System Report: Alley Cropping in Germany

Project name	AGFORWARD (613520)
Work-package	4: Agroforestry for Arable Farmers
Specific group	Alley Cropping Systems in Germany
Deliverable	Contribution to Deliverable 4.10 (4.1): Detailed system description of a case study system
Date of report	30 October 2015
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AGFORWARD (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

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 4.10: "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, 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 modelling activities which help to address Objective 3.

2 Background

Agroforestry for arable farmers is not a common practice in Germany. However alley cropping for woody biomass production is of interest because of its high potential to concurrently provide a biomass feedstock and an arable crop. One existing system, although at an experimental level, is the integration of rows of fast growing trees, such as poplar or willow, with arable crops.

The experiment is part of the German joint research project "AgroForstEnergie - Economic and Ecological Evaluation of Agroforestry Systems in Farming Practice", funded by the German Federal Ministry of Food and Agriculture (AgroForstEnergie 2015). The goal of this project was to study alley cropping systems, which concurrently produce a woody biomass feedstock and conventional agricultural crops.

The State of Brandenburg is known for its light sandy soils that are prone to wind erosion. The introduction of tree hedgerows within the agricultural landscape can reduce wind erosion (Böhm et al. 2014). In addition, microclimatic conditions such as soil moisture, wind speed reduction, relative humidity and air temperature have been more favourable for plant growth in crop alleys compared to reference crop areas (Böhm et al. 2014; Quinkenstein et al. 2009). However, planting trees within the agricultural landscape can also result in additional costs, make farming operations more complex and add administrative burdens to crop production. One other synergy is the input of organic matter by the trees through both above ground leaf fall and below ground fine root turnover (Pregitzer et al. 1995; Mirck et al. 2015).

3 Update on field measurements

Field measurements described in the research and development protocol (Mirck and Quinckenstein 2015) began in early June 2015 and will continue until the end of 2016. All measurements have been and will be conducted by researchers from the BTU Cottbus-Senftenberg.

4 Description of system

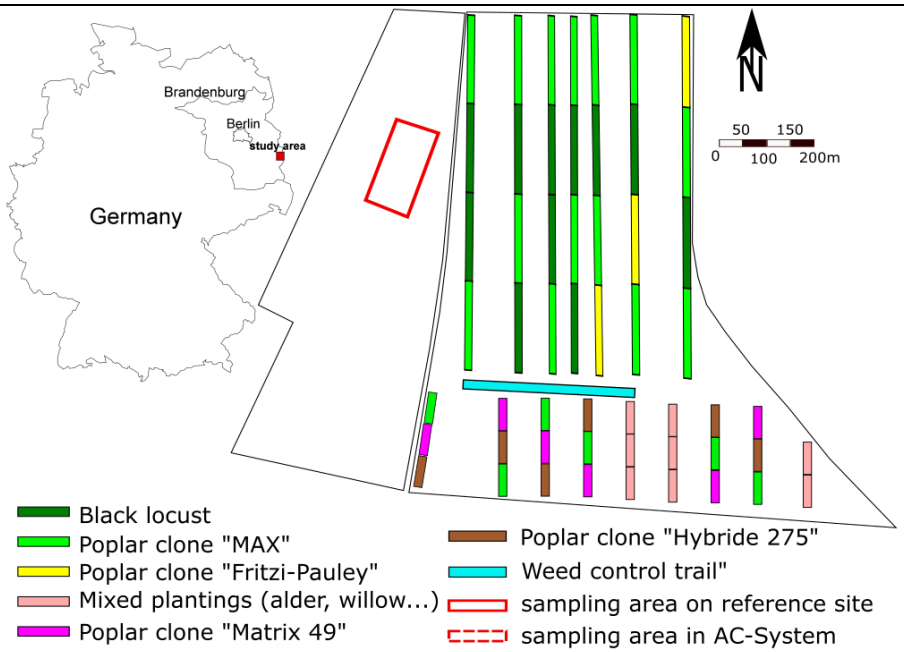
Table 1 provides a general description of the alley cropping system. A description of a specific case study system is provided in Table 2. Missing data will continue to be sourced during 2016.

