System report: Silvoarable agroforestry in Switzerland

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Work-package	4: Agroforestry for arable farmers
Specific group	Silvoarable agroforestry in Switzerland
Deliverable	Contribution to Deliverable 4.10 (4.1): Detailed system description of a case study system
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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, livestock, 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. This report was produced in 2015, and additional material will be presented over the remaining two years of the project.

2 Background

Trees have been an integral part in the Swiss agricultural landscape for many centuries (Herzog 1998). Historic pictures of the traditional countryside include agricultural systems with a variety of standard fruit trees (high-stem trees in traditional orchards) and hedges. However during the last 50 years, trees have however been disappearing from the agricultural landscape (Herzog 1998). The number of fruit trees have declined from over 15 million in 1905 to about 2.9 million in 2001 (Walter et al. 2010). One reason for this decline is Swiss policy. The introduction of standard fruit tree felling campaigns which were financially supported by the cantons between 1935 and 1975, more strict distillery controls, the abolishment of fixed prices for fruit liquors (SAB 2005), and the political promotion to rationalize fruit production (Walter et al. 2010) have led to the felling of fruit trees. This development has been associated with an increase in agricultural mechanization, the introduction of new production procedures, the decrease in the economic value for fruits and adverse market conditions, as well as through structural changes in landscape and the felling of trees due to fire blight (Walter et al. 2010).

However today, Swiss agricultural policy (AP) is targeted towards a more ecological and multifunctional agriculture (FOAG 2009). In the current AP, multi-functionality is compensated through direct payments. So called “ecological direct payments” are provided, among other ecological outputs, for single trees, adapted to their location, and fruit trees in traditional orchards, which can be accounted for as “Ecological Focus Areas” (FOAG 2011). However, the proportion of ecological rewards makes up only 20% of the total expenses of the direct payment system (Bosshard et al. 2010).

A multifunctional landscape implies the development towards a range of agricultural outputs (FOAG 2009) and hence innovative agricultural production systems. Hence agroforestry systems might play an important role for future agriculture as it provides an opportunity to diversify farm revenues.

Since about 2000, Swiss pioneer farmers have started to experiment with combinations of trees with arable crops. They have heard about agroforestry through the press and the internet, mostly from neighbouring Germany and France. Sereke et al. (2014) inventoried innovative agroforestry systems and evaluated their potential productivity and profitability.

In 2014, parallel to the start of the EU FP7 project AGFORWARD (www.agforward.eu), the Swiss Ministry of Agriculture commissioned AGRIDEA, the Swiss national farm extension service, to elaborate extension material for Swiss agroforestry farmers and to establish a participatory research and development network with up to 25 farmers (www.agroforst.ch / www agroforesterie.ch). The overall objectives are:

- To establish a network of farmers with agroforestry demonstration sites;
- To provide agroforestry extension material (website, leaflets, training);
- To record over the years the evolution of pioneer agroforestry sites, both in terms of biophysical growth as in terms of farmer expectations and satisfaction.

The last activity already started in 2011 (Kuster et al. 2012) and is pursued in the context of the AGFORWARD and AGRIDEA projects.

3 Update on field measurements

Field measurements described in the research and development protocol (Herzog, 2015) were started in June and July 2011, and a second assessment was carried out in 2014, when the trees were measured for the second time and soil properties were assessed. Social aspects were included with the use of questionnaires, in order to gather data on farmers' perception and opinion with regard to their agroforestry parcels. This report presents this data and provides a detailed description of the case study system at the Beckenhof-parcel in Sursee (Luzern).

