the area, and there is an existing structured market. Currently, poplar is an appropriate choice for establishing timber plantations or agroforestry systems on alluvial agricultural soils in many areas of Italy. Pedunculate oak (*Quercus robur*) seedlings were provided by a local nursery managed by the public regional Agency Veneto Agricoltura. Pedunculate oak is endemic to the study area and is being investigated for timber production in mixed plantations (Morhart et al. 2014; Corazzesi et al. 2010; Veneto Agricoltura 2010).

A meeting of the Alley Cropping Systems in Italy with stakeholder group was held on 24 June 2014 (Pisanelli et al. 2014). During this meeting a list of possible innovations was developed. These innovations will be addressed at the agroforestry system site close to Casaria, Italy. These include:

- Assessing competition and/or synergies between crops and trees for light and water;
- Compare productivity in agroforestry and conventional agricultural systems;
- Assessing tree spacing in agroforestry system on timber quality.

3 Objective of trial

The objective of the trial is to assess competition between crops and trees for light and water at different spatial designs. Key questions include:

- How does agroforestry affect crop yield?
- How does agroforestry affect water and light competition between trees and intercrop?
- How does tree spacing in agroforestry system affect timber quality?

Alongside these aims, a number of hypotheses can be developed:

- Young trees should not or only marginally affect crops (see Figure 1);
- Soil moisture competition between crops and trees is expected to be marginal because trees are expected to extract water from deeper soil layers than crops.
- Wide tree spacing may decrease timber quality in terms of stem form and branching habit.

4 System description

The agroforestry system comprises oaks and poplar intercropped with cereals. Trees are planted on the border of the fields: the distance between the rows is about 35 m. In the row, poplars (*Populus spp*) have been planted every 10 m, alternated with oak (*Quercus robur*), i.e. there is 5 m between the trees. In the photo only the poplars are still visible over the cereals (Figure 1).

Figure 1. Hybrid poplars and oak intercropped with cereals at Casaria Farm (source: P. Paris, summer 2014) (only the poplar are visible).

Table 1. Description of the site, with soil, tree, understorey and climate characteristics

Site characteristics	
Area (ha):	65 ha of which 15 ha are managed as agroforestry system intercropping poplar and oaks with established in 2013
Co-ordinates:	45°08'24.87"N, 11°30'25.61"E
Site contact:	Cristina Dalla Valle; Pierluigi Paris
Site contact email address	cristina.dallavalle@venetoagricoltura.org; piero.paris@ibaf.cnr.it

Soil characteristics	
Soil type (WRB classification)	WRB (1998): Calcari-Fluvic Cambisols USDA(1998): Oxyaquic Haplustepts coarse-loamy, mixed, mesic
Soil depth	Very deep soil > 1 m
Soil texture (sand%, silt%, clay%)	Alluvial soil, formed by sands and lime, from very to extremely calcareous. Loamy texture in surface and coarse in substrate. Good drainage, moderately high permeability and very deep aquifer.
Additional soil characteristics	Chart of Veneto soils- cartographic unit: BR2.2 http://www.arpa.veneto.it/suolo/htm/carte_web.asp

Tree characteristics		
System	Agroforestry system	Reference system*
Tree species	*Populus x euramericana* (Dode) Guiner and *Quercus robur peduncolata*	None
Variety/rootstock	*Clone I-214 (poplar)*	None
Tree density (spacing)	1 row each 35 m. In the row there is a poplar each 10 m, alternated with oak	None
Tree protection	Shelters	None
Additional details	Guardian pole for oak	

Crop characteristics		
System	Agroforestry system	Reference system
Species	Sugar beet (*Beta vulgaris*);	Sugar beet (*B. vulgaris*)
Coverage	Complete	Complete
Additional details	Previous year crops: maize, durum wheat and soya bean in green manure	Previous year crops: maize, durum wheat and soya bean in green manure

Climate data (2014)	
Mean monthly temperature	14.7 °C
Total annual precipitation	1024 mm
Details of weather station (and data)	Historical data from 2010 to 2014 http://www.arpa.veneto.it/arpavinforma/bollettini/dati-storici

* To which the agroforestry system is compared

5 Trial design

5.1 Conceptual design

A key objective of the research study is to measure yield differences between alley cropping and conventional agricultural systems. The treatments are described in Table 2.