Table 1. General description of the alley cropping system

General description of system	
Name of group	Alley Cropping in Germany
Contact	Jaconette Mirck and Michael Kanzler
Work-package	4: Agroforestry for Arable Farmers
Associated WP	None
Geographical extent	Short rotation coppice alley cropping systems are still at an experimental level in Germany. Research sites can be found in Mariensee, Wendhausen, Dornburg, Welzow-Sued and Forst (AgroForstEnergie 2015)
Estimated area	The total area of the research sites mentioned above is 172 ha.
Typical soil types	Fluvisols
Description	Large monoculture corps fields are present in some areas in Germany. These fields are prone to wind erosion. The hedgerows in short rotation coppice alley cropping systems can reduce wind speed resulting in lower sediment removal. At the same time the biomass feedstock that is produced can be used for heating, cooling or power production.
Tree species	Poplar: *Poplar* spp Black Locust: *Robinia pseudoacacia* Willow: *Salix* spp. Alder: *Alnus glutinosa*
Tree products	Wood chip for heating/cooling and power production. Wood chips yields in Germany range between 5 oven dry tonnes (odt) ha^{-1} a^{-1} to 15 odt ha^{-1} a^{-1} (Gruenewald et al 2007). Yields can vary depending on the tree species (Aust et al 2013). Calorific values also differ between black locust and poplar (Kaltschmitt 2011)
Crop species	Crop species such as sugar beet (*Beta vulgaris*), barley (*Hordeum vulgare*), maize (*Zea mays*), alfalfa (*Medicago sativa*)/SolaRigol (legume and not legume mix for potatoes), potatoes (*Solanum tuberosum*), winter wheat (*Triticum durum*)
Crop products	Crops can be harvested on an annual basis.
Animal species	None
Animal products	None
Other provisioning services	Possibility of using tree and crop leaves as fodder, or black locust trunks can be used as fence posts
Regulating services	The trees can provide a microclimate with reduced temperature fluctuations. The trees can promote nutrient cycling. The trees will increase both above- and below ground carbon storage.
Habitat services and biodiversity	During the first two years after tree establishment proper weed management is required to prevent weeds from competing with the trees and invading the crop areas.

Cultural services	Short rotation alley cropping systems may change employment requirements for farms
Key references	See end of report

Table 2. Description of the specific case study system

Specific description of site	
Area	73 ha (Northern part 40 ha, established in 2010 and poplars replanted in 2011; Southern part 33 ha, established in 2014/2015)
Co-ordinates	51°47'21"N, 14°37'42"W (or : N51.789278 ; W14.628202)
Site contact	BTU contact: Jaconette Mirck
Site contact email	jmirck@gmail.com
Example photograph	
Map of system	 Coloured lines indicate tree rows (for species see legend). Tree species are Poplar clone 'Max' (*Populus nigra L.× P. maximowiczii*), Poplar clone Fritzi-Pauley (*P. trichocarpa*), Poplar Matrix 49 (P. maximowiczii × P. trichocarpa), Poplar Hybrid 275 (P. maximowiczii × P.) and Black Locust (*Robinia pseudoacacia*).