4 Description of system

Table 1 provides a general description of silvoarable agroforestry systems. 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 silvoarable system

General description of system	
Name of group	Silvoarable agroforestry in Switzerland
Contact	Felix Herzog
Work-package	4: Agroforestry for arable farmers
Geographical extent	Silvoarable systems are found throughout Europe, but rare in Switzerland
Estimated area	Very small nationally
Typical soil types	Cambisols, Luvisols
Description	In recent years, a small but growing number of adventurous farmers and growers have been planting alley cropping systems. The tree component consists either of fruit trees (apples, pears and plums), short rotation coppice, and/or timber trees, with arable or vegetable crops in the alleys. The drivers behind planting trees into arable systems vary from farmer to farmer, but are often related to improving the environmental conditions for the crops (reduced wind speeds providing shelter; improved functional biodiversity) as well as diversifying the business by introducing a new product. The systems are usually organised as alley cropping systems with alleys varying in width from 10 m to 24 m (workable alley).
Tree species	Varied including fruit trees such as apple (*Malus domestica*) and cherry (*Prunus avium*) and fuelwood trees such as aspen (*Populus tremula*)
Tree products	Top fruit (apples, cherries) Woodchip for bioenergy and/or mulch/compost
Crop species	Winter wheat (*Triticum spp*), Sorghum (*Sorghum spp*), Maize (*Zea mays*) Rotational fallow, Green manure Field vegetables (strawberries, lettuce, pumpkins, courgettes, beans)
Crop products	Grain, vegetables and fruit
Animal species	None
Animal products	Not applicable
Other provisioning services	Ecological compensation
Regulating services	The tree rows enhance water and nutrient cycling within the appropriate soil, reduce soil erosion, and balance climatic extremes. They also enhance carbon sequestration, water-quality and soil improvement.
Habitat services and biodiversity	The tree row represents a stable habitat in an otherwise highly disturbed agricultural landscape. Thus it can provide shelter and resources for plants and animals, as well as act as a corridor linking up other semi-natural habitat patches. The species promoted by tree rows may be beneficial, neutral or detrimental to provisioning services.
Cultural services	Introducing trees into an arable system may increase job opportunities and skills with regard to tree management. The landscape also changes from an open arable landscape to a partly wooded environment depending on the design of the system. This landscape change can be both an improvement and degradation depending on the context and individual preferences.

