Research and Development Protocol for Agroforestry for Arable Farmers in Western France

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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 integration of trees on arable land.

2 Background

Trees intercropped with arable crops can grow as well as those within a forest environment (Balandier and Dupraz, 1998). However the work of Balandier and Dupraz related mostly to young trees aged below ten years; very few results are available on older trees.

The initial stakeholder meeting in Western France (Cirou and Hannachi, 2014) highlighted the silvoarable systems established by Mr Claude Jollett at the Eduts farm. In 1973, an agroforestry system was established on 55 ha: 45 ha of black walnut (*Juglans nigra*) and 10 ha of wild cherry (*Prunus avium*). The inter-row spacing is 14 m with 7 m between trees. The study site provides an excellent opportunity to study the influence of agroforestry on growing black walnut trees older than 38 years, and the effect of the trees on arable yields (Table 1). The recent low cereal yields meant that he did not plant a cereal crop in 2014, and the clover cover crop was unsuccessful. However, he remains open to enter into a process of research and demonstration subject to technical and financial support.

3 Objectives of research

The objectives of the research, related to the trees, are:

- to produce quantitative information about branches biomass of black walnut;
- to compare the branch biomass of trees in an agroforestry plantation with trees of the same age in a forest plantation;
- to define allometric equations relating branch biomass with tree diameter at breast height.

This research is being conducted by the Institute for Forest Development (IDF) in collaboration with the French Association of Agroforestry (AFAF).

The objective of the research, related to the crop, is

- to compare crop yields between an arable control, an unthinned agroforestry plot, and an agroforestry plot where the trees have been thinned.

4 System description

The system comprises of black walnut tree planted in 1973 (Table 1).

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

Site characteristics	
Area:	8.5 ha
Co-ordinates:	46°00'39.32"N - 0°13'3.75"W
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Soil characteristics	
Soil type	Rendosol (Baize 2009)
Soil depth	15-30 cm
Soil texture	Currently being analyzed
Additional soil characteristics	pH = 7-8

Tree characteristics		
System	Agroforestry system	Reference (forest) system*
Date of planting	1973	1973
Tree species	Black walnut (*Juglans nigra*)	Black walnut (*Juglans nigra*)
Additional details	Distance between the trees in the line : 7 m Spacing between lines: 14 m	Distance between the trees in the line : 7 m Spacing between lines : 7 m

Understorey characteristics		
System	Agroforestry system	Reference system*
Species	Cereals	Grass
Coverage	Complete	Mechanical maintenance

Climate data	
Mean annual temperature	10.0-11°C
Mean annual precipitation	901-975 mm
Details of data	Data (1961-90) from AgroParisTech et al (2015)

5 Tree measurements

The tree measurements will focus on determining the relationship between total above ground biomass, timber yields and branch yield. Studies of tree biomass partitioning (including the weight of branches) in a temperate climate are rare (Lotfi 2008). The steps include 1) felling a tree without leaves, 2) cutting the trunk and branches into small manageable pieces, 3) drying the wood in an oven, and 4) careful weighing (Walker et al. 2011). This destructive method is then used to develop allometric relationships. An above-ground biomass allometric equation is a statistical model relating the components of a tree to parameters such as diameter at breast height (DBH), height of the tree (Feldpausch et al. 2011), or the height of the crown (Chave et al. 2005).

The biomass and volume estimations will be achieved in two contiguous parcels of 40 year old black walnuts (Table 1)

- Forest plantation: on a 2.5 ha plot, the trees have been installed on four lines of 700 m, 7 m spacing on the line and 7 m between planting lines. The inter-rows have included cover crops and have been weeded using disks
- Agroforestry planting: a neighbouring plot covering 6 ha; black walnut were installed on seven lines of 700 m, 7 m spacing on the line and 14 m between rows; the inter-rows were cultivated every year, most often cereals, over a width of 12 m.

Tree circumferences at breast height were measured in April 2015. During the winter of 2015-2016, 30 trees will be felled in each plot (total = 60 units). The 30 trees will be selected randomly in each stand. The protocol of data collection in the field and building tree biomass allometric equations are based on work done in tropical Africa (Bauwens and Fayolle 2014; Picard et al. 2012). The measurements (Table 2) include total height, the diameter at a height of 1.3 m, and every 50 cm from ground to top of the trunk.