Possible modelling scenarios	
Comparison	Technical and economic analysis of alley cropping v monoculture
Climate characteristics	
Mean monthly temperature	9.3°C
Mean annual precipitation	608 mm
Details of weather station (and data)	Data from 01/01/1981-31/01/2010 (available here) for the Forst/Lausitz weather station (id: 1400, 51°44'N, 14°38'E) (See Mirck and Quinkenstein, 2015).
Soil type	
Soil type	WRB classification: Gleyic Fluvisol Fluvisols are soils developed in alluvial deposits which are named from the Latin "*fluvius*" which means river. (FAO. 2001). These soils receive fresh material or have received it in the past and still show the stratification (FAO, 2015). Gleyic properties are a set of diagnostic soil properties, referring to soil materials saturated by ground-water during part of the year (Canarache et al. 2006).
Soil depth	Approx. 2 m (until groundwater level), soil deeper
Soil texture	Loamy sands and sandy loams
Additional soil characteristics	German soil number: 45; Humus content 1.9%; Groundwater 1 – 2.5 m below soil surface. Topsoil: loamy sands; subsoil: pure sand and gravel layers, with clayey areas (Böhm et al. 2015)
Aspect	North-South
Tree characteristics	
Species and variety	Poplar (*Poplar* spp) and black locust (*Robinia pseudoacacia*)
Date of planting	Spring 2010 (black locust), Spring 2011 (poplar)
Intra-row spacing	0.9 m
Inter-row spacing	Double row system: 0.75 m within double row; 1.8 m between double row
Hedgerow spacing	24 m, 48 m, 96 m
Tree protection	None
Typical wood chip yield	8 odt ha^{-1} a^{-1} (first rotation)
Typical increase in tree biomass	
Crop/understorey characteristics	
Species	Sugar beet (*Beta vulgaris*), barley (*Hordeum vulgare*) and maize (*Zea mays*), alfalfa (*Medicago sativa*)/SolaRigol (legume and not legume mix for potatoes), potatoes (*Solanum tuberosum*), winter wheat (*Triticum durum*)
Management	Conventional arable crop management with the usual mixture of ploughing and herbicide spraying to keep down the weeds
Typical crop yield	
Fertiliser, pesticide, machinery and labour management	
Fertiliser	Assumed that this is not modified by tree hedgerows

Pesticides	Regular spraying of crops during the year to control weeds and pests
Machinery	Need for tractor access in crop alleys to allow soil preparation and spray application
Manure handling	Not necessary in field
Labour	Trees: the biomass feedstock needs to be harvested on a 3-5 year rotation; Crops: no additional labour requirements
Fencing	Not required
Livestock management	
Species and breed	Not applicable
Financial and economic characteristics	
Costs	Some example costs of establishment are provided by http://www.energieholz-portal.de and will be provided by http://agroforst-info.de/ soon.

5 Description of the tree component

5.1 Tree species

The tree hedgerows of short rotation coppice alley cropping systems consist of fast growing woody crops. Common fast growing woody crops include poplar (*Poplar* spp), black locust (*Robinia pseudoacacia), w*illow (*Salix* spp.), and alder (*Alnus glutinosa*). The northern part of the alley cropping system is 40 ha and consists of poplar (*Poplar* spp, varieties Max 1 (*Populus nigra L.× P. maximowiczii*) and Fritzi-Pauley (*P. trichocarpa*) and black locust (*Robinia pseudoacacia*). This part of the experimental site was planted in 2010 and the poplars were replanted in 2011. The southern part consists of poplar Max 1, Matrix 49 (*P. maximowiczii × P. trichocarpa*) and Hybrid 275 (*P. maximowiczii x P. trichocarpa).*

5.2 Tree spacing and hedgerow design

Short rotation coppice agroforestry systems have been established for the "AgroforstEnergie" project at five sites across Germany; research sites can be found in Mariensee, Wendhausen, Dornburg, Welzow-Sued and Forst (AgroForstEnergie 2015). All sites consist of tree hedgerows that are about 10 or 11 m wide and crop alleys ranging in widths from 24 to 144 m.

The site in Forst will be studied during the AGFORWARD project. Research will focus on the northern section of the system, which consists of seven tree hedgerows that are 11 m wide (four double rows) and approximately 600 m long. The distance between the tree hedgerows varies between 24, 48 and 96 m. The southern part of the alley cropping system is 33 ha and was planted in 2014 and 2015. It consists of six hedgerows of poplars that are 17.4 m wide and three hedgerows of mixed planting. The spacing between the tree hedgerows in the southern area is 72 m and 144 m.

