SWISS FUTURE FARM

Annual Report 2019

Thurgau BBZ Arenenberg
AGCO Your Agriculture Company
GVS Agrar

Farm

The **Swiss Future Farm** is located south of Aadorf in the Canton of Thurgau and can be reached by car within 40 minutes from Zurich or St.Gallen.

Farm size and structure:
81 ha agricultural land
55 ha arable farming
20 ha grassland farming
6 ha biodiversity area

Livestock:
65 dairy cows
55 sows

Objectives

The Swiss Future Farm makes modern precision farming technologies visible, tangible and understandable for sustainable and competitive agriculture.

- Practice-oriented field trials are carried out on site and presented to the public
- Digital farm management is implemented in an exemplary and practice-oriented way on an agricultural enterprise
- Research and development results are applied in practical application
- Innovative cooperation between private agricultural enterprises and public education and consulting
- Tänikon as a meeting point for agriculture

Partners

AGCO Corporation
Leading manufacturer of high-tech solutions for farmers.
Brands: Fendt, Challenger, GSI, Massey Ferguson, Valtra.

BBZ Arenenberg
Agricultural education and advisory center of the Canton of Thurgau with three research and pilot farms.

GVS AGRAR
Market-leading importer of agricultural machinery in Switzerland. Import, sales and service for all AGCO brands.

Foreword

Welcome to the second annual report of the Swiss Future Farm!

At AGCO we create hi-tech solutions for farmers feeding the world. We actively focus on the top agronomic challenges farmers are faced with. In some cases that means developing new sensors, systems, or machines; but in others it means collaborating with partners to solve problems together. The Swiss Future Farm is a collaboration project between AGCO, GVS Agrar and BBZ Arenenberg where we work together to test the latest farming technologies to learn how crop yields can be maintained or improved while reducing waste of crop inputs like seed, fertilizers, and agrochemicals. We are also working to be good stewards of the soil with a goal to increase soil organic matter by 1% over the next ten years. Through this work we are building a more profitable sustainable farming system today and for the future.

And it is important that we share what we are learning. We do that through our website[1], through blog posts[2], Social Media[3], tours and grower events at the farm, speaking engagements at conferences, and of course this report. We hope you learn something new about Smart Farming applications!

Darren D. Goebel
Director, Global Agronomy and Farm Solutions
AGCO Corporation

[1] www.swissfuturefarm.ch

[2] https://blog.agcocorp.com/tag/swiss-future-farm/

[3] https://www.facebook.com/swissfuturefarm/

Probably no other innovation is currently penetrating agriculture as massively as digitalization, and it is being discussed with corresponding intensity. Whether in research based on data, in the analysis of Big Data in agriculture or in the area of Agriculture 4.0, digitalization is seen as the key to solving future challenges, especially in agriculture. At the Swiss Future Farm, the combination of research by Agroscope, education and consulting by the BBZ Arenenberg Education and Advisory Center and the involvement of private partners such as GVS Agrar and AGCO provides an innovative basis for tackling these challenges. Agroscope, as a research partner of the Swiss Future Farm, will in future become even more involved in the field of overall farm-based, indicator-based management at the Tänikon site. For farmers, it is almost impossible to grasp, let alone assess, the wealth of offers. Certainly, all possibilities for a simultaneously resource-efficient and sustainable agriculture should be realized. This should be done in economically viable steps. Making the technologies visible and tangible is an important step in this direction. Special thanks go to the Operating Team of the Swiss Future Farm with Florian Abt, Marco Meier and Dr. Nils Zehner for the enormous commitment, processing, presentation and publication of the findings and data to farmers and the general public.

Walter Schönholzer
Councilor, Department of the Interior and Economics
Canton of Thurgau

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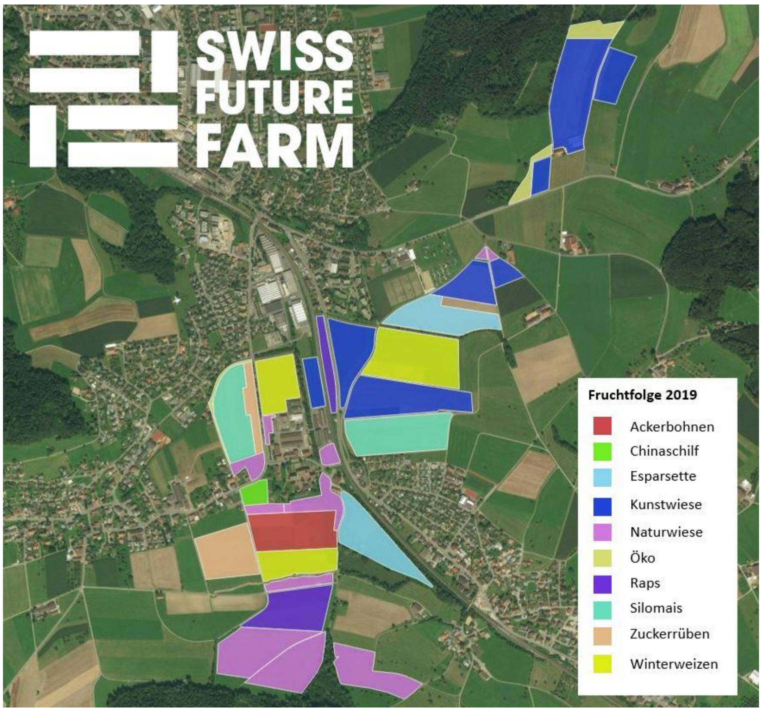
1. Harvest year 2019

1.1 Cropping plan



1.2 The year 2019 at the SFF

The year 2019 was strongly influenced by sugar beets. The sugar beet trials from 2018 were continued this year in a large-scale randomized trial (see Chapter 2) so that after two harvest years, the first results on the effect of sowing depths, liquid fertilization, population density and coulter pressure settings are available. It turned out that also this year, the sowing depth of 4.0 cm, which is unusual for Switzerland, produced good results. The trial for Variable Rate nitrogen fertilization was also carried out for the second year in 2019 and it was shown that the amount of fertilizer could be reduced by an average of 10% while maintaining equal yields.

In 2019, the training and course program was further expanded with events organized by the three partners. The topic of smart farming has found its way into basic education and into the farm management school at BBZ Arenenberg via the elective module Energy and Agricultural Engineering. With the foundation of the GVS Agrar Academy the competences within GVS Agrar AG have been further developed. In March 2019, the exhibition on renewable energy and electric mobility in agriculture was opened at the SFF as part of a conference of the International Lake Constance Conference (IBK). Until the end of the year, the exhibition attracted numerous visitors to Tänikon. The event highlight in 2019 was the 1st Swiss Future Farm Days. A broad spectrum of visitors was addressed with topics relating to mechanical weed control, stubble cultivation in rapeseed, Controlled Traffic Farming and Variable Rate nitrogen fertilization. The International Straw Bale Arena, which took place as part of the Farm Days, was also a major visitor magnet.

There were two personnel changes in the SFF Operating Team. Marco Landis (GVS Agrar AG) left the team at the end of October 2019. We thank Marco very much for his work! In November 2019, Marco Meier (GVS Agrar AG) took up the vacant position and is now responsible for Technology and Applications at the Swiss Future Farm. We wish Marco a good start! Also in November 2019, Raphael Bernet (BBZ Arenenberg) took up the newly created position as Operations Manager for Arable and Forage Production at SFF. We also wish Raphael a great start in this exciting position!

Figure 1. The Swiss Future Farm Operating Team (from left) with Raphael Bernet (Operations Manager for Arabale and Forage Production, BBZ Arenenberg), Dr. Nils Zehner (Research and Innovation, AGCO Corporation), Florian Abt (Education and Consulting, BBZ Arenenenberg), Marco Meier (Technology and Application, GVS Agrar AG).

