AGFORWARD
Agroforestry for Europe

System report: Alley Cropping in Hungary

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Approved	Jaconette Mirck (February 2016)

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 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 used to be a widespread technology of land use in Hungary during the last century. However during recent decades, it has disappeared from large areas of the Hungarian countryside. (Gál, 1961; Varga and Bölöni, 2009). Protective tree systems such as field and farmstead shelterbelts remain a common practice in Hungary. The number of shelterbelts increased significantly in the 1960-70s, but their numbers have subsequently fallen and are still declining.

Area estimations of the extent of agroforestry in Hungary are not available, although Frank and Takács (2012) provide an estimated area of windbreaks and shelterbelts in Hungary of about 16 000 ha. Other arable agroforestry systems such as alley cropping have been established on a small scale mostly as pilot systems for educational and/or experimental purposes (Szalai et al. 2012; Vityi et al. 2014).

In Hungary, agricultural land (including crop and grasslands) occupy about 60% of the land area. Of the arable land, 85% occurs in agro-environmentally sensitive areas (Vityi and Marosvölgyi, 2013). The high area of land that is considered susceptible to the "triple-risk" of floods, droughts, and poor drainage in the Hungarian Great Plain demonstrates the strong need for development of climate-smart agro-technologies (Láng et al. 2007). The use of arable agroforestry systems or re-adaptation of traditional systems can provide a pathway for realising more resilient and sustainable agricultural production.

This trial is being conducted in association with a local stakeholder - Kék Duna Agricultural Cooperative. The aim of this integrated on-farm research is to develop the cooperative's own field trials on issues that they consider to be of interest. Basically, it is the development of more resilient production systems by decreasing the risk of agricultural production in areas without access to irrigation. The cooperative's two main agricultural activities are plant and livestock breeding. Due to the relatively great number of livestock (> 400 cattle) fodder shortages are experienced during part of the year.

A silvoarable system consisting of alfalfa (*Medicago sativa*) as the crop component and empress tree (*Paulownia tomentosa*) as fast growing tree species[1], seems to be a promising mix. This system produces both a highly nutritious forage supply and quality timber on the same area of land. In the future Kék Duna Cooperative (and local farmers) plan to extend the use of agroforestry with a wider number of plant species. NyME KKK provides the scientific and technical support to the experiments in a way that leads to the harmonisation of the aim of the trial with the Hungarian rural development strategies and ongoing European research.

3 Objective of trial

The main purpose of the trial is to produce quantitative information about the change of crop production and vulnerability in an unirrigated system placed in an environmentally- and climate-sensitive area. Key questions include:

- How does alley cropping affect the local microclimate, the resilience of the system, forage and tree yields, and the water, nutrient and carbon content of the soil?
- How to control weeds (cost) effectively, to reduce the amount of labour and the use of chemicals in tree rows?
- How to protect effectively trees from wild animals?

Alongside these questions, the following innovations can be tested:

- By-products from the treatment of trees could be used as forage for animal breeding
- Savings will be made on the cost of weed control and plant disease control (if using no or less chemicals), although these may be partly offset by the additional labour related costs associated with distribution of surface covering materials.

4 Update on field measurements

Field measurements described in the research and development protocol (Vityi et al. 2015) began in October 2014 and will continue until the end of 2016. All measurements have been and will be conducted by researchers from the University of West Hungary Cooperational Research Centre, in close cooperation with the leader agronomist of Kék Duna Cooperative.