6 Description of crop component

6.1 Crop species

The crop alleys in between the tree hedgerows are planted with conventional arable crops common to Germany such as sugar beet (*Beta vulgaris*), barley (*Hordeum vulgare*), maize (*Zea mays*), alfalfa (*Medicago sativa*)/SolaRigol (legume and not legume mix for potatoes), potatoes (*Solanum tuberosum*), winter wheat (*Triticum durum*).

6.2 Crop spacing and design

Crop spacing and design is according to common agricultural practice. For 2015, the sugar beet crop at the research site in Forst crop densities ranged from 8 to 13 beets m^{-2}.

6.3 Yield measurement

The manual harvest of sugar beets at the Forst site took place between 30 September and 6 October 2015. Measurements took place at the three western crop alleys of the alley cropping system (Figure 1). The measurements were focused on this area because German legislation allows farmers to only plant a limited area with sugar beet. For the 96 m and 48 m wide crop alleys crop plots were measured at 4 m, 12 m lee- and windward side and in the centre of the alley and for the 24 m wide alley at 4 m lee- and windward and in the centre (Figure 1). Six replications were carried out for each treatment. Sampling plots were approximately 3-5 m^2 in size and consisted of three sugar beet rows.

Prior to sugar beet extraction all beets in those sampling plots were counted and the exact plot size was measured. These values were required for subsequent yield calculations. For sugar beet harvest in each of the plots the following protocol was used: 1) above- and below-ground biomass of 12 sugar beets were harvested and weighted separately (in kg, rounded to two decimals); 2) two sugar beets were collected for dry matter determination. These were stored in ziploc bags, transported to the laboratory and dried until a constant weight at 105°C.

Initial results showed yield reductions for sugar beets in close proximity to the tree hedgerow and yield increases at 12 m and in the middle of the alleys in comparison with the adjacent reference crop field. The quantity of sugar beet canopy was less for all distances (except for 12 m west side of the 48m alley) within the alley cropping system than in the control crop.