1.3 The 2019 harvest year at a glance

The year 2019 is considered the fifth warmest year in Switzerland since measurements began in 1864 (MeteoSwiss 2019). The winter started with a very warm December, followed by a cold January. In February, temperatures already rose to as high as 14°C. Striking were the strong fluctuations between day and night temperatures. This is especially due to the high number of winter sunshine hours (Figure 2). Due to the rapidly rising spring temperature, the soils in Tänikon were able to warm up quickly and the low precipitation period from mid-March onwards provided a good time window for optimum seedbed preparation and sugar beet planting on 28 March 2019, which was rather early for the site. The constantly rising temperature influenced the good juvenile development of the sugar beets. At the beginning of May, the corn was planted after a dry phase. Growth conditions remained favorable thereafter and the summer was again characterized by extreme heat in 2019, which started as early as June. However, compared with the dry year 2018, sufficient rain fell throughout Switzerland. The Tänikon site, with its 938 mm, was below the long-term site mean of 1184 mm, but compared to 2018 (793 mm) it was more humid. The grain harvest started early throughout Switzerland. In Tänikon, the wheat was harvested during a series of hot days in the third week of July, which is a usual timeframe in the region. Precipitation at the end of August made tillage and seeding of rapeseed and winter wheat difficult on the heavy Tänikon soils. The autumn of 2019 was again characterized by high temperatures. The corn could be harvested at the end of September under ideal conditions. As early as October 1, 2019, sugar beet was harvested in dry conditions in Tänikon. The last winter wheat was not sown until December 5, 2019, due to the area occupied for the SFF farm days and the subsequent high precipitation period.

For interpretation of local weather data in 2019, the measured values can be compared to the long-term average values of the Tänikon weather station between 1981-2010, which is located at the Swiss Future Farm (WIGOS Station Identifier: 0-20000-0-06679). The winter of 2019 was characterized throughout Switzerland by a high number of hours of sunshine. Table 1 shows the average solar radiation in Tänikon in the course of 2019 on monthly basis in comparison to the long-term average values during the period of 1981-2010.

Table 1. Average monthly solar radiation (W/m²) in Tänikon 2019 compared to the long-term site average of 1981-2010.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Period
34	85	133	162	184	257	255	194	153	75	38	25	133	2019
40	70	116	165	202	221	227	195	136	78	42	30	127	1981-2010
-6	15	17	-3	-18	36	28	-1	17	-3	-4	-5	6	Difference

Figure 2 shows that increased solar radiation in 2019 compared to the long-term average occurred particularly during early spring (February to March) and mid summer (June to July) 2019. Contrary, lower solar radiation than in the long-term average was measured for May 2019, which affected particularly the growth of corn that was planted in this period.

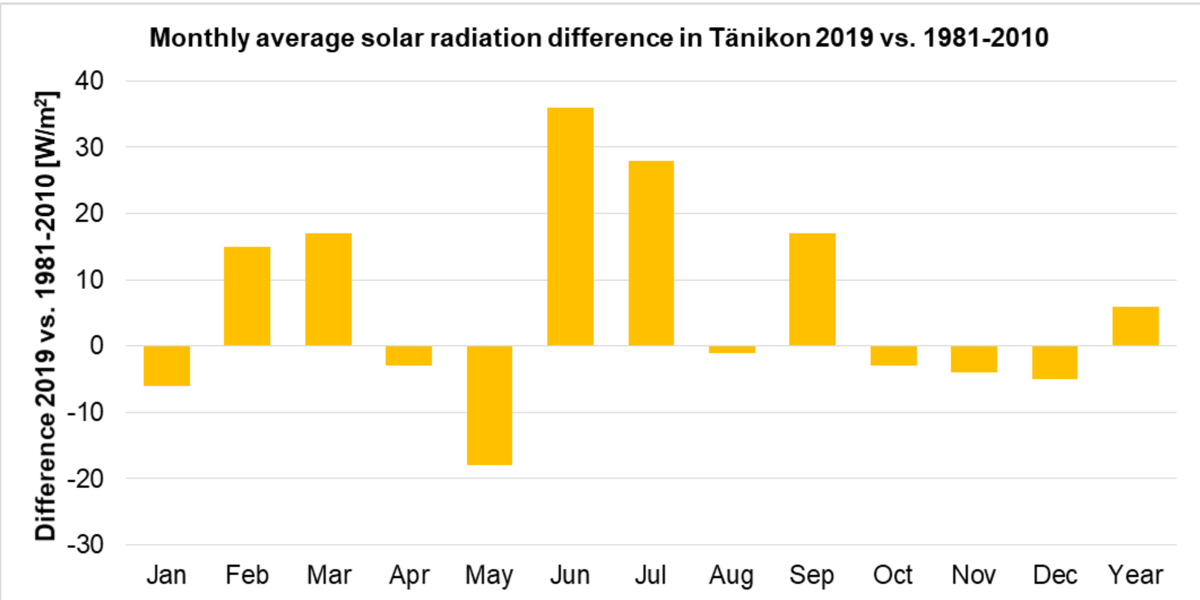


Figure 2. Differences in the monthly average solar radiation (W/m²) in Tänikon 2019 compared to the long-term site average of 1981-2010.

The average monthly temperatures in Tänikon in the course of 2019 show an increase particularly in February to March and June to July compared to the long-term site average. Overall, the annual average temperature in 2019 was 10.0 °C compared to a long-term annual average from 1981-2010 of 8.7 °C (Table 2).

Table 2. Average monthly temperature (°C) in Tänikon 2019 compared to the long-term site average of 1981-2010.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Period
-0.4	2.6	6.4	8.6	10.5	19.5	20.7	18.9	14.6	11.2	5.0	2.9	10.0	2019
-0.3	0.4	4.5	7.9	12.7	15.9	18.0	17.4	13.5	9.2	3.7	0.9	8.7	1981-2010
-0.1	2.2	1.9	0.7	-2.2	3.6	2.7	1.5	1.1	2.0	1.3	2.0	1.3	Difference

Figure 3 shows the differences between monthly average temperatures in Tänikon in the course of 2019 vs. 1981-2010, where the warm February and the hot summer months are clearly visible. Contrary, May 2019 had a significantly lower monthly average temperature in 2019, with negative effects for corn growth, which was a common occurrence all over the Northern hemisphere during this period in 2019.

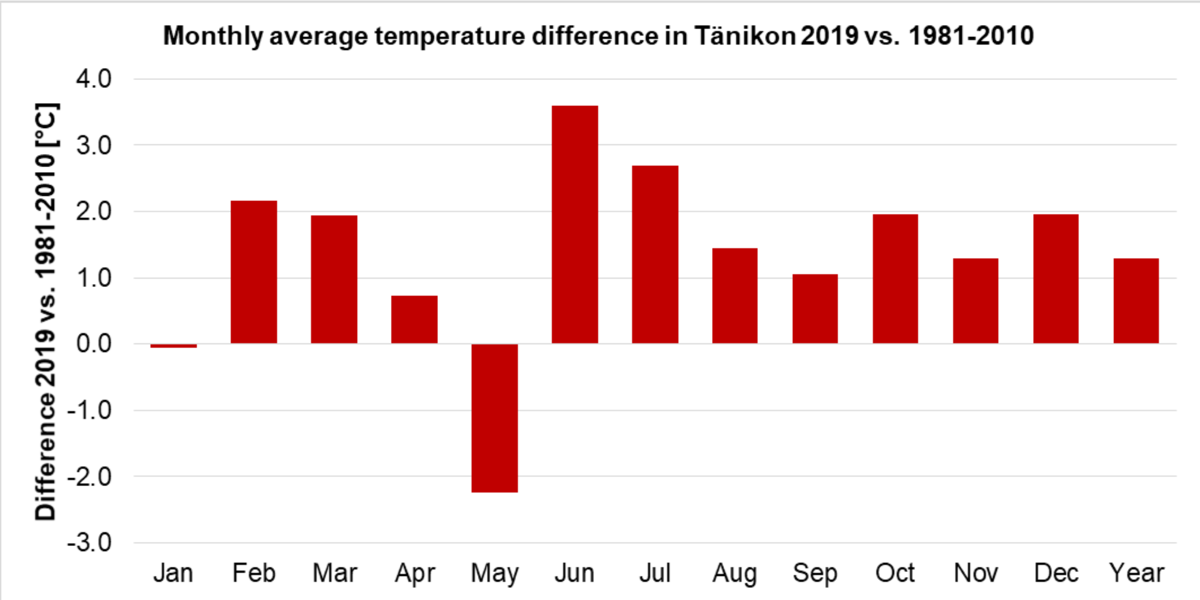


Figure 3. Differences in the monthly average temperatures (°C) in Tänikon 2019 compared to the long-term site average of 1981-2010.

Precipitation in Tänikon during 2019 was lower than the long-term average, with an annual amount of 938 mm in 2019, compared to an average annual amount of 1184 mm in 1981-2010, which resulted in a difference of -246 mm (Table 3).

Table 3. Monthly precipitation (mm) in Tänikon 2019 compared to the long-term site average of 1981-2010.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Period
92	46	56	56	152	9	24	111	81	153	74	84	938	2019
76	73	88	90	124	124	117	120	102	91	84	96	1184	1981-2010
16	-27	-32	-34	28	-115	-93	-9	-21	62	-10	-12	-246	Difference

The differences in average monthly precipitation comparing the values of 2019 vs. 1981-2010 (Figure 4) show the reduced amount of precipitation particularly during June and July 2019, whereas increased precipitation occurred during May and October 2019.

