System Report: Bocage Agroforestry in France

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Work-package	2: High Natural and Cultural Value Agroforestry
Specific group	Bocage agroforestry in France
Deliverable	Contribution to Deliverable 2.4: Detailed system description of a case study system
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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 the second objective of the project. It contributes to the initial research and development protocol, Deliverable 2.4, for the participative research and development network focused on the use of agroforestry in high natural and cultural value agroforestry systems. This report was produced in February 2016, and additional material will be presented over the remaining two years of the project.

2 Background

The hedgerow systems of Brittany in France are ancient agroforestry systems comprising lines of high- and medium-stem trees (Antoine and Marguerie 2008). The main period of expansion of this agroforestry system was from the eighteenth century to the end of the nineteenth century. From the 1950s, the process of agricultural modernization and intensification, led to a general decrease of hedgerow density and their reduced importance in farming management. From the 1990s, hedge planting schemes have been implemented but these have not compensated for hedgerow losses over the same period (Le Dû et al. 2008; Thenail et al. 2014). The objectives in hedgerow planting include the maintenance of the cultural landscape and the regulation of nitrate and phosphorus pollution.

The research developed in work-package 2 of the AGFORWARD project focuses on recent hedgerow networks planted in the 2000s, promoted by the farmers of ”Terres et bocages” group, and designed and managed with an adaptive strategy to allow multiple ecosystem services. The objective is to quantify the ecosystem services provided by such systems in three domains: 1) support and regulation services associated to biodiversity, 2) support and regulation services associated to soil and water, and 3) provisioning services from the hedgerows and associated fields.

3 Description of system

Our research is based on a pseudo-trial, i.e. a comparison of two sites where hedgerows have been planted in the 2000s and that can be compared from a limited set of varying factors. Table 1 provides a general description of the bocage agroforestry system in Brittany, western France. A description of the specific pseudo-trial case study systems is provided in Table 2.

Table 1. General description of the bocage agroforestry system in Brittany

General description of system	
Name of group	Bocage agroforestry in France
Contact	Claudine Thenail, Stéphanie Avrion or Valérie Viaud
Work-package	2: High Natural and Cultural Value Agroforestry
Geographical extent	Bocage systems in the traditional sense are to be found throughout Brittany (western France). New hedgerows are also planted throughout Brittany, but innovative hedgerows networks, with adaptive design and management are rarer. They are mainly planted in central Brittany.
Estimated area	Bocage agroforestry systems occur all over Brittany. Total hedgerow length is estimated to 183,000 km over 27,208 km². Hedgerow density varies between 16 and 94 m ha^{-1} (IFN, 2009).
Typical soil types	Varied
Description	Bocage agroforestry systems consist of hedgerows planted on field boundaries, often organized into a spatial network at the landscape scale. They include high-stem and medium stem trees associated with an herbaceous stratum on the ground. Their purpose was traditionally to delimitate property boundaries, to provide protection for livestock (shelter) and crops (windbreaks), and to produce adequate resources of firewood and timber. They are associated with mixed livestock-cropping farming systems. Traditional hedgerows in Brittany are characterized by a diversity of boundary structures (e.g. with or without bank), of management regimes by farmers, and of vegetation structures and composition (Baudry and Jouin 2003). The recognition of the environmental value of hedgerows (see, for instance, Baudry et al. 2000) has led to the implementation of several programs of hedgerow plantations throughout Brittany. Amongst them, a few programs rely on innovative approaches, promoting adaptive design and management of hedgerows by farmers, as well as spatial connections between hedgerows on the farm. We focus on the evaluation of these innovative agroforestry systems.
Tree species	Varied: main tree species include *Quercus pedonculata*, *Castanea sativa*, *Fagus sylvatica*, *Fraxinus excelsior*, and *Alnus glutinosa*
Tree products	Firewood, timber, mulch
Crop species	Varied: maize, wheat, barley, grass species
Crop products	Varied: silage maize provided animal feed. Grass can be grazed directly by livestock or cut to provide animal feed (silage or hay).
Animal species	Varied: including no animals, cattle in the field, and housed pig and poultry systems.
Animal products	Varied: including none, milk, beef, pork, and eggs
Regulating services	The trees modify the microclimate: wind speed, evapotranspiration, temperature. They can provide shelter for cattle. The trees can improve water infiltration, reduce runoff and reduce nutrient leaching. Denitrification can also be enhanced in the tree rooting zone. The trees and associated vegetation increase carbon storage.
Habitat services and biodiversity	The hedgerow is a stable semi-natural habitat and refuge for several plant and animal species. The tree layer can create suitable microclimatic conditions for plant and insect species associated to semi-natural habitats

	such as forests. The trees can provide nesting resources for birds or invertebrates (e.g. pollinators) early in the season. The herbaceous layer on hedgerow banks can provide food resources and overwintering sites for beneficial insects (e.g. pollinators, natural enemies of crop pests), for flagship species such as butterflies, but also for species that are detrimental to provisioning services (crop pests, e.g. aphids or weeds). Hedgerows can act as corridors between habitats for species associated to semi-natural habitats, but also as barriers for species of open habitats.
Cultural services	Field delimitation. Landscape: bocage agroforestry is the traditional agricultural landscape in Brittany.
Key references	See end of report