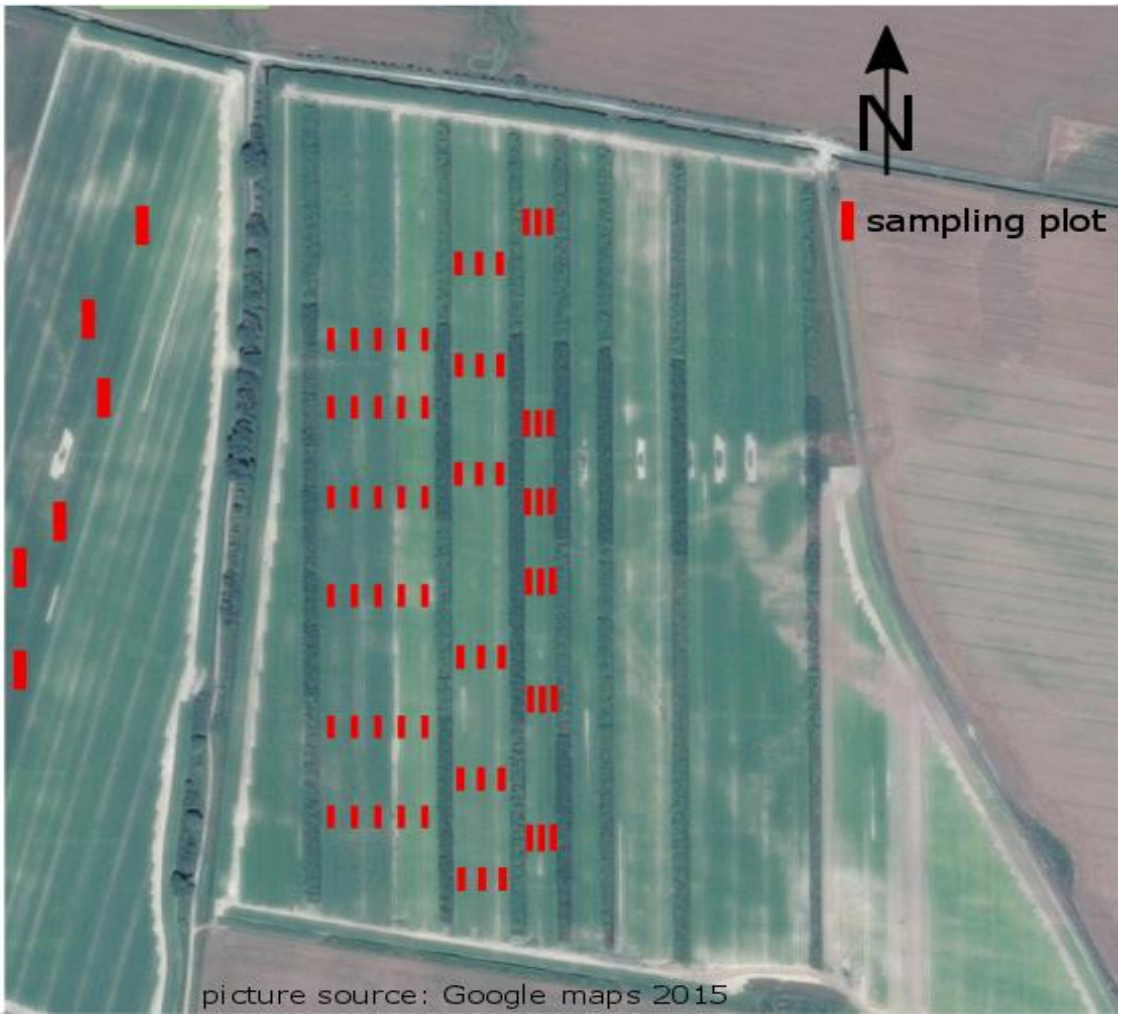


Figure 1. Map of the Agricultural Cooperative Forst field site. Coloured squares indicate sampling plots for the manual sugar beet harvest. Plot size varies between 3-5 m².

