Research and Development Protocol for Silvopastoral Management with Quality Wood Production in Spain

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Work-package	3: Agroforestry for High Value Trees
Specific group	Silvopastoral Management with Quality Wood Production in Spain
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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 10 (3.3), for the participative research and development network focused on the use of agroforestry with high value trees.

2 Background

Europe has a shortage of quality wood and therefore there is a growing interest in the establishment of hardwood plantations. In Spain, hardwood species are commonly harvested after long rotations of up to 50 or 60 years. However with intensive management, rotation length can be reduced by half to 20-25 years. Fertilization and herbicide application are the most controversial management practices because of the high costs involved (Rigueiro-Rodríguez et al. 2009) and their impact on soil and water pollution. Silvopastoral management and implementation of legume pastures could reduce the economic costs of these plantations and optimise their environmental functions (Gselman and Kramberger, 2008; López-Díaz et al. 2010; McCarteney and Fraser 2010).

This study will be carry out in an intensive plantation of walnut for the production of quality timber located in Extremadura owned by the company Bosques Naturales S.A. This company owns 1300 hectares in Spain for timber quality production with forestry certification by the Forest Stewardship Council (FSC).

3 Objective of experiments

The objectives of these experiments are to test alternatives to the traditional methods of fertilization and the control of competing herbaceous vegetation by the use of legumes and grazing with sheep. The initial hypotheses are:

- There is not significant competition for soil water between trees and herbaceous plants because their root systems are developed at different depth and their water requirements are separated in time.
- Tree growth is not reduced by herbaceous strata due to the nutrient competition.
- Legumes fix nitrogen and improve the availability of soil phosphorus, however there may be some competition for other nutrients.
- Grazing beneath trees improve soil fertility and tree nutrition.
- Silvopastoral systems reduce nitrogen contamination. Trees in silvopastoral systems develop deeper root systems that reduce nitrate leaching.
- The establishment of silvopastoral systems increases carbon sequestration of the system, as a result of increased productivity of the system.

4 System description

The experiments were carried out in Extremadura (Spain) (Figure 1 and 2) in a 15-year old hybrid walnut (*Juglans major* x *nigra* mj 209xra) plantation, with a density of 333 trees ha^{-1} owned by the company Bosques Naturales S.A. Two experiments have been established: one for testing alternatives to the traditional mineral fertilization called “Fertilized walnut”; and one with different techniques for controlling the competition of herbaceous strata behind trees hereafter called “Grazed walnut”.

Figure 1. Fertilized walnut experiment

Figure 2. Grazed walnut experiment

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

Site characteristics	
Area:	9.72 ha
Co-ordinates UTM:	ETRS89 huso 20: X:298.303 Y:4.442326
Altitude	309 m.o.s.l
Slope	<5%
Site contact:	Gerardo Moreno
Site contact email address	gmoreno@unex.es

Soil characteristics	
Soil type (WRB classification)	Fluvisols
Soil depth	>140 cm
pH	5-6
Soil texture	Sandy loam

Tree characteristics		
Experiment	Fertilized walnut	Grazed walnut
Tree species	*Juglans major* x *nigra*	*Juglans major* x *nigra*
Variety/rootstock	mj 209xra	mj 209xra
Tree density (spacing)	5 x 6 m	5 x 6 m
Mean height	8.33	8.33
Mean breast diameter (1.3m)	19,4	16,1
Tree protection	None	None

Understorey characteristics		
Experiment	Fertilized walnut	Grazed walnut
Species	Grass except in ploughed plots	Grass expected in sown plots with legumes
Coverage	Complete	Complete
Additional details	Grass managed by grazing in late Spring	Grass managed by mowing, clearing and grazing depending on treatments

Livestock characteristics		
Experiment	Fertilized walnut	Grazed walnut
Species	Sheep	Sheep
Stocking density	1 sheep ha^{-1}	

Climate data	
Mean monthly temperature	14.1°C
Mean annual precipitation	844 mm

5 Experimental design

Two sets of experimental treatments have been established (Table 2 and Figures 3 and 4).

Table 2. Description of the treatments in the two experiments

Experiment	Treatments			Replications
Fertilized walnut experiment	*Mineral fertilization:* application of 40 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1}	*Sowing of legumes:* complemented by the same quantities of PK as mineral treatment	*Control treatment*	*6 replicated plots per treatment*
Grazed walnut experiment	*Ploughing*	*Clearing*	*Grazing*: 1 sheep ha^{-1}	*9 replicated plots per treatment*

[1]Each plot is formed by 3 alleys and 2 tree rows of 30 trees each one.

