AGFORWARD
Agroforestry for Europe

Lessons learnt: Agroforestry with fruit trees in Switzerland

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Specific group	Fruit tree agroforestry in Switzerland
Deliverable	Contribution to Deliverable 4.11 Lessons learnt from innovations within agroforestry for arable farmers
Date of report	28 September 2017
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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 field-, farm- and landscape scales, 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 in that it contains results of the studied innovations from one of the systems being studied within work-package 4 which focuses on agroforestry for arable systems. Together with other reports, this document will contribute to Deliverable 4.11 on lessons learnt from agroforestry for arable farmers. Similar reports exist for agroforestry of high nature and cultural value, agroforestry with high value trees, and agroforestry for livestock systems.

2 Systems with fruit trees on arable land in Switzerland

The “agroforestry for arable framers in Switzerland stakeholder group” is part of a national network of agroforestry farmers, which was set up in 2014 within the framework of the national project "Agroforestry Network Switzerland". This practice-on-farm network includes a total of 25 agroforestry farm sites, mainly with fruit trees. This extension project is based on a participatory approach in which a new concept of land management is to be put into practice with farmers. The following objectives are pursued:

- Building a network of agroforestry pioneer farmers and monitoring the development of the agroforestry plots;
- Farmer to farmer exchange of experience regarding management, environmental impact, economics and practical tree knowledge;
- Establishing the Swiss Interest Group on Agroforestry as a contact and extension centre, development of tools, creating a website and organization of events

The activities of the Swiss interest Group on agroforestry include a regular exchange in the field in the form of further education courses, the annual meeting of “IG Agroforst”, maintenance of the website www.agroforst.ch and information exchange via newsletter. The Initial Stakeholder Meeting Report: "Silvoarable Systems with Fruit and High Value Timber Trees in Switzerland" describes the activities more closely and refers to the practical experience of farmers in the French-speaking part of Switzerland who have already gained initial experience with agroforestry systems (Jaeger and Herzog, 2014).

Content of the project

The core element of the project is the development of practical experience in silvoarable agroforestry systems with fruit trees in Switzerland. The experience of the farmers is systematically recorded by questionnaires and during annual visits. Monitoring "light" includes surveys on individual plots for soil structure development (regular spade samples and tests on aggregate stability). In addition, the nature conservation potential of the individual sites is assessed by checklists with the aim of assessing the habitat for endangered species of birds and ground beetles occurring in the environment. The method for this is described in detail by Kaeser et al. (2009).

In order to quantify the carbon storage in the trees and thus to assess the climatic impact of the agroforestry plots, the growth rates (stem circumference, stem length and crown volume) of the different types of trees are measured in the plots. The objective of this survey is to document the carbon accumulation under various production conditions (organic, conventional) and for different tree species and on different soils.

Field measurements and the design of the individual agroforestry plots in the farms are described in the research and development protocol (Herzog, 2015). The measurements started in June and July 2011. 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. The "progress report on the research including a system description" (Petrillo and Herzog 2016) presents this data and provides a detailed description of the case study system at the Beckenhof-parcel in Sursee (Luzern). On this parcel the experiment on monitoring soil organic matter also took place.

The method "monitoring light" is described in more detailed by Kuster et al. (2011). It has been specially adapted for the Agroforestry Network Switzerland project. At the end of 2016 the practical knowledge about this land-use system was summarized in a comprehensive brochure. This brochure is available for download in German and French on the website www.agroforst.ch. The website also contains the presentations of the annual stakeholder meetings of the Swiss interest group on agroforestry.

Figure 1. Members of the Agroforestry Network Switzerland visiting farm trials

Soil organic matter monitoring in Swiss agroforestry systems – Results from a case study

In 2016, Emilie Carrard from the Berne University of Applied Sciences studied the soil organic carbon stock in a 7-year-old agroforestry system in Central Switzerland. Benjamin Seitz from Agroscope accompanied this study and summarized the results in a publication in the journal *Agricultural Research Switzerland* in Seitz et al. (2017).