5 System description

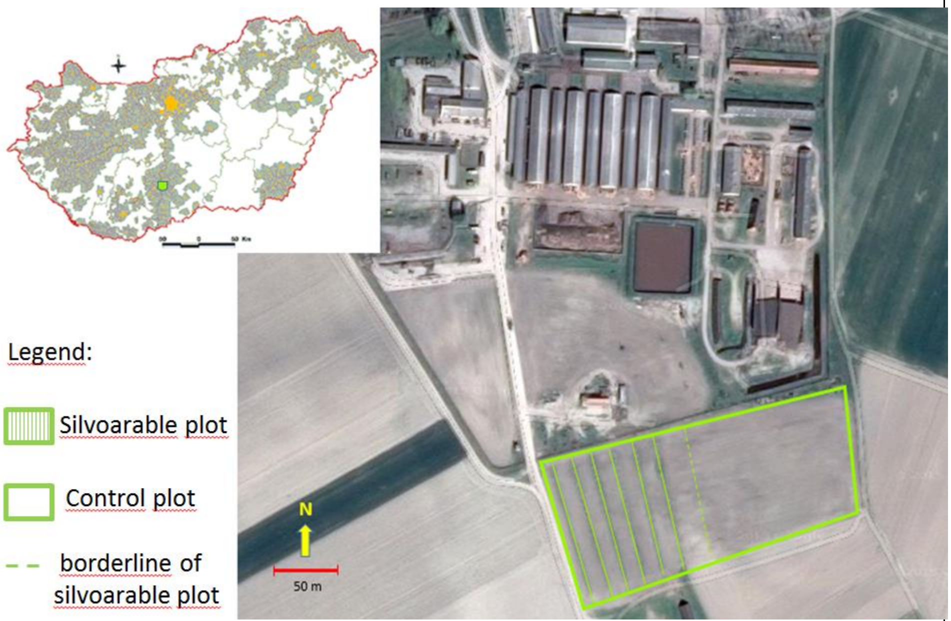
The experiment is carried out at Fajsz (Hungary) in a 2-year old *Paulownia tomentosa* var. *Continental E.*) plantation (Table 1 and 2), with a density of 126 trees ha^{-1} owned by the company Kék Duna Agricultural Cooperative. Missing data will continue to be sourced during 2016 and 2017.

[1] Earlier local experiments with Paulownia for bioenergy purposes resulted in great yearly production (50-55 t/ha wet mass) (Vityi and Marosvölgyi 2014)

Table 1. General description of silvoarable system

General description of system	
Name of group	Alley cropping systems in Hungary
Contact	Andrea Vityi
Work-package	4: Agroforestry for arable farmers
Geographical extent	Silvoarable systems in the traditional sense e.g. trees integrated in arable lands and windbreak or shelterbelt systems used to be found throughout Hungary in the old days (up to the 18^{th}-19^{th} centuries). Currently the number of these systems has declined. Current knowledge suggests that alley cropping is rare in Hungary; this is in particular the case of modern silvoarable systems such as alley cropping for bioenergy or fodder purposes.
Estimated area	No data available, but preparation of a survey has begun
Typical soil types	Chernozems, Phaenozems, Fluvisols, Arenosols, Cambisols
Description	Silvoarable systems have always served as multifunctional systems. Providing firewood or building timber, shelter, protection of crops against wind and snow, or forming natural border-line of the land. Intensive agricultural technologies and large monoculture crop fields are more sensitive in terms of erosion and effects of hot and dry periods that - among others - can reduce the volume and quality of agro-products. Existence of trees can improve the balance and flexibility of arable systems by reducing erosion and crop failures while providing additional products like biofuel, timber, or fodder.
Tree species	Systems discovered so far involve: indigenous forest species e.g. *Fraxinus, Prunus, Tilia*, fruit species e.g. *Juglans, Pyrus, Malus*, and hybrids e.g. *Populus, Salix*.
Tree products	Quality timber, firewood, woodchips
Crop species	Maize (*Zea mays*), alfalfa (*Medicago sativa*)
Crop products	Maize for edible corn or silo corn, alfalfa for fodder. Maize can be harvested on an annual basis. Alfalfa is harvested 4-6 times per year.
Animal species	None
Animal products	None
Other provisioning services	Possibility of using tree prunings or offshoots (in short rotation coppice) as livestock fodder.
Regulating services	The trees can provide a more favourable microclimate for crops in terms of water balance and temperature. Trees can improve nutrient cycle and carbon storage. Trees can reduce the risk of wind erosion.
Habitat services and biodiversity	The trees can give shelter to birds and flower pastures for bees.
Cultural services	Rural employment, landscape enhancement and agro-tourism

Table 2. Description of the specific case study system

Specific description of site	
Area	2 ha
Co-ordinates	46°40’51.41”N, 18°92’71.98”E
Site contact	Andrea Vityi
Site contact email	vityi.andrea@gmail.com
Example photograph	
Map of system	
Possible modelling scenarios	
Comparison	Technical and economic analysis of alley cropping vs. monoculture
Climate characteristics	
Mean monthly temperature	12.5°C (11.0°C)*
Mean annual precipitation	429 mm (534 mm)*