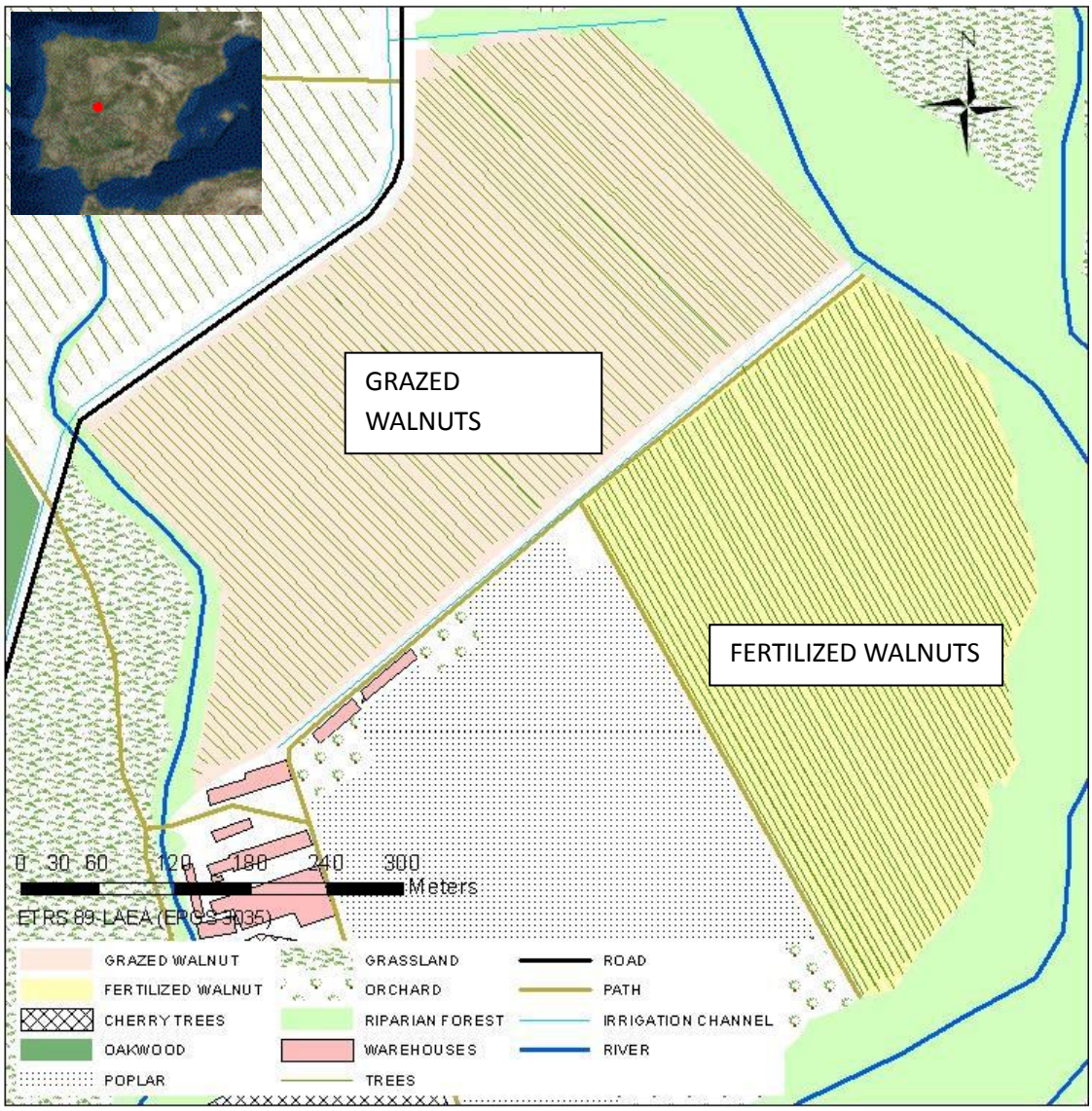

Figure 3. Map of location of the two field experiments for silvopastoral management of walnut plantations: sown legumes as alternative to mineral fertilization, and grazing to control of herbaceous vegetation