Table 2. Description of the specific case study system

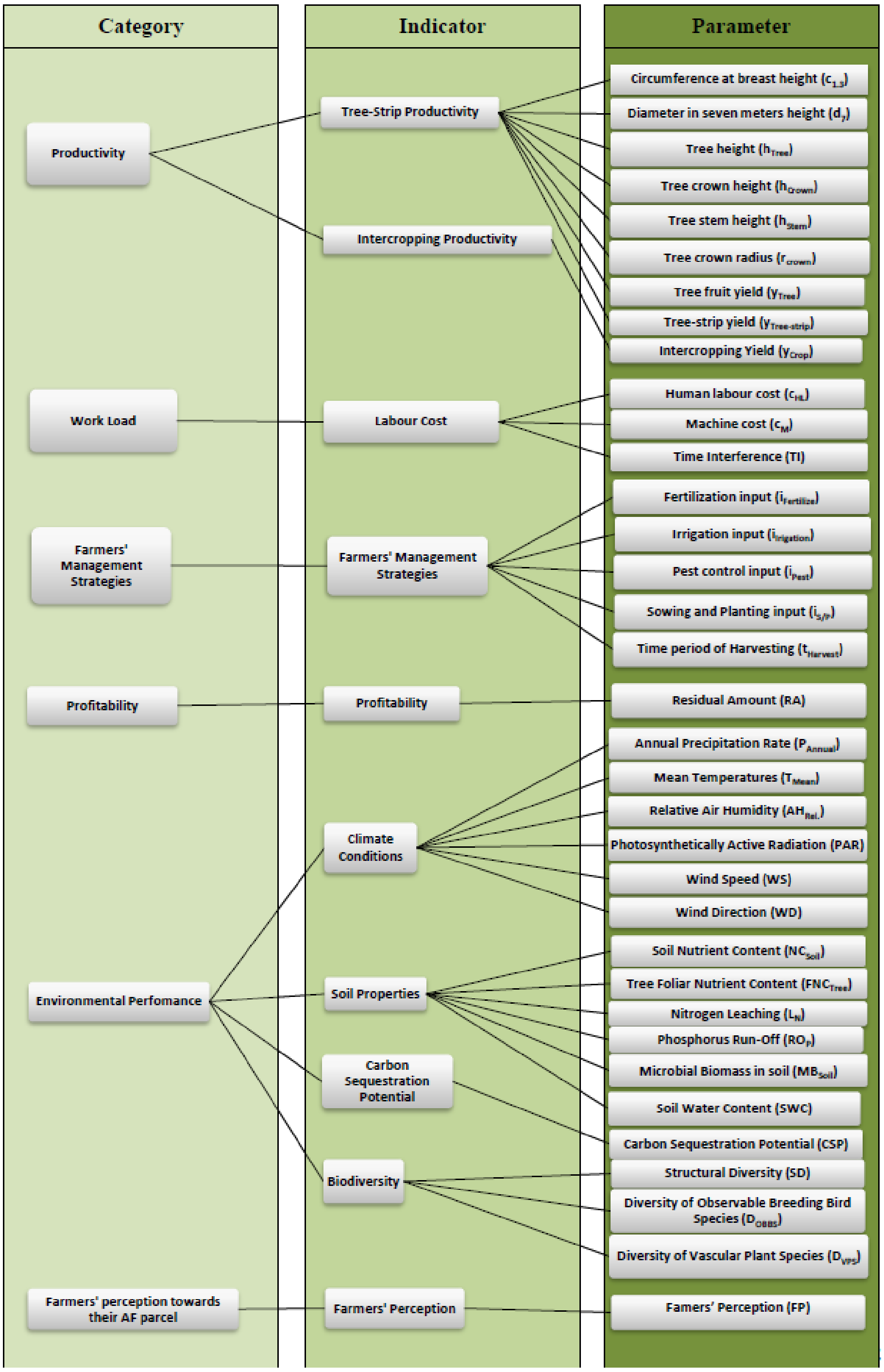
Specific description of site	
Area	5.6 ha
Co-ordinates	47.181568, 8.120794
Site contact	Felix.herzog@agroscope.admin.ch
Example photograph	 Figure 1. Silvoarable system at Sursee (Luzern, CH)
Map of system	 Figure 2. Aerial view of the site
Possible modelling scenarios	
Comparison	Technical, economic and social analysis of agroforestry vs non-agroforestry
Climate characteristics	
Mean monthly temperature	8.9 °C
Mean annual precipitation	96.7 mm
Details of weather station (and data)	http://home.isa.utl.pt/~joaopalma/projects/agforward/clipick/
Soil type	
Soil type	Eutric cambisol
Soil depth	>100 cm
Soil texture	Sandy-loam
Aspect	North-West

Tree characteristics	
Species and variety	545 apple trees (*Malus domestica*) of two different varieties, *Boskoop* and *Spartan*
Date of planting	2007
Intra-row spacing	2.5 m
Inter-row spacing	10 m
Tree protection	None
Typical apple yield	The apple are used to produce apple juice (cider)
Crop/understorey characteristics	
Species	Strawberries, winter wheat, and rotational fallow
Management	To be confirmed
Typical vegetable yield	To be confirmed
Fertiliser, pesticide, machinery and labour management	
Fertiliser	To be confirmed
Pesticides	Thiram / Cuproxat liquid, herbicide
Machinery	5 tractors, 2 syringes, plough, harrow, Liquid manure, fertilizer spreaders, loaders, dump trucks, Rake, Kreisler Shredder
Manure handling	To be confirmed
Labour	To be confirmed
Fencing	To be confirmed
Livestock management	
Species and breed	None
Description of livestock system	None
Financial and economic characteristics	
Costs	To be confirmed

5 Category-indicator-parameter scheme

The initial step was the gathering of potential indicators and corresponding parameters. The monitoring tool exhibits a hierarchical structure including categories, indicators and parameters while the uppermost level is built by categories which are based on the overall goal of the monitoring (Table 3).