Details of weather station (and data)	Short-term (5 years) data from the Hungarian Weather Network from weather station at Kalocsa-Öregcsertő[2], accessed from website http://www.flaiszg.hu/wxtempsummary.php (data available from 2010) Long-term data (110 years) from the Hungarian Meteorological Service, climate data series http://www.met.hu/eghajlat/magyarorszag_eghajlata/eghajlati_adatsorok/Szeged/adatok/eves_adatok/ **selected data series of Szeged city which is located in the same average temperature and precipitation zone as Kalocsa*
Soil type	
Soil type	WRB classification: Phaenozem
Soil depth	>140 cm
Soil texture	Clay loam
Additional soil characteristics	Plasticity according to Arany (K_A): 52 ; Humus content 3.6%; Groundwater: 3.8-4.4 m below soil surface. Topsoil: loam/clay loam; subsoil: clay loam or clay with gleyic colour pattern (stagnic gley)
Aspect	North-West/South East
Tree characteristics	
Species and variety	*Paulownia tomentosa* (var. Continental E.)
Date of planting	2013
Intra-row spacing	14 m
Inter-row spacing	5 m
Tree protection	Artificial fence and tree guard protector (in winter)
Crop/understorey characteristics	
Species	Triticale
Management	Fertilization once per year, harvest 3-4 times per year
Crop products	Fodder
Fertiliser, pesticide, machinery and labour management	
Fertiliser	200 kg N ha^{-1}
Pesticides	None
Machinery	Need for tractor access between trees for the fertilization, harvesting machines (mowers), and swath turners.
Manure handling	Needed in the tree rows against weeds (no herbicides applied)
Labour	The plot is ploughed once (before sowing), afterwards only harvesting (4-5 times a year) until the elimination of the crop Young trees: pruning and fixing trunk protectors every year
Financial and economic characteristics	
Costs	Unknown

[2] located at 14 km far from the experimental trial at Fajsz

6 Description of the tree component

6.1 Tree species

The tree lines in alley cropping systems consist of Paulownia, which is a fast growing woody crop. The experimental site was first planted in 2012 and after serious damage (caused by standing water) the trees were replanted in 2013. *Paulownia tomentosa* (var. Continental E.) is a variety selected for local conditions. The young trees grow relatively fast, reaching 12-15 m tall in 5-8 years, under optimal site conditions. This selected variety is observed to be vigorous under local weather conditions while resistant to extreme climate.

6.2 Tree spacing and alley design

The alley cropping system consists of six tree rows that are 2 m wide without crop cover. The distance between the stems is 5 m. The spacing between the tree lines is 14 m, 12 m of which is covered by the intercrop.

6.3 Tree and alley management

Trees are manually pruned each spring. The aim is to grow knotless straight stems harvestable for timber production at age 10-12 years. In the tree rows weed management is carried out manually in the first year, henceforward by mower.

7 Description of crop component

7.1 Crop species

The crop alleys in between the tree lines are planted with alfalfa (*Medicago sativa*). Decision on the crop species was based on the requirement of a shade tolerant crop and the need for forage.

7.2 Crop spacing and design

Crop spacing and design is according to common agricultural practice. The width of intercrop rows has been determined by the technical parameters of the cooperative's sowing and harvester machines.

7.3 Crop management

Each year in Spring, 200 kg ammonium nitrate (34%) ha^{-1} is applied. In the tree rows weed management was carried out manually in the first year, to be followed in subsequent years with a motorised mower. The site management is described in Table 4. The intercrop treatment will be the same in each of the plots (Agroforestry and Control) so that results would be comparable.

8 Design

8.1 Conceptual design

The primary goal of the research study is to measure the differences in system vulnerability and yield between alley cropping and conventional agricultural systems. (Table 3).

Table 3. Description of the two treatments

	Treatment A Agroforestry system (AF) Intercropped cereal	Treatment B Agricultural control (C) Cereal cultivated in open area
Treatment	• pruning • weed control in tree rows • conventional agricultural treatment	• Conventional arable crop management
Plot size	1 ha	1 ha
Tree species	Paulownia tomentosa (*Continental E*)	No trees
Crop species	One variety of Triticale: Viktória	One variety of Triticale: Viktória

A map of the Agricultural Cooperative Kék Duna field site is shown in Table 2. The 2 ha block has been divided in parallel with the line of the trees into roughly equal plots of about 1 ha each. The thick green line indicates the boundaries of the plot (dotted line separates agroforestry system and control system). The light green rows indicates the tree rows in alley cropping.