Table 2. Description of the specific case study system

Specific description of site	
Area	The case study system comprises 2 sites where new hedgerows have been planted in 2005
Address and co-ordinates	Site 1: Les Ecoupées, 22600 La Motte (48.245868°N, 2.695410°W) Site 2 : Coacavec, 22600 Saint-Barnabé (48.123801°N, -2.739273°W)
Site contact	Claudine Thenail
Site contact email	claudine.thenail@rennes.inra.fr
Example photograph	 Figure 1. Example of a hedge

Map of system

Figure 2. Aerial photograph of site 1: Les Ecoupées

Figure 3. Aerial photograph of site 2: Coacavec

Possible modelling scenarios	
Comparison	Innovative hedgerow systems will be compared to traditional ones.
Climate characteristics	
Mean monthly temperature	10.7°C
Mean annual precipitation	725 mm
Details of weather station (and data)	Weather station located approximately 5 km from the experimental sites : Loudéac station (Météo-France)
Soil type	
Soil type	Haplic Luvisol
Soil depth	To be determined
Soil texture	Clay-loam
Tree characteristics	
Species and variety	Main species: *Castanea sativa*, *Fagus sylvatica*, *Pinus sylvestris*, *Quercus pedunculata*, *Quercus sessilflora*, *Carpinus betulus*, *Coryllus avellana*, *Acer campestre*, *Prunus cerasifera*, *Crataegus monogyna*, *Ligustrum vulgare*, *Prunus spinosa*, *Vuburnum sp.*
Date of planting	Site 1: 2005; Site 2: 1999-2000
Hedgerow structure	One line and two lines hedgerows (see maps); one potential high stem tree every 4 or 6 m along hedgerows
Ground structure	Plantation on flat ground, novel or old bank
Typical tree yield	No harvest to date
Typical increase in tree biomass	To be determined
Crop characteristics	
Species	Site 1: permanent grassland Site 2: silage maize/ winter cereals/ grassland rotation
Management	Site 1: cattle grazing Site 2: silage maize harvested in October; cereals harvested in July, straw exported; grassland grazed
Typical crop yield	To be determined
Fertiliser, pesticide, machinery and labour management	
Fertiliser	Site 1: none (except manure from the cattle when grazing) Site 2: to be determined
Pesticides	Site 1: none Site 2 : to be determined
Machinery	To be determined
Manure handling	Site 1: none Site 2: to be determined
Labour	To be determined
Fencing	To be determined
Livestock management	
Species and breed	To be determined
Description of livestock system	To be determined
Date of entry to site	To be determined
Date of departure	To be determined

from site	
Stocking density	To be determined
Animal welfare issues	To be determined
Supplementary feed	To be determined
Technical data, livestock	
Production volume	To be determined
Litter performance	To be determined
Feed consumption	To be determined
N and P-balance	To be determined
Financial and economic characteristics	
Costs	To be determined

4 Update on field measurements

The hedgerow agroforestry systems being studied in Brittany were planted between 1999 and 2005. Field measurements carried out within the framework of the AGFORWARD project and described in the research and development protocol (Thenail et al. 2015) will begin in spring 2016.

5 Expected results

5.1 Description of the tree component

Facilitators and farmers will help with estimated and effective yield evaluation of tree products. Farmers will help with answering a survey of management practices at hedgerows scale. Harvest assessments made by farmers and facilitators after maintenance pruning will seek to quantify the biomass produced for mulch and firewood. There is potential for timber production given the age of hedgerows: this will be assessed by measuring the structure of the high-stem trees that were initially designated for potential timber. Biomass production by the innovative hedgerows will be compared to references on biomass production by traditional hedgerow systems.

5.2 Description of the crop component

The principal crops grown in the area are maize, winter cereals and temporary or permanent grass. Permanent grasslands are mainly encountered on soils of lower quality and on redoximorphic soils. Temporary grasslands are frequently grown in rotation with annual crops. The mean annual yield in the area (Morbihan department) over the past three years are 7.6 $t.ha^{-1}$ for winter wheat, 9.7 $t.ha^{-1}$ for grain maize, 14.7 $t.ha^{-1}$ for silage maize, and 8.7 $t.ha^{-1}$ temporary grasslands (Agreste 2015). Farmer interviews will be used to quantify the components of crop yields (total biomass, grain), to compare the yields of the land parcel of site 1 or 2 with those of other comparable land parcels, and to quantify the provisioning services in the study sites.