3 Aim of the study

Two questions were the focus of this study

- Can we monitor soil organic matter dynamics in agroforestry systems?
- What is the variability of soil organic carbon and soil total nitrogen in the studied agroforestry system?

4 Methodology

The examined agroforestry plot (5.6 ha) is located in the canton of Lucerne. It is conventionally farmed. In 2009, 545 apple trees of the varieties Boskoop and Spartan were planted as rows in northwest-southeast orientation. The tree rows occupy 22% of the plot area. Between the rows of trees the following crop rotation was followed: winter wheat/maize/rapeseed/strawberries/fallow land. Crops are fertilized with mineral fertilizers and/or mixed slurry derived from suckler cows and pigs. The tree rows are not fertilized. The type of soil is a calcareous lime brown earth with the soil texture of sandy loam to clay. Since 2011, the development of trees and crops has been observed on the four northernmost tree rows. The humus investigation was undertaken in the third row of trees and in the cultivated area between the tree rows (Figure 4).

Table 1. Specific description of the experiment in Sursee, near Luzern, Switzerland.

Specific description of site	
Area	5.6 ha
Co-ordinates	47.181568°N, 8.120794°E
Site contact	Felix.herzog@agroscope.admin.ch
Example photograph	 Figure 2. Silvoarable system at Sursee (Luzern, CH)
Map of system	 Figure 3. Aerial view of the site

Climate characteristics	
Mean monthly temperature	8.9 °C
Mean monthly precipitation	96.7 mm
Details of weather station (and data)	http://home.isa.utl.pt/~joaopalma/projects/agforward/clipick/

On 4 November 2016 soil sampling took place in the third row of trees and in the cultivated area between the tree rows. In the tree row, five replicas were established between the trees Nos. 6 and 7, Nos. 11 and 12, Nos. 16 and 17, Nos. 21 and 22 and Nos. 26 and 27 (Figure 4). The soil samples were taken exactly in the middle between the trees in the middle of the tree row.

Figure 4. Soil sampling scheme, Sursee

From each replicate in the cultivated area in 3.5 m and 7.25 m distance to the row, further soil samples were taken. The distance of 7.25 m is the center between the tree rows.

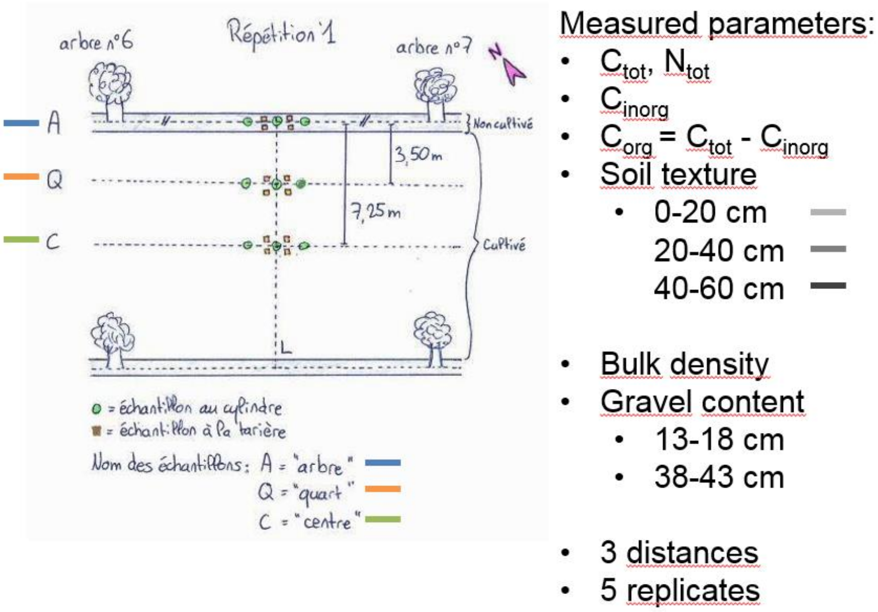

Figure 5. Schematic representation of the soil sampling of the first replicate. Sampling of the remaining replicates was carried out in the same style.