8.2 Description of design

Table 3. System characteristics of the agroforestry system

Feature	Value
Distance between rows (inter-row tree spacing)	14 m
Tree distance within a row (intra-row tree spacing)	5 m
Tree strip width	2 m
Crop width	12 m
Crop length	105 m
Borderline width (between fence and plots)	8 m
Mean breast diameter (1.3 m)	27.96 mm
Mean height	279 cm
Trees per hectare	126
Rotation	10-15 years
Proportion of area occupied by crop	69% [a]
Planting date	2014 March
Harvest date	3-4 times/year*

[a]: if compared to the total (tree+crop+borderline) of AE site (but if compared to the tree+crop area of agroforestry site it is 85%)

*Typically in May, July, Aug./Sept., and Oct/Nov.

9 Measurements

The planned measurements to be taken in the two plots are described in **Error! Reference source not found.**5.

Table 5. List of measurements to be taken in the two treatments

Element	Parameter	Method	Measured
Trees	Height and diameter at breast height Damage by wild animals	One measurement per year Extent of damage will be recorded annually in AE and control trees	October 2015 Continuously
Crop	Crop production Crop disease	Crop yield of each plot (AE and C) will be measured at each harvest Samples will be taken if effects of disease are noted	From 2016 Continuously
Soil	Organic matter content Nutrient availability in soil N, P, K	Soil samples taken in three depths (0-10 cm, 10-30 cm, 30-60 cm) and OM is analysed Extension of soil measurements according to the common soil protocol Analysis of OM and root distribution Soil samples taken in three depth (0-10 cm, 10-30 cm, 30-60 cm) and nutrient content is analysed	Autumn 2014 and 2015 In 2016 Autumn 2014 and 2015
Microclimatic parameters		Parameters gathered on hourly basis by automatic sensors (measured parameters detailed in the next paragraph)	Data are available for 2015 (and part of 2014)
Weed control		Test and development of alternative weed control methods (e.g. cover with natural materials)	From 2016
Utilization of biomass by-products		laboratory measurements on basic nutrients and monitoring the animal attitude towards the biomass from alley treatment	Some data available for 2015, extended experiments starts in 2016

9.1 Measuring yields for each plots

- Diameter and height measurements for alley cropping plot will be carried out for trees on an annual basis. First measurements were carried out in October 2015. (Data on tree plantations of the same species located outside the system are potentially usable for control)
- Forage biomass production for each plot will be measured in each harvesting period.

9.2 Recording crop disease

- In case effects of disease are noted samples will be taken from both plots. Four sampling point for agroforestry and four points in control.
- Photographs of any damage to be taken.

9.3 Measuring microclimatic parameters

Microclimatic parameters (below and aboveground) are detected with an automatic agrometeorology station established by the Cooperative in the research site (Figure 3). The following data is provided by the main station with two substations in the agroforestry plot and one substation in the control plot: air temperature, air humidity, precipitation, wind direction and speed, global radiation, leaf surface humidity (at two levels), soil moisture and temperature (10, 20, 40, 60 cm depth).

9.4 Measuring soil nutrient and humus content

For determining soil humus and nutrient content in the soil as the "null-position" a sampling grid was used. Representative soil sampling to determine the effects of agroforestry on nutrient and humus content will be repeated annually, based on the common protocol.

9.5 Recording damages caused by wild animals

Experience has shown that animals can harm the Paulownia plant in its first and subsequent years. The extent of damage in the agroforestry plot and external to a fence will be recorded annually. The trees in the agroforestry plot may be damaged by small mammals such as voles and rabbits while trees outside the plot are potentially exposed to larger wild mammals. Photographs of any damage will be taken.

9.6 Recording the effectiveness of alternative method tested for weed control

If the weeds cannot be managed mechanically in tree rows, then the labour cost for weed control is likely to be higher than in large-scale monocultures. In order to investigate the option to reduce the need for herbicides, the following activities are planned:

- Alternative method of weed control (straw/first-cut lucerne cover and use of aromatic shrubs) will be tested in a part of the agroforestry system and the effectiveness measured by the relative extent of weed cover before and after action. Tree row(s) without using alternative method will be the control in these measures.
- Aromatic shrubs (lavender, lemongrass, mint, and oregano) have been planted in three tree rows in October and November 2015.
- First-cut lucerne cover will be applied in Spring 2016.
- Labour time and costs spent on covering the surface for weed control will be recorded.
- Photographs of weed covering before and as result of the test method to be taken.

9.7 Supplementary measurements

Besides the above mentioned measurements, as a step towards an integrated system, tests on by-products of alley treatment (leaves, branches) usability as fodder for the local livestock farm will be undertaken. The aim is to get precise information on the fodder quality of the biomass and experience on its adoptability in animal feeding system.

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