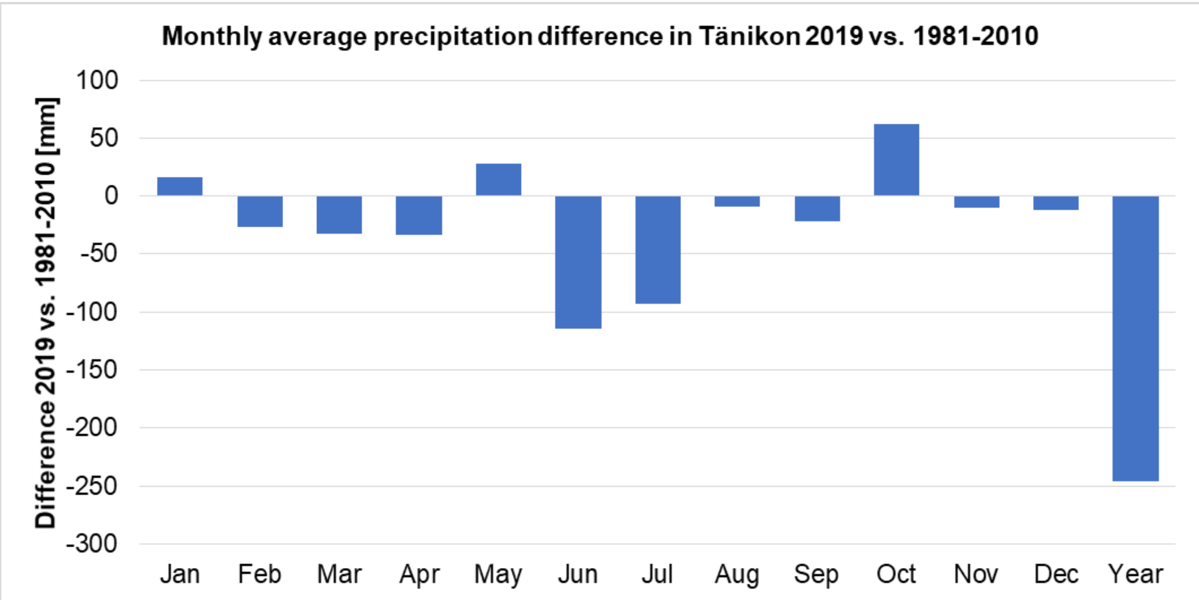


Figure 4. Differences in the monthly precipitation (mm) in Tänikon 2019 compared to the long-term site average of 1981-2010.

In an overall consideration, 2019 was characterized by a warm and dry spring from February to April, contrary to a cold and humid May, followed by a hot and dry summer period during June and July, and a comparably mild autumn and winter from September to December. This resulted in drier planting conditions for sugar beets than usual, extraordinary disadvantageous growing conditions for corn in May, tendencies to drought but good harvest conditions in peak of summer and comparably late winter wheat planting in autumn on the Swiss Future Farm.

2. Field trials

2.1 Variable Rate nitrogen fertilization in winter wheat using drone and soil data

Objectives

The aim of this multi-year experiment is the targeted application and automated monitoring of nitrogen in plants using drone, satellite and soil data. The precise fertilisation method should fix as much nitrogen as possible through the plants and as little as possible should be lost to the environment via leaching and denitrification.

Study design

The experiment will be carried out as part of the PhD thesis of Francesco Argento (Agroscope Tänikon, ETH Zurich) during the years 2018-2020 at the Swiss Future Farm. In 2019, three areas were available for the trial: Grund (2 ha), Herrenpünt (1.7 ha) and Schürpünt (2.5 ha). There is a high degree of heterogeneity between and within the fields, therefore the trial plots were distributed within the trial fields according to the differences in soil and repetitions were inserted (Figure 5.). Between the trial fields the clay content varies in the range of 25-30% and the organic matter is in the range of 1.5 and 3% (Table 4). Within the fields, F1 and F4 in particular are characterized by a slightly increased clay variability. Winter wheat of the Arnold variety was sown in all areas. Sowing in area F4 took place one month later than in areas F2 and F3.

Four different fertilization methods are compared in the trial (Figure 5, right picture). The standard strips (ST) were fertilized with a constant amount of fertilizer as is common practice. In the strips with variable fertilization (VR), the fertilization rate was adjusted based on the N-min measurements (1^{st} application) and the aerial photograph (2^{nd} and 3^{rd} application). The strips NF (no fertilizer during the whole season) and NR (increased 1^{st} and 2^{nd} application if 3^{rd} application was omitted) served as a control. The test plots have a dimension of 30 x 90 m, whereby a 15 m strip between two tramlines was considered for the evaluation.

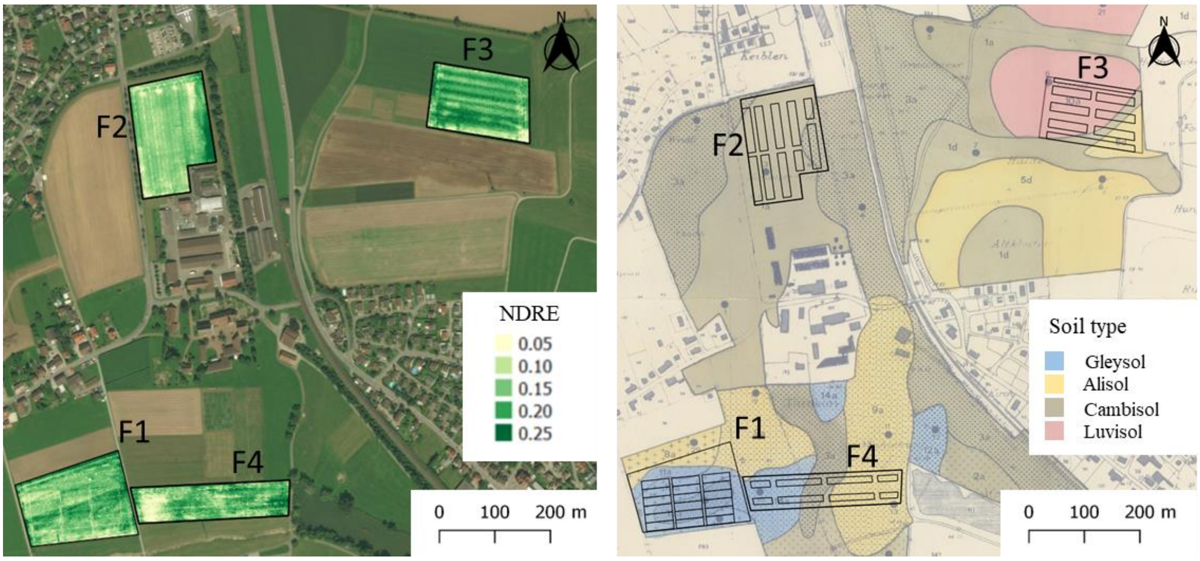


Figure 5. The NDRE index recorded with the drone for the trial fields Rüedimoos (F1, year 2018), Schürpunt (F2), Grund (F3) and Herrenpünt (F4) (left picture) and the soil map with the distribution of the treatments over the trial plots (right picture).

Table 4. Field characteristics of the four experimental plots of the fertilizer trial.

Field properties	F1	F2	F3	F4
Area (ha)	2.2	2.5	1.9	1.6
Previous crop	Silage corn	Silage corn	Silage corn	Grassland
Seeding date	19 Oct 2017	9 Oct 2018	12 Oct 2018	5 Nov 2018
pH	7.7 ± 0.1	6.9 ± 0.4	6.9 ± 0.4	7.5 ± 0.2
C_{org} (%)	3.2 ± 0.9	2.4 ± 0.1	1.5 ± 0.3	2.8 ± 0.6
P (mg kg^{-1})	1.9 ± 0.6	1.3 ± 0.5	2.7 ± 1.1	1.3 ± 0.46
K (mg kg^{-1})	38.5 ± 14	17.9 ± 5.8	32.6 ± 9.5	18.7 ± 6.4
Mg (mg kg^{-1})	381.7 ± 77.1	377.0 ± 43.1	172.5 ± 71.7	282.3 ± 123.4
Clay (%)	24.5 ± 4.1	34.6 ± 7.3	25.9 ± 9.1	35.0 ± 9.5
Silt (%)	37.5 ± 2.5	39.1 ± 1.5	38.4 ± 3.1	34.1 ± 2.4
Sand (%)	37.9 ± 5.1	26.3 ± 6.9	35.6 ± 8.9	30.9 ± 9.3
Soil type (WRB)	Gleysol	Cambisol	Luvisol, Alisol	Gleysol, Alisol

Applied technology

Table 5. Technology and equipment used for the fertilizer trial.