5.3 Evaluation of other ecosystem services related to soil, water and biodiversity

5.3.1 Services related to soil and water quality

The impact of hedgerows on soil and water have been quantified to date on old hedgerows in Brittany.

Hedgerows significantly modify the water cycle in their vicinity. The average percentage of rainfall intercepted by oaks was 28% for the leafed period and 12% for the leafless period (Ghazavi et al. 2008). Thomas et al. (2008) report transpiration rates equivalent to 5.6 mm day^{-1} in summer and estimated that oak hedgerow transpiration was nearly twice than oaks transpiration in forestry. Near oak hedgerows, Grimaldi et al. (2009) found very high chloride concentrations in soil compared with nearby crops soil, indicating the intense water uptake by tree roots.

The role of ancient hedgerows in nitrogen recycling has also been investigated and shows that nutrient uptake by trees reduces soil nitrate concentration, and that denitrification can reduce the loss of nitrate. At a watershed scale, the nitrate flux brought by water surface decreased when the hedge tree density increased (Benhamou 2012; Benhamou et al. 2013). Regarding soil conservation, several studies demonstrated also the anti-erosive effect of hedgerows, although there is high spatial variability at the landscape scale (Follain et al. 2006; Lacoste et al. 2014; Lacoste et al. 2015).

Hedgerows also directly and indirectly affect soil organic carbon (SOC) content. Soil organic carbon contents measured in topsoil under old hedgerows can be up to 2.5 times higher than those in the adjacent crop field (Walter et al. 2003). Total SOC stocks measured on the whole soil profile in the vincinity of hedgerows are higher than that measured in cultivated fields (Follain et al. 2007) for three main reasons: 1) C input to the soil by trees are higher than those provided by crop residues (which are often exported from the field); 2) deep soil horizons have significant amont of C, related to enhanced soil biological activity, and tree rooting depth; and 3) because of its impact on soil erosion, hedgerows modify SOC spatial distribution and dynamics at the hillslope scale.

Soil sampling and measurements described in the Research and Development protocol (Thenail et al., 2015) will provide us quanticiation of ecosystems services related to soil and water in innovative 3D hedgerows network. These results will be compared with the references for old hedgerow networks.

5.3.2 Services related to biodiversity

The field surveys to be realized in 2016 will evaluate the effects of new hedgerows on biodiversity of conservation interest (associated to semi-natural habitats), on flagship biodiversity (butterflies) and on beneficial biodiversity involved in regulating services (e.g. generalist predators of crop pests).

Evaluation studies have been performed on traditional, old hedgerows and their spatial networks in similar types of agricultural landscapes in Brittany. They have shown that hedgerow is a stable semi-natural habitat and refuge for several plant and animal species. Old hedgerows with dense shrub and tree layers were found to provide stable habitats for forest species of carabid beetles (Burel 1991, Petit 1994a), due to specific microclimatic conditions. Hedgerow banks also provide habitats or refuges for species depending on grass and floristic resources, such as butterflies or bees. The diversity of butterflies was found to be higher in hedgerow banks than other herbaceous habitats, in relationships with a high diversity of plant species (Ouin and Burel 2002). Le Feon (2010) found that the diversity of pollinators such as solitary bees increased with hedgerow density in farming landscapes, due to the high quality of nectar and nesting resources in these elements. Regarding the communities of natural enemies of crop pests, the diversity of predatory carabid beetles, of ladybirds and of aphid parasitoids in cereals fields was found to be positively related to the density

of hedgerows and/or their proximity to crops in the surrounding landscape (Puech et al. 2015; Duflot et al. 2016). This is explained by the role of overwintering sites or refuges that hedgerows play for these beneficial insects.

Regarding dispersal processes in farming landscapes, hedgerows were found to play a crucial role of corridor for the dispersal of forest carabid species between remnant fragments of forest habitats (Petit and Burel 1998a, 1998b; Petit 1994b). It explains why hedgerows located in areas with a dense and spatial connected hedgerow network are characterized by the presence of forest carabid species, whilst these species do not persist in landscapes where hedgerows have been removed (Burel et al. 2004). The effect of hedgerows on the dispersal of species associated to herbaceous habitats can be antagonistic. For instance, they were found to act as barriers to butterfly movements between herbaceous habitats, but to facilitate their dispersal when parallel to movement trajectories (Ouin 2000).

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