Table 3. Hierarchical structure of the monitoring tool (Kuster et al. 2012).



6 Description of the tree component

In 2009, the agroforestry was planted with 545 apple trees (*Malus domestica*) of two different varieties, *Boskoop* and *Spartan*. The trees are arranged in 15 lines with a tree-strip width of around 3 m while in every strip one tree variety is dominating. Tree density is 100 trees/ha, the mean tree diameter was 8 cm in 2011 and 15.9 cm in 2014, the mean tree height was 160.3 cm in 2011 and 201 cm in 2014. Seven trees were replanted in 2014. In 2015 ten trees died because of mice damage, and 15 fell down because of wind, and were replanted. The rabbits are also a problem for the trees, but no system for tree protection has been used.

The stem volume (*V*) was calculated using an allometric equation for *Malus domestica*:
$V = a*(DBH)^2 - b*DBH + c$, were a=0.0003, b=0.0025 and c=0.0101 (Scheuber, 2001) (Figure 1).

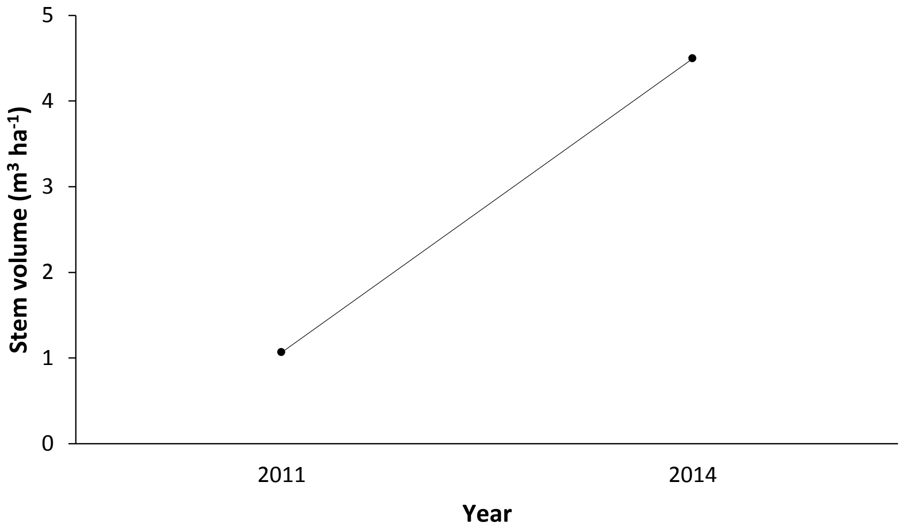


Figure 1 Increment of average stem volume (m^3 ha^{-1}) in the year 2011 and in 2014.

7 Description of the crop component

The crop component constitutes 78% of the agroforestry surface, of which 33% is manged with winter wheat, the 33% with strawberries and the remaining 12% is rotational fallow. These crops are managed according to the Swiss minimum standard for ecological management (ökologischen Leistungsnachweises, ÖLN, http://www.blw.admin.ch/themen/00006/00049/index.html?lang=de).

For strawberries, the phytosanitary products that are used are: liquid Thiram/Bogard (2.5 kg ha^{-1}/0.5 l ha^{-1}), Stroby/Switch (300 g ha^{-1}/1 kg ha^{-1}), Magister (1 l ha^{-1}), Teldor (1 l ha^{-1}), Devrinol Plus (3 l ha^{-1}), liquid Cuproxat (3 lt ha^{-1}), and Soluplant (50 kg ha^{-1}). Winter wheat is managed with manure (25 m^3 ha^{-1}), Ammonsalpeter (150 kg ha^{-1}), Speleo/Lotus/CCC (25 g ha^{-1}/0.25 l ha^{-1}/1 l ha^{-1}), Opera (1.75 l ha^{-1}), and Bell (1.5 l ha^{-1}). The average production is 6-10 t ha^{-1} for winter wheat, and 10-20 t ha^{-1} for strawberries.