The chosen design consisted of three sampling points (tree row, quarter and center) of the cultivated area with five replicates each. For each replicate, four Pürckhauer incisions were taken up to a soil depth of 60 cm for the analysis of soil texture, carbon (C) and nitrogen (N) content. In addition, three cylinder samples were used for the soil depths of 13-18 cm and 38-43 cm.

Labaratory analysis

The soil texture, the total C and N contents (C_{tot} and N_{tot}) and the lime content were determined in the Pürckhauer samples for the soil depths of 0-20 cm, 20-40 cm and 40-60 cm. The bulk density of the fine earth and the rock content of the soil were determined with the cylinder samples in the depths 13-18 cm and 38-43 cm. The samples were dried at 40°C for 72 hours and sieved to 2 mm. The soil texture was measured in accordance with the Federal Reference Method COM (Agroscope 1996). The C_{tot} and N_{tot} contents were measured with a CN analyzer (Vario MAX CN, elementary). The calcium content and the calculated inorganic C content (C_{anorg}) were determined according to the federal reference method $CaCO_3$ (Agroscope 1996). The content of organic C (C_{org}) was calculated as the difference between C_{tot} and C_{anorg} ($C_{org} = C_{tot} - C_{anorg}$).

The determination of the bulk density and the stone content was carried out with the three cylinder samples (100 cm^3) from both depths (13-18 cm and 38-43 cm) for each of the 15 sampling points. The cylinder samples were dried at 40°C for 72 hours and weighed (Gewtot). After the samples were saturated with water overnight, the stones were washed out in a 2 mm sieve. The weight of the dry stones (GewSt) was determined and the volume (VolSt) was estimated by water displacement in a measuring cylinder.

The bulk density of the fine earth (*LD*) was calculated according to the formula: $LD = (Gewtot - GewSt) / (100\ cm^3 - VolSt)$.

Humus and humus accumulation

To calculate humus stocks, the soil profile was divided into four segments: 0-20 cm, 20-25 cm, 25-40 cm and 40-60 cm. The determined C_{org} and N_{tot} contents were assigned to the respective segments according to their depths. The bulk density of the fine earth for the bottom depth of 13-18 cm was used for the two segments of the plow horizon (0-20 cm and 20-25 cm), the bulk density for the bottom depth 38-43 cm for the two lower segments. The calculated inventories of C_{org} and N_{tot} were normalized to a uniform mass of fine earth per m^2 for comparability according to the Equivalent Soil-Mass method (Lee et al. 2009; Schrumpf et al. 2011). In our case, we decided for the ground layers 0-350 kg fine earth / m^2 (≈ 0-25 cm), 350-550 kg fine earth / m^2 (≈ 25-40 cm) and 550-900 kg fine earth / m^2 (≈ 40- 60 cm).

There is no soil data before 2009 available and a control-parcel does not exist, so the C or N accumulation in the soil can only be calculated under certain assumptions:

1) The average soil stocks of C_{org} and N_{tot} in the cultivated area between the tree rows are in equilibrium and have not changed since 2009.
2) The average soil stocks in the cultivated area are also representative for a hypothetical, non-agroforestry used control parcel.

The accumulation rate per hectare and year is calculated by means of the following formula:

Accumulation rate per hectare and year = (0.22 [area proportion of tree row] * soil stock tree row - 0.22 * soil stock cultivated area) / 7 [number of years].

The 0.22 factor refers to the tree proportion of the agroforestry system. The calculated accumulation rate corresponds to the C or N accumulation per ha of agroforestry compared to a hypothetical hectare of only arable cultivation.

It is important to note that the calculated C and N accumulation is only an estimate, which is also specific to the location and the system. It is possible that the values on other soils or in systems with other tree species differ significantly.