Table 2. Description of treatments

Agroforestry treatment	Arable treatment
Alley cropping	Reference crop
Trees: Poplar and oak	No trees
Crop: crops rotation	Crops rotation

5.2 Description of design

Intercrop alleys are alternated with tree rows with a distance of about 35 m. Tree rows are oriented in a north-south direction along field edges and drainage ditches. Tree rows are 400-450 m long, and poplars are planted at approximately 10 m intervals, alternated with oak (*Quercus robur*). As shown in Figure 3 only the poplars are visible over the cereals.

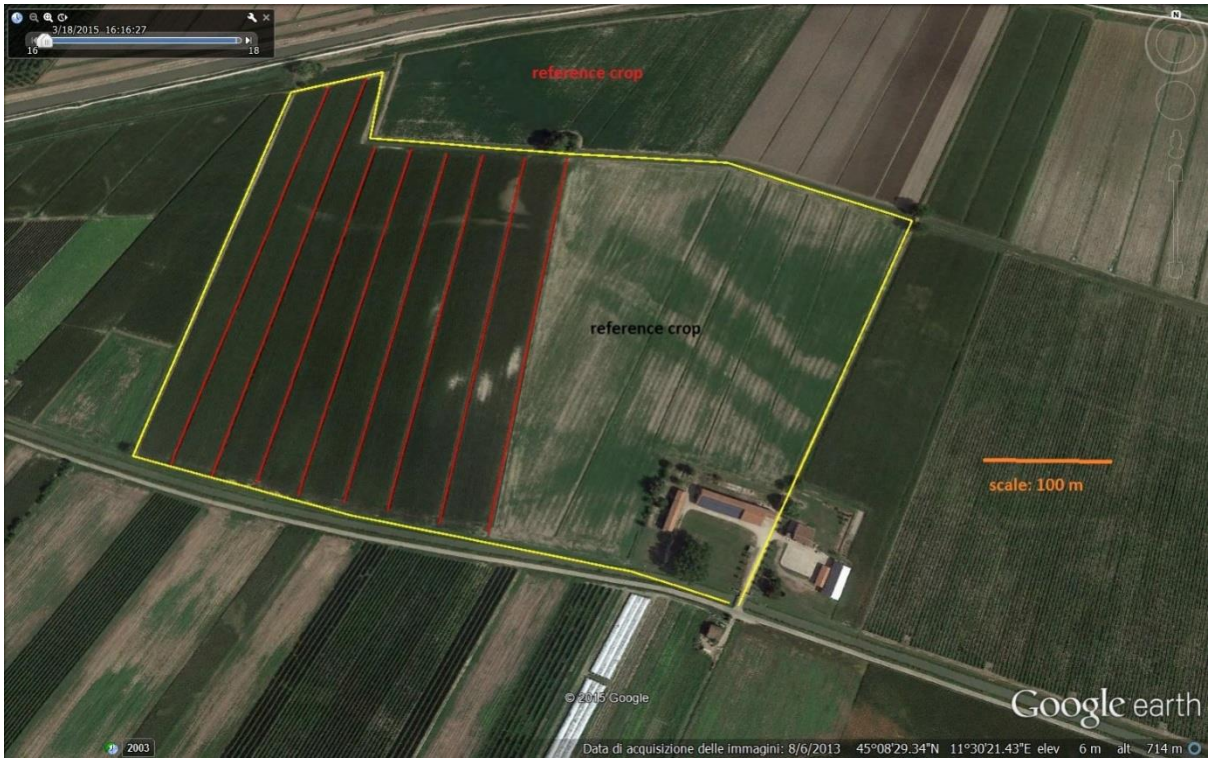

Figure 2. Map of the Casaria Farm. The yellow line is the border of the agroforestry area. The red lines represent the tree rows alternated with arable areas.

6 Measurements

The planned measurements to be taken in the three treatments are described in Table 3.

6.1 Growth and yield measurements

Measuring tree growth

- Tree total height, DBH, branching height, crown radius of poplar and oak trees will be measured annually, during the winter season

Measuring yield for crop

- Within the intercrops alleys, sample plots will be laid out in perpendicular direction to the tree rows, with increasing distance from the tree base. For the reference site, several crop plots will be sampled.
- Above ground biomass in these plots will be manually harvested at crop maturity using 1 m x 1 m sampling area.