8 Biodiversity

In the parcel, there are 10 transition zones, where endangered species of insects can benefit from the presence of trees. One example is the blue-violet forest beetle (*Carabus problematicus*). This beetle profits from the edges, bushes and trees in the northern part of the parcel.

The other species of ground beetles that are potentially found in the parcel are: *Abax parallelepipedus, Abax parallelus, Amara lunicollis, Amara ovata, Anchomenus dorsalis, Carabus nemoralis, Nebria brevicollis, Platynus assimilis,* and *Pterostichus madidus*.

Many bird species can also take advantage of the agroforestry system. The species that are potentially found in this research trial are: *Cardelius cardelius, Phenicurus phoenicurus, Serinus serinus, Muscicapa striata, Picus canus, Picus viridis, Ficedula hypoleuca,* and *Dendrocopos minor.*

9 Soil description

This soil is well-suited for arable production. The pH-values indicate a slight alkaline to alkaline characteristic and top soil consists of slight humus content. The supply with phosphorus and potassium are abundant for crop cultivation (Flisch 2009). The high phosphorus content is probably a historical legacy of over-fertilisation of soils due to a period with a high density of pigs on Swiss farms (Frossard et al. 2004). Pig manure is rich in phosphorus while cattle manure has a high degree of potassium (Frossard et al. 2004). On the other hand, magnesium concentrations appear to be low. The mean measured soil parameters are: humus 3 %, clay 18 %, silt 30 %, pH 7.6, and C 1.84 % (Tables 4 and 5).

Table 4. Soil description of the three agroforestry parcels. The humus content refers to estimations by Urs Zihlmann (Agroscope).

Parcel	Soil depth	Description	Soil type
Beckenhof- parcel	0 – 25 cm	Slight humus content, sandy loam, low stone content	Eutric cambisol with slightly gley characteristics
	25 – 32 cm	Below plough layer, sandy loam, low stone content	
	32 – 60 cm	Sandy loam to loam, low stone content	
	60 – 100 cm (end of soil profile)	Loam, very deep	

Table 5. Characteristics of top soil samples: clay, silt, humus, phosphorus (P), potassium (K), and magnesium (Mg) content. (Spec. = specification (supply-class) based on Flisch et al. (2009)

Plot ID	Clay (%)	Silt (%)	pH	P (mg kg^{-1})	K (mg kg^{-1})	Mg (mg kg^{-1})	Humus (%)
Beckenhof A2	18	30	7.8	23.6	4.0	4.8	3.2
Beckenhof A3	18	30	7.6	18.8	2.2	5.4	3.1
Beckenhof B2	18	30	7.7	20.1	3.5	4.0	3.2
Beckenhof B3	18	30	7.6	18.9	4.1	5.0	3.3

10 Farmer's perception

A system of scores and a questionnaire were conceptualised to evaluate the perception of the farmers on their agroforestry plots. The score system ranged from -3 to 3 points: -3 (absolutely irrelevant), -2 (irrelevant), -1 (rather irrelevant), 1 (rather relevant), 2 (relevant) and 3 (highly relevant).

In 2011 the farmer compiled the first questionnaire (Table 6). In the initial year, tree productivity was considered a rather relevant point (1). Regulation functions (soil protection, ground water protection, local climate conditions, and climate protection) of the agroforestry system were considered irrelevant or having only a minor influence (-1). The farmer perceived the relevant role of the system for species protection and for contributing to the characteristic landscape (2). The farmer considered the agroforestry parcel very interesting in terms of direct payments (3), but not in terms of fruit and wood production (1). Considering the potential risks of light and water competition between trees and crops, the farmer did not consider these as major issues (-1), but he perceived as relevant the risk of increased pest pressure (2). For instance, in the parcel, the mice were a relevant problem. A minor role was played by the impaired mechanization on the agroforestry parcel (1).