5 Results

Regarding the calculated stocks of C_{org} and N_{tot} in the tree row and in the cultivated area centre, already seven years after establishment of the agroforestry system, significant differences ($p < 0.05$ for all comparisons) could be observed (Figure 6). The ground stocks in the tree row were 18% higher for both C_{org} and N_{tot} than in the cultivated area centre between the tree rows. Surprisingly, the enrichment of the soil with C and N was observed not only in the upper soil (≈ 0-25 cm) but also in deeper layers (≈ 25-40 cm and 40-60 cm). On the contrary, no significant differences were observed when comparing the results of C and N stocks between the cultivated area quarters and the cultivated area centre.

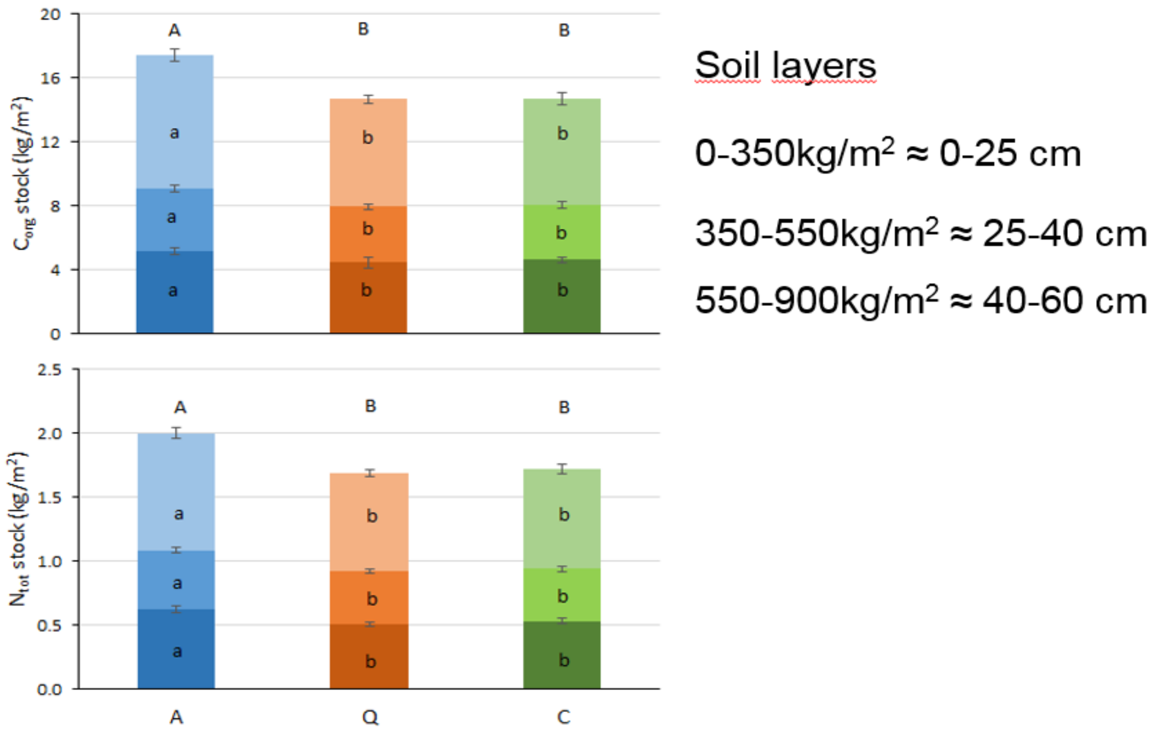

Figure 6. Soil carbon and nitrogen stocks - Comparison tree row (blue = in the tree row), cultivated area quarters (orange = 3.50 m to the tree row) and cultivated area center (green = 7.25 m to the tree row).