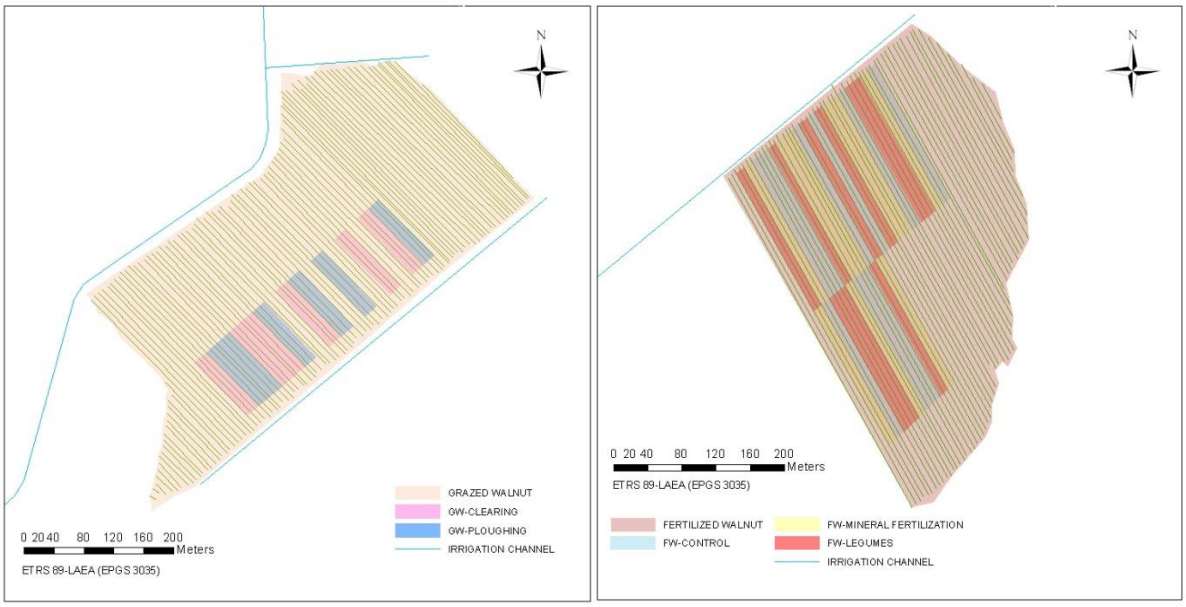

Figure 4. Map of location and distribution of plots in the fertilized walnut experiment (with different treatments of fertilization) and grazed walnut experiment (with different treatments to control herbaceous vegetation). Note: each plot is formed by 3 alleys and 2 tree rows of 30 trees each.

6 Measurements

The measurements will include tree diameter and height (Figure 5). A full set of measurements in described in Tables 3.

Figure 5. Measurements of tree diameter and height

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

Element	Parameter	Method
Trees	Diameter at breast height Leaf nutrients (N, P, K, Ca)	One measurement per year (Figure 4). In 120 trees, dendometers are installed (Figure 6).
Pasture	Pasture production	Three herbage samples (50 cm x 50 cm) were taken from each plot using hand clippers at a height of 2.5 cm in June (Figure 7)
Soil	Organic matter content	Soil samples are taken each 10 cm until 1 m depth and OM is analyzed
Pasture and tree roots	Biomass, length and surface	Soil samples are taken each 10 cm until 1 m depth and roots are separated in tree and pasture. Samples are weighted and analysed with Winrrhizo program for determining length and surface
Nutrient availability in soil	N, P, K and Ca	Ion exchange resins (50 cm^2) installed at 15-20 cm depth for one month in Spring (Figure 8).
Nitrate leaching	$N\text{-}NO_3^-$	Two ceramic cup samplers were installed in each plot at 30, 60 and 90 cm (Figure 9). Measurements depends on rain frequency
Soil moisture	%	72 Diviners are located in plots (Figure 10). Measurements are taken each 10 cm until 1 m each month
Carbon sequestration		Variations in carbon sequestration are calculated based in OM in soil and biomass in tree trunk and herbaceous and tree roots

Figure 6. Dendrometers on trees

Figure 7. Pasture sampling

Figure 8. Ion exchange resins

Figure 9. Ceramic cup samplers

Figure 10. Measuring soil moisture with in permanent access tubes/

7 Acknowledgements

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