The farmer's perception has been also monitored in 2012, 2013 and 2015. The perception changed with time (Table 6), especially regarding the production and regulation functions, for which an increase in the perceived positive effect of the trees was registered.

Table 6. A farmer's perception of their agroforestry parcel in the period 2011-2015 (no data for 2014). Score scale: -3 (absolutely irrelevant), -2 (irrelevant), -1 (rather irrelevant), 1 (rather relevant), 2 (relevant) and 3 (highly relevant).

Year	2011	2012	2013	2015
Tree productivity	1	3	3	2
Regulation functions				
Soil protection	-1	1	2	1
Ground water protection	-1	2	1	3
Local climate conditions	-1	-1	1	2
Climate protection	-1	1	2	1
Shading for cattle	-1	-3	-3	-3
Wildlife protection	2	1	2	nd
Characteristic landscape	2	3	2	3
Economical value				
Income from production	1	3	nd	-2
Income from direct payments	3	3	3	3
Potential risks and limitations				
Light competition	-1	-3	-3	-2
Water and nutrient competition	-1	-3	-3	-3
Root competition	-1	-3	-3	-3
Pest increase	2	3	3	3
Yield loss due to tree litterfall	-2	-3	-3	-3
Limitation for machinery	nd	3	1	-1

nd: not determined

11 Cost forecast

The estimated cost of monitoring the trial over 60 years is outlined in Table 7. It assumes voluntary monitoring inputs from the farmers and some external persons. For the Agroscope labour an income of 45 CHF per hour has been assumed based on a non-agricultural employee relationship (Gazzerin and Vögeli 2009) and assuming the time to drive to the sites. Regarding fuel costs, a petrol consumption of seven litre per 100 km has been assumed. The destinations are approximately about 80 km away, whereby the *Asphof*-parcel and the *Eulenhof*-parcel have been merged due to their proximity to each other. It is considered that Agroscope employees have to meet the farmers once a year to collect data on farmers' management strategies. The cost of material refers to expendable items like aerosols or measuring tapes. The resulting cost for the monitoring over 60 years is estimated to be around 36,000 CHF.

Table 7. Cost forecast (CHF) by resource type over 60 years (assuming no discount rate) and assuming regular measurements after 1, 3 or 5 years (Kuster, 2011).

Resource	Parameter	Time	Periodicity of measurement			Total
			1 year (CHF)	3 years (CHF)	5 years (CHF)	over 60 years (CHF)
Farmers	y_{Tree}, $y_{Tree\text{-}strip}$, y_{Crop} $i_{S/P}$, $i_{Fertilize}$, $i_{Irrigation}$, i_{Pest}, $t_{Harvest}$, c_{HL}, c_M, TI, FP		0	0	0	0
External persons	P_{Annual}, T_{Mean}, AH_{Rel}, D_{OBBS}		0	0	0	0
ART personal	h_{Tree}, h_{Crown}, h_{Stem} $c_{1.3}$, r_{crown}	5-10 min per tree (Total 122)		915		18,300
	RA, CSP	30 min	22			1,320
	NC_{Soil}, D_{VPS}	30 min			22	264
	Fuel (7l/h)					3,584
	Personal cost	*Asphof*, *Eulenhof* (2h) *Beckenhof* (2h)	180		180	11,880
Cost of material					50	600
Total forecast						35,948

12 Plans for 2016

The next step will be to assess root competition in agroforestry systems. The assessment will be carried out extracting soil cores for total root length density measurements at different depths and distances from the trees. Within this work there will be also the possibility to assess water competition trough isotopic analysis.

13 Acknowledgements

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