Tree basal area and crop reference yield

- Tree basal area (TBA) and crop equivalent ratio (CER) will be used to evaluate the effect of trees on intercrops. Basal tree area (TBA, m^2/ha) will be calculated as TBA = (π / 4000) x DBH^2 x *d* (where *d* is the number of trees per hectare). CER is the crop agroforestry yield ($Y_{crop\text{-}AF}$) underneath the tree canopy cover, expressed in percentage to the crop monoculture yield ($Y_{crop\text{-}mono}$), not affected by the tree competition (CER = ($Y_{crop\text{-}AF}$ x 100) / $Y_{crop\text{-}mono}$). Significant correlations could be found between TBA and CER, and these regression equations can be used to estimate the relationship between crop agroforestry yield and tree growth/dimension in agroforestry systems (Paris et al. 2013, Minotta et al. 2015).

Timber quality

Non-destructive measurements and observations on tree trunk will be carried out to detect the effect of wide tree spacing on timber quality of poplar trees. The following equation will be used (VVAA, 2000):

$Q = 3H - (E + F + DI + DF + DM + CF + Kn + EB)$

with: *Q*= index of wood quality; *H*= log value, as function of log length and straightness index of log axis; *E* = log eccentricity; *F*= fibre orientation; *DI* = absence/presence of insect damage; *DF* = absence/presence of bacteria/fungi damage; *DM* = absence/presence of mechanical damage; *CF* = presence/absence of critical fork; *Kn* = presence/absence of knots with a diameter ≥ 2 cm; *EB*= presence/absence of epicormic branches.

6.2 Hemispherical photos

Hemispherical photos are digital photos taken with a fish-eye lens from underneath the tree canopy. These photos can be used to estimate solar radiation penetrating through the canopy, as Total Light Transmittance (TLT, in %). TLT is an estimation of available for the herbaceous vegetation in agroforestry systems. Hemispherical photos will be taken at increasing distances from the tree row, along transects perpendicular to tree lines, in order to estimate the available solar radiation for intercrops progressively far away from tree shading. Measurements will be replicated in representative dates throughout growing seasons. Digital photos will be analysed with the Gap Light Analyser software (Frazer et al. 2000),

6.3 Water oxygen stable isotopes

Oxygen stable isotopes can be used as natural tracers for studying the sources of water and processes of water use by plants. Soil water is usually characterized by varying patterns of isotopic composition ($\delta^{18}O$) along the soil profile. Both climate and hydrology influence $\delta^{18}O$ values of different water pools, as a result isotopic compositions are different for shallow, medium and deep soil layers. No isotopic effects occur during water uptake by roots or during xylem transport, so that xylem water $\delta^{18}O$ reflects a weighted average of the different water sources used by the plant. In contrast, leaf water $\delta^{18}O$ is enriched by evaporative effects that occur during transpiration. Oxygen stable isotopes will be used to elucidate the strategies of plant water use in pure and mixed systems, based on quantifying the variation in oxygen isotope composition of soil and plant tissue water.

More insights on the theoretical and practical issues of oxygen isotope composition of soil and plant tissue water are reported in Dawson et al. (1998; 2002), Lauteri et al. (2006) and Alessio et al. (2004). We will test the hypothesis that poplar trees exploit different water pools from intercrops due to the effects of rainfall distribution pattern and soil moisture stratification.

Analysis of oxygen isotope composition will be performed on water samples cryogenically extracted from small-lignified stems (xylem water) of poplar, and soil (soil water). Data will refer to soil and xylem water that will be collected during summer 2016 and/or 2017. Particularly, twigs will be collected from intercropped poplar trees. We are planning to sample xylem and soil water in two different periods of the growing season, reflecting the non-limiting and limiting dry periods of the season. Soil samples will extracted with a manual auger at different depths to determine gravimetric soil moisture assessment. Xylem and water samples (about 1 ml) will be analyzed using a dual inlet isotope ratio mass spectrometer (SIRA II, VG ISOTECH, Middlewich, UK) equipped with a water-CO_2 equilibration system (ISOPREP 18, VG ISOTECH, Middlewich, UK).

Table 3. List of measurements to be taken in the treatments

Component	Agroforestry treatment (Tree and crop components)	Arable treatment
Tree component	Tree height, DBH, branching height, crown radius Timber quality Hemispherical photos Leaf phenology	 Hemispherical photos
Crop	Crop phenology and yield	Crop phenology and yield
Soil	Soil moisture	Soil moisture
Water use	Soil and plant water stable isotopes	Soil and plant water stable isotopes

7 Acknowledgements

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