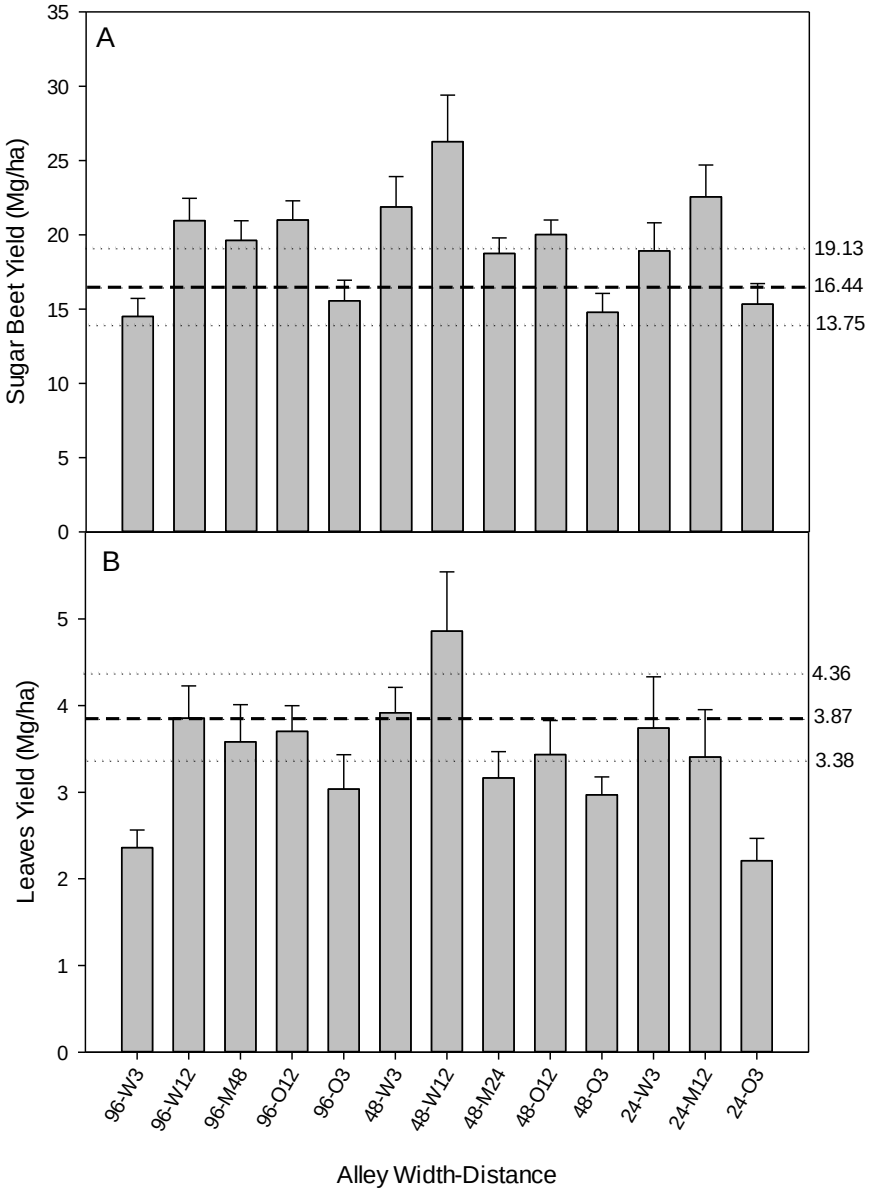


Figure 2. Mean (± SE) sugar beet yield (A) and yield of leaves (B) at different distances (W3 = 3 m west from middle, W12 = 12 m west from middle, M48 = middle 96 m, M24 = middle 48 m, M12 = middle 24 m) from the tree hedgerow for the three alley widths 96 m, 48 m and 24 m. Dotted lines indicate the means (± SE) for the crop reference area. (n=6). Yields are expressed on a dry matter basis.

7 Modelling input parameters

Table 3 describes the key modelling input parameters that will be collected at the research site in Forst.

Table 3. Key modelling input parameters

Parameter type	Parameter	Collected in Forst Y/N	Collection time
Weather	Air Temperature (T_{min}, T_{max})	Y	Year round
Weather	Relative humidity	Y	Year round
Weather	Precipitation	Y	Year round
Weather	Radiation	Y	Year round
Tree	Day bud break	Y	Spring
Tree	Day onset senescence	Y	Fall
Tree	Leaf area index	Y	DC22†, DC33, DC65, DC92
Tree	Specific leaf area	Y	LA max trees
Tree	Fraction of light intercepted	Y	DC22, DC33, DC65, DC92
Crop	Day sowing	Y	Spring
Crop	Day harvest	Y	Fall
Crop	Leaf area index	Y	DC22, DC33, DC65, DC92
Crop	Specific leaf area	Y	LAmax crop, DC65?
Crop	Fraction of light intercepted	Y	DC22, DC33, DC65, DC92
Crop	Temperature Sum to emergence	Y	
Crop	TSum for harvest	Y	
Crop	Radiation use efficiency	Y	
Crop	Water use efficiency	Maybe	
Soil	Soil texture	Y	Known
Soil	Soil depth	Y	Known
Soil	Water table	Y	Year round
Soil	pF value	Y	Spring

†DC= decimal code Zadoks scale (Zadoks et al. 1974). DC22=tillering; DC33=jointing; DC65=anthesis; DC92=maturity

8 Acknowledgements

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