Field operation	Machine	Brand	Model
Tillage	Tractor	Fendt	516 with RTK incl. front weight
	Cultivator	Horsch	Terrano 3 FX
Seeding	Tractor	Fendt	516 with RTK incl. front packer Rabe
	Seeder	Horsch	Express 3 KR
Fertilization	Fertilizer spreader	Sulky	Econov X40 (incl. SC and VRC)
	Tractor	Massey Ferguson	5713S with RTK and TC GEO
Weed control	Tractor	Fendt	313 with RTK
	Harrow	Treffler	TS 1520, 15m
Harvest	Combine	Fendt	5275 C PLI yield monitor RDS Ceres 8000i
Data transfer	FMIS	Farmfacts	NEXT Farming Office
Aerial images	Drone	DJI	Phantom 4 Pro with Parrot Sequoia multi-spectral camera

Crop care and fertilizer applications

In 2019, the crops were managed without herbicides, fungicides and growth regulators. Weed control was carried out mechanically with the harrow in spring. Table 6 shows the applied fertilizer amounts in kg N/ha for the different methods. MgS ammonium nitrate (24% N, 5% Mg, and 8.5% S) was used as fertilizer. In the standard strips (ST) a total nitrogen quantity of 155 kg N/ha was applied, in the NR strip 160 kg N/ha were fertilized. In 2019 the fertilizer amounts applied in the strips with Variable Rate application ranged between 95-149 kg N/ha.

Table 6. Overview of fertilizer amounts and distributions in kg N/ha for the different treatments in 2018 and 2019.

Field	**Treatment**	**Application 1**	**Application 2**	**Application 3**	**Total**
		BBCH 23	BBCH 32	BBCH 45	
F1	ST	80 - N_{min} = 36	60	20	116
2018	VR	80 - N_{min} = 0 - 50	40-70	0-20	50-132
	NF	-	-	-	0
		BBCH 25	BBCH 31	BBCH 39	
F2-4	ST	70	60	25	155
2019	VR	80 - N_{min} = 52 - 75	40-70	10-30	95-149
	NF	-	-	-	0
	NR	100	60	-	160

Technical implementation

The fields were flown over by drone (DJI Phantom 4 Pro with on-board multi-spectral sensor Parrot Sequoia) shortly before the upcoming N-fertilization in order to determine the spectral information on the N content in the wheat. The PhD student Francesco Argento compiled an application map in shape format from the data obtained. As the MF 5713S tractor used did not allow processing data in shape format, the data had to be converted to ISO XML format using NEXT Farming Office software. It was important to note that in ISO XML format the grid is always automatically aligned to north. Therefore the prescription map (Figure 6, left picture), which was created based on the aerial photograph, had to be manually transferred into the north-aligned grid (Figure 6, right picture). In order to achieve the best possible result, it was determined what maximum grid resolution could be processed by the tractor. In the end, the data was transferred from the software to the tractor with a resolution of 7.5 x 7.5 m via the VarioDocPro server interface.

Figure 7 shows the as-applied map with the actually applied fertilizer amounts for the field Herrenpünt in 2019. In principle, the created prescription map could be carried out by the fertilizer spreader. However, it can be seen that when switching between two zones, especially with large gradations (from 0 to 60 kg N/ha or also from 20 to 40 kg N/ha), a certain adjustment time was required for the dosage controller. The fine zone gradation also meant that the prescription map could not always be implemented precisely. This situation was countered during the evaluation of the experiment, in which samples were always taken in the middle of an experimental plot. For the coming season, a larger control range will also be defined, in which a larger time window will be available for increasing or reducing the dosage amount.

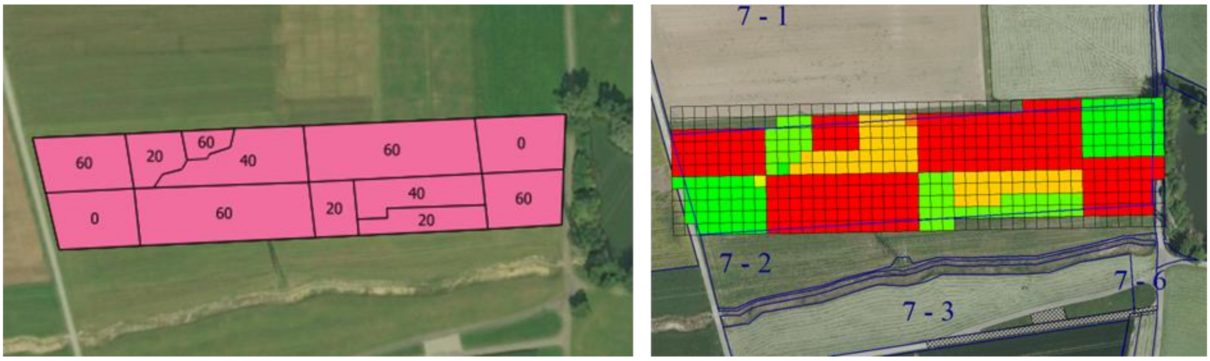


Figure 6. The left image shows the distribution of the plots based on the drone image for the 2nd N-application on 24 April 2019. The right image shows the plots after conversion to ISO-XML format.

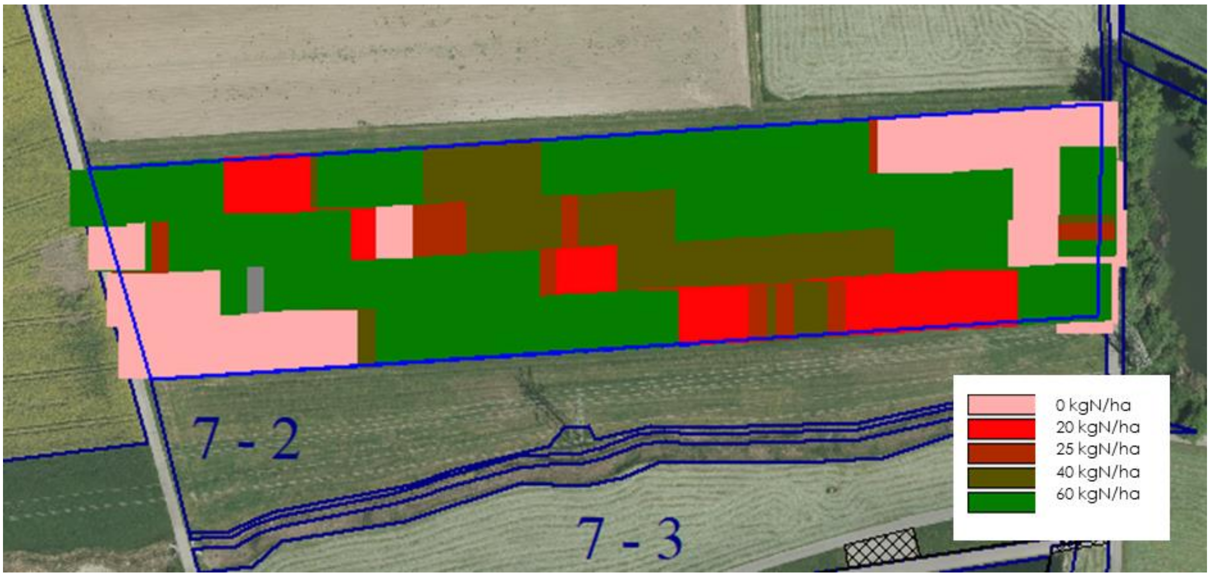


Figure 7. As-applied map of the effectively applied fertilizer amounts in the field.

Results

The two trial years so far have shown that by applying Variable Rate fertilization using drone patterns and soil data, the amount of fertilizer applied could be reduced by an average of 10% without any loss in yield. The trial areas F1, F2 and F3 have a yield of 65-75 dt/ha, which is the average for Switzerland. The low yields in F4 are due to late sowing and a considerable loss of wheat due to an application error in mechanical weed control. In area F2, the amount of fertilizer used was reduced by 12 kg N/ha compared to the standard method (ST) with a Variable Rate fertilization (VR) and the yield was increased by approx. 5 dt/ha.