Table 2. List of measured and calculated tree variables

Tree component	Variable	Abbreviation and formula	Unit
Tree	[f] Reference circumference	C_{ref}	m
	[f] Reference circumference height	H_{ref}	m
	[f] Total height	H_{tot}	m
	[c] Total woody aerial biomass	$B_{tot} = B_{Sa} + B_{La} + B_{Ba}$	kg
Stump	[f] Stump height	H_S	m
	[c] Stump surface	S_S	m^2
	[l] Wet stump sample biomass	m_{Sw}	kg
	[l] Dry stump sample biomass	m_{Sd}	kg
	[c] Water content of stump wood	$WC_S = (m_{Sw} - m_{Sd})/m_{Sw}$	%
	[c] Dry stump biomass	$B_{Sa} = V_{Sw} \times ID_S$	kg
Log	[f] Length of piece$_i$	l_{pi}	m
	[f] Wet biomass of piece$_i$	m_{pi}	kg
	[f] Top diameter of piece$_i$	d_{ti}	m
	[f] Butt diameter of piece$_i$	d_{bi}	m
	[c] Log length	$L_L = \Sigma_i\, l_{pi}$	m
	[c] Wet log biomass (if weighing)	$B_{Lw} = \Sigma_i\, m_{pi}$	kg
	[l] Dry log sample biomass	m_{Ld}	kg
	[c] Water content of log wood	$WC_L = (m_{Lw} - m_{Ld})/m_{Lw}$	%
	[c] Dry log biomass	$B_{La} = V_{Lw} \times (1 - WC_L)$	kg
Branches	[f] Length of piece$_j$	l_{pj}	m
	[f] Top diameter of piece$_j$	d_{tj}	m
	[f] Butt diameter of piece$_j$	d_{bj}	m
	[c] Wet branches biomass	B_{Bw}	kg
	[l] Wet branches sample biomass	m_{Bw}	kg
	[l] Dry branches sample biomass	m_{Bd}	kg
	[c] Water content of branches wood	$WC_B = (m_{Bw} - m_{Bd})/m_{Bw}$	%
	[c] Dry branches	$B_{wBa} = B_{wBw} \times (1 - WC_B)$	kg

Letters [c], [l] and [f] respectively indicate that the variable is calculated, measured in the laboratory or measured in the field.

6 Crop measurements

The AGFORWARD project provides an opportunity for the partners in the area (IDF, AFAF and APCA) to investigate the interactions between crop yield and tree density. As operational constraints on the farm prevent the establishment of a fully-replicated experiment, the study will focus on a demonstration of cereal yields on three contiguous sites with mature trees at three different densities (Table 3). The thinning of the trees will occur during the winter 2015-2016. The farmer has committed to managing the arable crop in the same way across the three treatments.

Table 3. Description of the three arable treatments

Treatment	Tree density and spacing	Dimensions of arable plot
Arable control	None	
Thinned agroforestry	14 m x 14 m	9 m x 700 m
Unthinned agroforestry	7 m x 14 m	9 m x 700 m

The arable rotation will start with buckwheat (*Fagopyrum esculentum* Moench), which is a relatively undemanding species. By 2016-17, the plan is to plant a cereal crop after discussion with INRA. The buckwheat seeds will be planted in April 2016 using a no-till disc harrow. The appropriate seed rate will be determined from the thousand seed weight and a germination rate of the seeds, established in a germinator. Measurements of above ground biomass and yield (Table 4) will be undertaken in four sample plots (measuring 1 m x 1 m) within each treatment. The location of the samples will be determined after a physicochemical analysis of the homogeneity of the soil at the site. Dry weights will be determined using oven drier or the ABAC MERCI method.

Table 4. Proposed crop measurements

Variable	Unit
Seedling emergence	m^{-2}
Above-ground biomass (fresh weight and dry weight) at flowering	kg m^{-2}
Fresh weight of harvested grains at harvest	kg m^{-2}
Thousand drain weight at harvest	kg

7 Acknowledgements

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