Carbon and nitrogen accumulation rate

The C and N accumulation rates were calculated for the whole plot (22% area of the tree rows, 78% area of the cultivated area) against a hypothetical control area (100% area of the cultivated area). The upper layer (≈ 0-25 cm) of the agroforestry plot enriches C_{org} with a rate of 0.51 t C per hectare per year. For the total examined soil depth (≈ 0-60 cm), a C accumulation rate of 0.86 t C per hectare and year, for nitrogen 91 kg N per hectare per year is achieved.

The results show that the planting of an agroforestry system has a significant influence on the C and N accumulation in soil already within the few years after establishment. Significant quantities of C and N were accumulated in both the upper and the lower layers of the tree row. The calculated C-accumulation rates of 0.51 t C per hectare and per year for the topsoil and 0.86 t C per hectare and per year for the total of 0-60 cm tested soil depth are rather high but within a realistic range.

Discussion

The nitrogen enrichment of 91 kg N per hectare and per year for the total examined soil depth (0-60 cm) is the result of the relatively constant C / N ratio of the organic soil substance of an average of 8.62 ± 0.10. However, the number is comparatively high, especially since the accumulation rate for the parcel was calculated, but the enrichment only occurs under the tree row. It must also be taken into account that there is no N-Fixation on the parcel caused by the crops (winter wheat, maize, rapeseed, strawberries, rotation fallow land and apple trees). In the herbaceous vegetation of the tree row no leguminous where found, but an exact assessment of the tree strip vegetation was not carried out. If a portion of the accumulated nitrogen is to be explained with lower nitrogen losses, agroforestry systems would be an interesting alternative for arable farming areas which currently leach high nitrate levels to the groundwater.

Comparison of this study with observations of aggregate stability

Since 2015, spade samples have been taken from the parcel at the same points within the tree row and in the middle of the cultivated area, and small soil particles were tested for water stability (Table 2).

Table 2. Effect of time and soil depth on the proportion of water stable aggregates in the tree strip and in the arable alleys between the tree rows.

Place of sampling in the tree strip	Proportion of water-resistance soil crumbs (%)		
	Year 2015	Year 2016	Year 2017
Surface	62.5	67.5	70
Soil depth 0-15 cm	75	60	65
Soil depth 15-30 cm	75	70	60
Soil depth 40-40 cm	65	60	52.5

Place of sampling between tree rows	Proportion of water-resistance soil crumbs (%)		
	Year 2015	Year 2016	Year 2017
Surface	50	52.5	65
Soil depth 0-15 cm	55	52.5	62.5
Soil depth 15-30 cm	55	45	45
Soil depth 40-40 cm	45	42.5	50

The observations only allow for a qualitative assessment, since this is not a quantitative analysis. The qualitative analysis assumes that increased organic matter and biological activity should increase the water stability of the aggregates. The observations in Table 2 are consistent with the results of the organic carbon measures is that the humus content in the tree strip is higher in all soil layers than in the cultivated area between the tree rows.

6 Lessons learnt

The principal lessons learnt from the measurements and observations in this fruit tree silvoarable system include:

- The agroforestry system in Central Switzerland accumulated substantial amounts of carbon and nitrogen under the tree rows in both topsoil and subsoil up to a depth of 60 cm after only seven years.
- Carbon accumulated in the subsoil could be of particular interest in the context of soil carbon sequestration. Short-term carbon accumulation might be caused by the herbaceous vegetation of the tree rows and not by the trees themselves.
- Qualitative observations regarding the development of water-resistant crumbs on the plot are consistent with the above mentioned results.
- Another qualitative observation on the parcel is that the trees grow very quickly and the parcel is well supplied with nutrients from mineral and organic fertilization. The tree strip itself, however, is unfertilized and the grass strip has no significant proportion of legumes. The assumption suggests that the trees can access nutrient reserves after only seven years in soil layers, which are not available for the crop plants.

2009

2015

Figure 7. Trees develop rapidly and benefit from the fertilizer in the field and the mineralization by the tillage

7 Acknowledgements

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