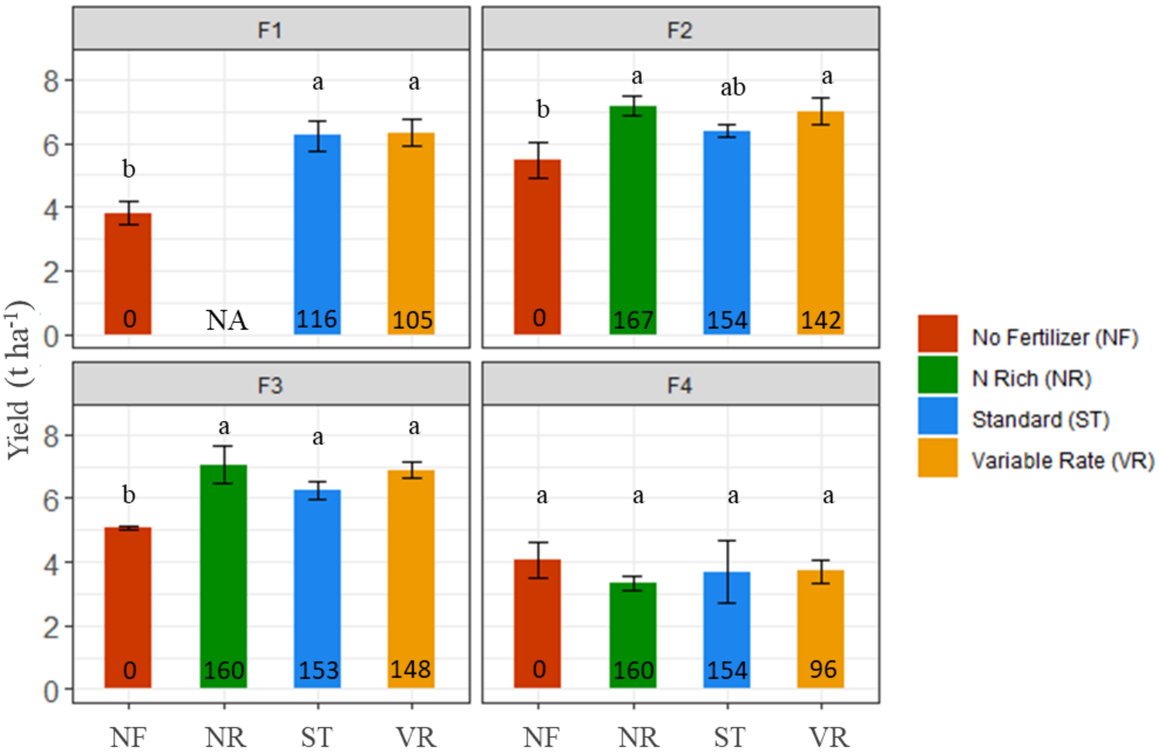


Figure 8. Wheat yield (t/ha) and amount of N applied (kg/ha) for experimental plots F1, F2, F3, F4 in 2018 and 2019.

Knowledge transfer

The results of the trial on Variable Rate nitrogen fertilization were presented to a wide range of interested parties from agricultural practice, education and consulting as part of the public relations work of the Swiss Future Farm during visitor tours, workshops and external events.

Outlook and next steps

In the coming season, the trials will continue to run on 2-3 fields with a total of 11.5 ha. The focus will again be on the successful technical implementation. The conversion of the drone patterns will be carried out in a larger grid (15 x 15 m) for exact adjustment to the working width of the fertilizer spreader. For this purpose, coarser gradations will also be selected in the aerial photography.

Trial team

- Study design: Francesco Argento, Frank Liebisch and Thomas Anken (Agroscope Tänikon, ETH Zurich)
- Drone flights and sampling: Francesco Argento und Eric Vogelsanger (ETH Zurich)
- Coordination and practical implementation: Operating Team Swiss Future Farm

Further information

Project description:
http://swissfuturefarm.ch/index.php/projekte/teilflaechenspezifische-stickstoff-duengung-mit-digitalen-technologien

Video "Mechanical weed control and fertilizing with digital tools":
https://www.youtube.com/watch?v=hbkaTwy2wtA&t=6s

Conference proceedings:
Argento F., Anken T., Liebisch F., Walter A.:
Crop imaging and soil adjusted variable rate nitrogen application in winter wheat.
In: Precision Agriculture '19 - Proceedings of the 12th European Conference on Precision Agriculture. 8-11 July, Hrsg. ECPA, Montpellier, France. 2019, 1-8.
https://www.agroscope.admin.ch/agroscope/de/home/aktuell/dossiers/sortenlisten/_jcr_content/par/columncontrols/items/0/column/externalcontent_1476908975.external.exturl.html/aHR0cHM6Ly9pcmEuYWdyb3Njb3BlLmNoL2RlLUNIL3B1YmxpY2F0aW9uLzQzMDUw.html

2.2 Sugar beet planting with Precision Planting

2.2.1. Objective of the 2019 sugar beet trial

Research question

In the 2019 harvest year at the Swiss Future Farm, the effects of different down force settings, planting depths and planted populations on field emergence, juvenile development and sugar beet yield for planting were repeatedly investigated. In addition, since this year, the effects of using various liquid starter fertilizers have been analyzed.

Trial design

The Swiss Future Farm's sugar beet trial was conducted in 2019 on the Rüedimoos field (3.3 ha) in Tänikon with the variety "Strauss" (Strube seeds).

The trial was designed and planted as a randomized block trial with 3 blocks:

- 12 trial strips per block
- 3 m width per trial strip
- 50 cm row spacing
- One strip per block as reference
- Three strips as tramlines (excluded from evaluation)

For the evaluation, the trial was divided into separate studies to compare the planter settings:

- Down Force: Auto Light (23 kg), Standard (45 kg), Heavy (68 kg); Fixed (45 kg)
- Planting depth: 1.0, 2.5, 4.0 and 6.5 cm
- Planted population: 100'000 and 150'000 seeds per hectare
- Liquid starter fertilizer: Hasorgan 0-0-5 and Kristalon 12-12-36

Equipment and technology solutions

A Precision Planting test planter with 3 meters working width, 6 rows and 50 cm row spacing, equipped with Precision Planting's vSet, vDrive, DeltaForce, SpeedTube, SmartFirmer and FurrowJet technologies, was used for these AGCO Crop Tour trials and the cantonal sugar beet focus trial (Figure 9).

Figure 9. Precision Planting test planter with newly assembled liquid fertilizer system for sugar beet planting 2019 on the Swiss Future Farm.

The vSet seed meters and vDrive electric drives of the Precision Planting planter are designed to achieve the highest possible singulation accuracy for precision seeding. The automatic down force control with DeltaForce ensures consistent planting depth even in heterogeneous soil conditions. SmartFirmer soil sensors measure soil moisture, soil temperature and organic matter in real time during planting. The FurrowJet liquid fertilizer system allows the exact placement of fertilizer on the grain and in the walls of the seed furrow. The 20/20 Gen3 terminal is used to monitor and document the planter settings in high resolution.

The Precision Planting test planter was used with a Fendt 516 equipped with the VarioGuide automatic guidance system with RTK accuracy of ± 2 cm, which enabled planter passes with the highest precision. Planter, fertilizer spreader and sprayer for operations in the sugar beets were used with automatic Section Control technology.

2.2.2. Results of the 2019 sugar beet trial

2.2.2.1. Down Force Study

Objective:

The objective of this study was to apply different planter down force using the automatic down force control system DeltaForce™ and to evaluate the resulting yield in sugar beets.

Study Design:

The study was carried out on the Swiss Future Farm with randomized block design and contained three repetitions per down force setting. The following down force (DF) settings were tested:

- Auto Light DF (23 kg)
- Auto Standard DF (45 kg)
- Auto Heavy DF (68 kg)
- Fixed Standard DF (45 kg)

The trial plot was in a field with very heterogeneous soil conditions (texture, moisture, and organic matter). Properties of the soil zones are described in Table 7.

Table 7. Soil properties of the trial plot for the SFF 2019 Down Force Study in sugar beets.

Soil zone	Soil type and properties
8a	Gleyic brown earth, skeletal, slightly sandy loam and silty loam, good water storage.
9a	Stagnogleyic calcaric brown earth, strongly skeletal, sandy loam and clayey silty loam, good water storage.
11a	Partly decarbonated, browned gley, strongly skeletal, slightly sandy loam with a sandy base.
13a	Partially decarbonated pale gley, skeleton poor, clayey soil and clayey loam, waterlogged.
14a	Partially decarbonated pale gley, poor in skeleton, clayey loam with peat bedding, waterlogged.
15a	Boggy, very pale gley, poor in skeletons, skeleton-rich subsoil, clayey loam and silty loam.

Each treatment was planted with three repetitions across the field in order to minimize effects of heterogeneity in soil (Figure 10). The trial was planted on 28th March 2019. All trial strips were planted at 4.0 cm planting depth and with a planting rate of 100,000 seeds per hectare, whereas down force was changed between the settings described above.

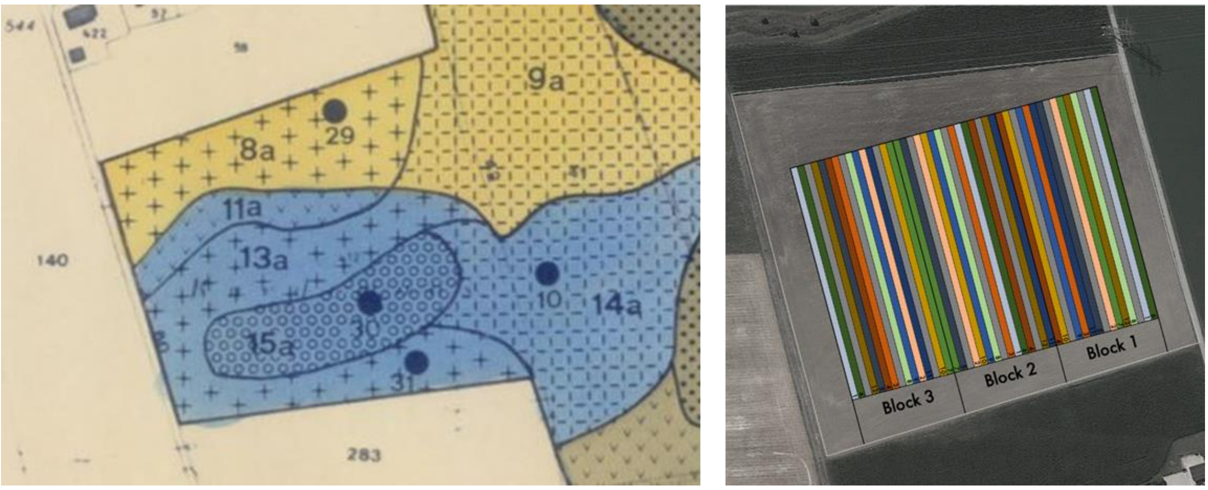


Figure 10. Soil zones in the trial field (left) and randomized design with three repetitions (right).

Results:

The trial was harvested on 1st October 2019 (188 days after planting). Highest fresh mass yield was obtained from the treatment with Auto Standard DF (45 kg), whereas Auto Light DF (23 kg), Fixed Standard DF (45kg) and Auto Heavy DF (68 kg) produced significantly lower yields (Figure 11, top left). Lowest fresh mass yield was achieved with Fixed Standard DF (45 kg), which represents typical settings of conventional planters with constant down force. The yield difference between highest (Auto Standard DF 45 kg) and lowest yield (Fixed Standard DF 45 kg) amounted to 4.4 tons per hectare. These results demonstrate that the use of DeltaForce automatic down force control can improve yield by applying optimal down force, especially on fields with varying soil conditions.

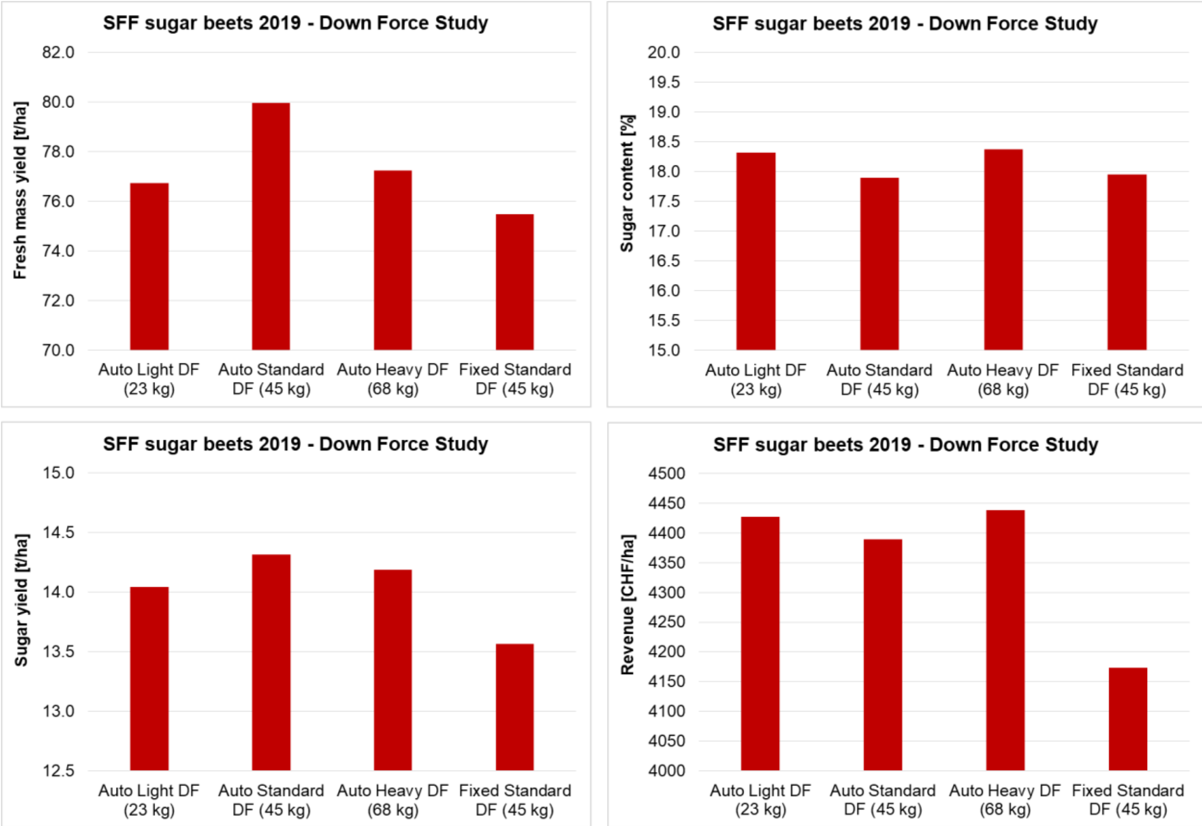


Figure 11. Yields and revenue of the SFF Down Force Study 2019 in sugar beets.

The differences in sugar content (Figure 11, top right) were less obvious, ranging from 18.4% to 17.9% for the Auto Heavy DF (68 kg) and Auto Standard DF (45 kg) treatments. The sugar yield (Figure 11, bottom left) was highest (14.3 t/ha) in the treatment planted with Auto Standard DF (45 kg) , whereas the treatments planted with Auto Light DF (23 kg) and Auto Heavy DF (68 kg) had slightly lower sugar yields with 14.0 and 14.2 t/ha, respectively. Clearly, the sugar beets planted with Fixed Standard DF (45 kg) had the lowest sugar content (13.6 t/ha). Highest revenue was generated by the trial plots planted with automatic downforce control (on average CHF 4419) compared to the trial strips planted with fixed standard downforce (CHF 4173), which in our study represents an additional revenue of CHF 246 per hectare when planting with Precision Planting DeltaForce .

Additional Observations:

Field emergence was measured twice during the trial: 27 days after planting and 42 days after planting, in the growth period until the 4-6 leaf stage. The second measurement also comprised investigation of late emergers and juvenile development. Overall, the Auto Standard DF (45 kg) treatment had highest emergence at 89.8% whereas the other treatments showed lower emergence (Figure 12, top).

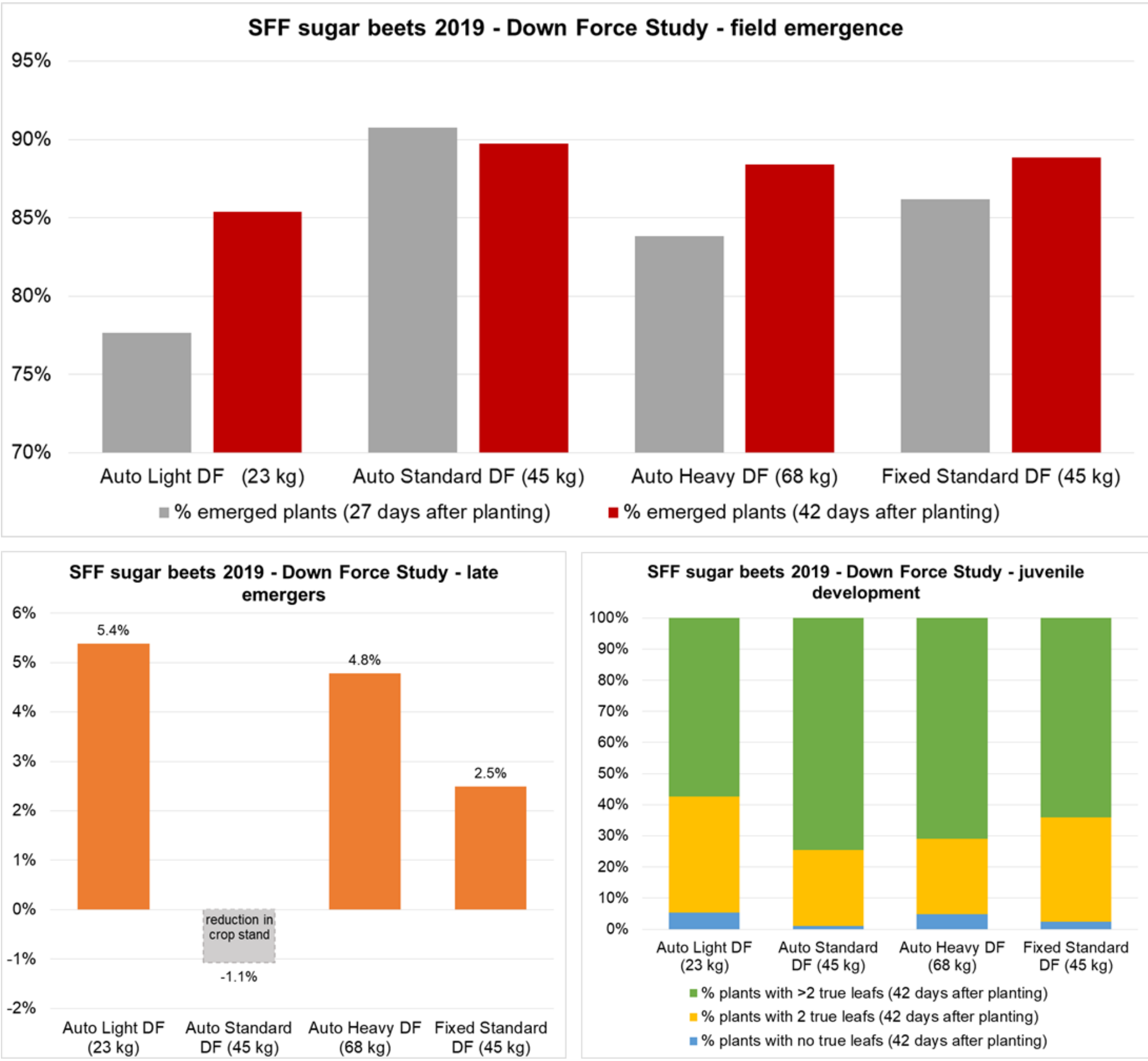


Figure 12. Crop measurement results of the SFF Down Force Study 2019 in sugar beets.

We found the highest number of late emergers in the Auto Light DF (23 kg) and Auto Heavy DF (68 kg) treatments (Figure 12, bottom left). For the light down force treatment, this may be due to reduced capillarity action in the topsoil resulting in lower moisture availability to the seed, whereas for the heavy down force treatment, compaction of the seed furrow impeding the development of the taproot may have caused the late emergence. In the Auto Standard DF (45 kg), we found 1.1% reduction of crop stand between the two measurements of field emergence, shown as negative value in the diagram.

During juvenile development, sugar beets are very sensitive to growth-inhibiting influences (e.g., capping, incrustation, drought, frost, pest infestation) than in later stages of development. In conjunction to agricultural machinery, the juvenile phase is of particular importance to assess, if the applied tillage regime and planter settings are beneficial to the development of the crop. In the assessment of juvenile development 42 days after planting, the Auto Standard DF (45 kg) showed the highest percentage of plants with >2 true leaves (Figure 12, bottom right). Hence, these plants were able to perform best. Lowest percentage of plants with >2 true leaves was found in the Auto Light DF (23 kg) treatment, which indicates a retarded juvenile development. Comparing these data with the fresh mass and sugar content, a distinct correlation between juvenile development and plant performance can be seen.

Figure 13. Precision Planting test planter with DeltaForce down force control and Fendt 516 with RTK VarioGuide, which were used for planting the trial plot.

2.2.2.2. Planting Depth Study

Objective:

The objective of this study was to evaluate yield in sugar beets planted at different planting depths using a Precision Planting test planter with a DeltaForce™ down force control system.

Study Design:

The study was carried out on the Swiss Future Farm with a randomized block design and contained three repetitions per planting depth setting. The following planting depths were tested:

- 1.0 cm (shallow)
- 2.5 cm (standard)
- 4.0 cm (slightly deeper)
- 6.5 cm (deep)

The trial plot was located in a field with very heterogeneous soil conditions. Each treatment had three repetitions across the field in order to minimize effects of heterogeneity in soil. In order to ensure consistent planting depth, all treatments were planted with DeltaForce automatic down force control set to a target down force of 45 kg and with a plant population of 100,000 seeds per hectare. Planting date was 28th March 2019.

Figure 14. Planting depth setting on the planter (left) and manual check of seed placement (right).

Results:

The trial was harvested on 1st October 2019 (188 days after planting). Planting at a depth of 4.0 cm resulted in the highest yield with 79.9 tons/ha (Figure 15, top left). Planting at 6.5 cm resulted in a lower yield of 76.4 tons/ha, similar to planting at standard planting depth of 2.5 cm (75.4 tons/ha). Lowest yield (67.5 tons/ha) was obtained from the treatment planted at 1.0 cm, which clearly shows that this planting depth was too shallow to enable effective crop development.

Figure 15. Yields and revenue of the SFF Planting Depth Study 2019 in sugar beets.

Differences in sugar content was less obvious and ranged between 17.9% and 18.5% for the 4.0 cm and 6.5 cm planting depth respectively (Figure 15, top right). Sugar yield reflected the trend found in fresh mass yield. As in the fresh mass yield, the highest sugar yield (14.3 t/ha) was found in the 4.0 cm planting depth, while the lowest (12.4 t/ha) was found in the 1.0 cm planting depth (Figure 15, bottom left). Due to the highest sugar content, the revenue was highest in trial strips planted at 6.5 cm planting depth. The additional revenue of the 4.0 cm planting depth trial strips with highest sugar yield compared to 1.0 cm trial strips with lowest sugar yield was CHF 459 per hectare.

Additional Observations:

Field emergence was measured twice during the trial, 27 and 42 days after planting, in the growth period until the 4-6 leaf stage. The second measurement also comprised investigation of late emergers and juvenile development (Figure 16).

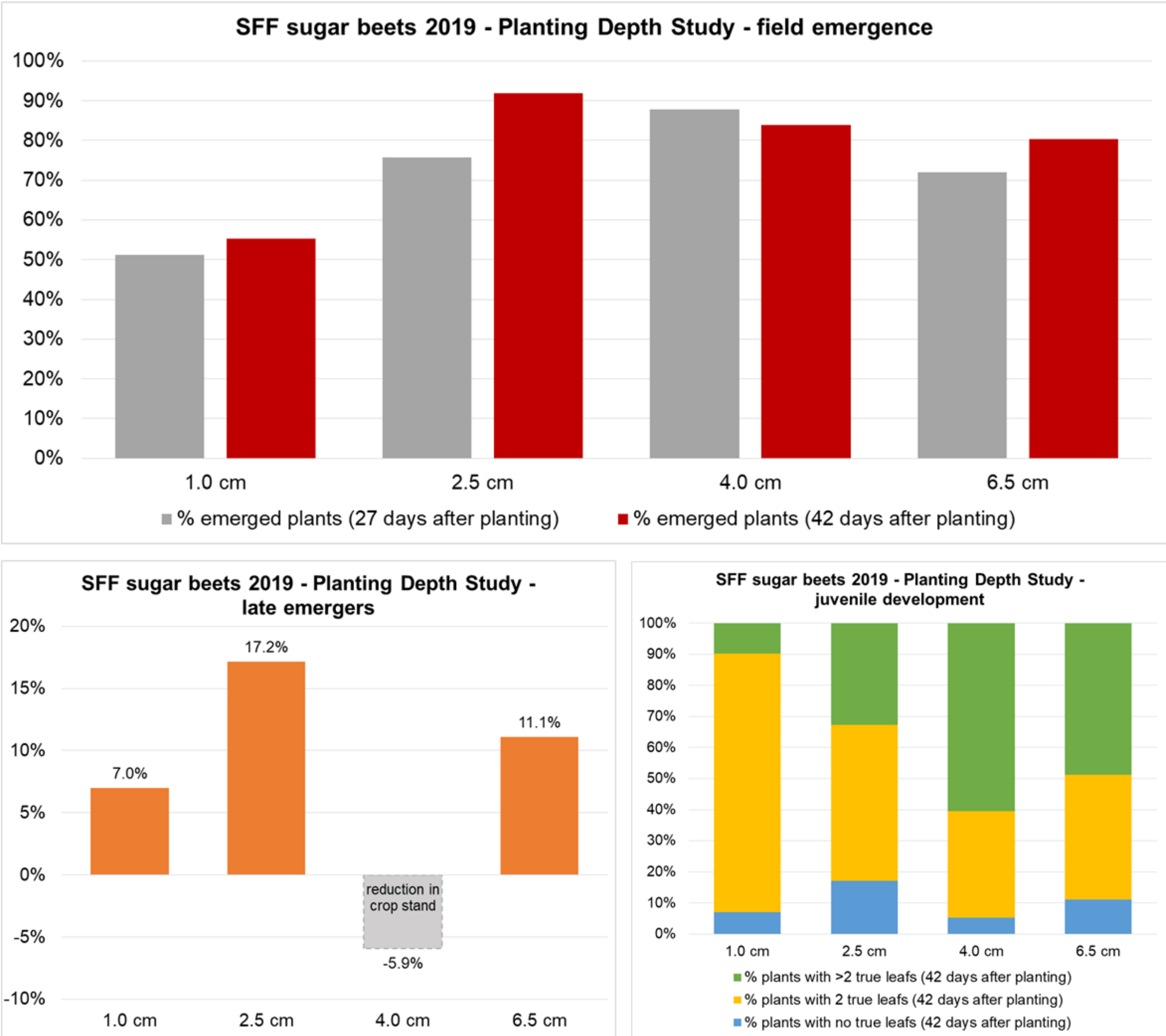


Figure 16. Crop measurement results of the SFF Planting Depth Study 2019 in sugar beets.

Field emergence data shows that the critical threshold of 70,000 plants per hectare was not achieved in the 1.0 cm planting depth. Between the coarse crumbs of the uppermost soil layer the seeds are partially exposed and lack the moisture to germinate, which explains the reduced emergence of sugar beets planted at 1.0 cm depth. Even if germination is activated by precipitation, the seedlings may dry out if no adequate soil contact is reached. In general, the lighter and drier the soil, the deeper the seed should be placed. In the relatively dry spring of 2019, our results show that, planting depths of 2.5 cm and 4.0 cm had the highest field emergence.

The proportion of late emergers was relatively high in the 2.5 cm planting depth (Figure 16, bottom left), and corresponds to the lower fresh mass and sugar yield obtained from the treatments. In the 4.0 cm planting depth trial strips, we found 5.9% reduction of crop stand between the two measurements of field emergence, shown as negative value in the diagram.

During juvenile development, sugar beets are more sensitive to growth-inhibiting factors than in later stages of development (e.g., capping, incrustation, drought, frost, pest infestation). Therefore, the juvenile phase is of particular importance for the assessment of machine settings that were applied for tillage and planting. Placing the seed too deep increases the way to the surface and costs a considerable amount of energy to the plant, which is also evident in the results obtained from assessment of juvenile development (Figure 16, bottom right). Until the leaves develop and sufficient photosynthesis occurs, the sugar beet remains very weak and vulnerable, which may later on result in reduced fresh mass and sugar yield. The high proportion of late emergers is also evident in the juvenile development of beets on the 2.5 cm planting depth. Slightly lower placement depths (4.0 cm vs. 2.5 cm) can offer advantages in connection with mechanical weed control (blind harrowing in pre-emergence) without loss of yield.

2.2.2.3. Population Study

Objective:

The objective of this study was to evaluate yield in sugar beets planted at two different planting rates using the Precision Planting vSet™ seed meters and vDrive™ electric drives.

Study Design:

The study was carried out on the Swiss Future Farm with a randomized block design and contained three repetitions per treatment. The following planting rates were tested:

- 100,000 seeds per hectare (100 KS/ha, standard planting rate for sugar beets in Europe)
- 150,000 seeds per hectare (150 KS/ha, increased rate)

The trial was planted in a field with very heterogeneous soil conditions in texture, moisture, and organic matter. Each treatment had three repetitions across the field to minimize the effect of heterogeneity in soil. Planting date was 28th March 2019. All seeds were planted at 4.0 cm planting depth and with DeltaForce automatic down force control set to a target down force of 45 kg.

Figure 17. Sugar beet seeds (left) and 20/20 Gen3 monitor for setting the planted population (right).

Results:

The trial was harvested on 1st October 2019 (188 days after planting). Higher fresh mass yield was obtained in the treatment planted with the standard planting rate of 100 KS/ha (79.9 tons/ha) compared to 75.2 tons/ha from the treatment with increased planting rate of 150/KS (Figure 18, top left). The yield difference of 4.7 tons per hectare indicates that the standard planting rate of 100 KS/ha achieves the optimal plant population for sugar beets in this region. Hence, increasing the planting rate to 150 KS/ha, and considering the high cost of seeds, cannot be recommended.

Figure 18. Yields and revenue of the SFF Population Study 2019 in sugar beets.

The difference in sugar content between the different treatments was less distinct and ranged between 17.9% and 18.3% for 100 KS/ha and 150 KS/ha respectively (Figure 18, top right). The difference in sugar yield was 0.5 tons per hectare between the treatments with 100 KS/ha at 14.3 t/ha, and 150 KS/ha at 13.8 t/ha as shown in Figure 18, bottom left. The disadvantage in revenue for an increased population rate of 150 KS/ha was CHF 90 for lower yield and additional seed costs of CHF 152, resulting in a total disadvantage of CHF 242 per hectare.

Additional Observations:

Field emergence was measured twice during the trial 27 and 42 days after planting, in the growth period until the 4-6 leaf stage (Figure 19, left).

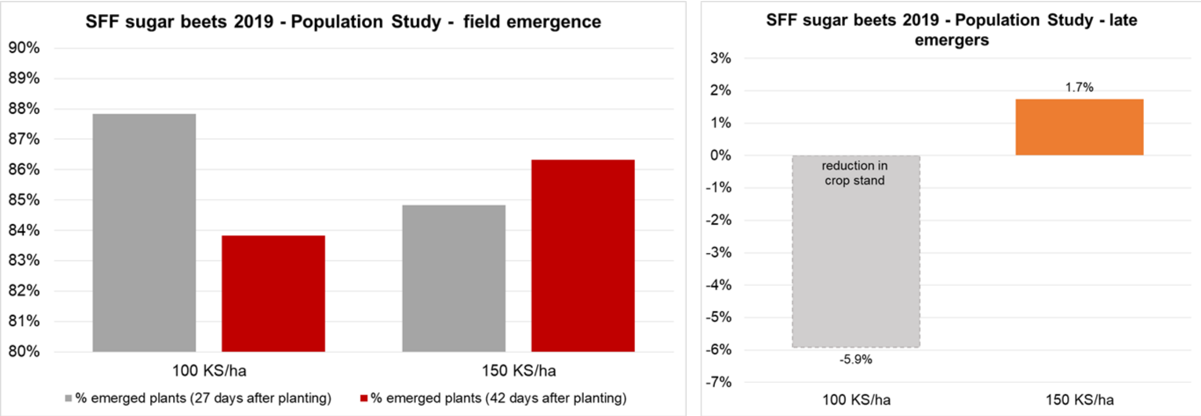


Figure 19. Crop measurement results of the SFF Population Study 2019 in sugar beets.

For a planting rate of 100 KS/ha, we found 5.9% reduction of crop stand between the two measurements of field emergence, shown as negative value in the diagram (Figure 19, right). However, the reduced crop stand in the 100 KS/ha plots did not have any negative influence on fresh mass yield or sugar yield.

2.2.2.4. Liquid Fertilizer Study

Objective:

The objective of this study was to compare yield of sugar beets planted with two different liquid starter fertilizers applied using Precision Planting FurrowJet™, and sugar beets planted without liquid starter fertilizer.

Study Design:

This study was carried out on the Swiss Future Farm, with a randomized block design and contained three repetitions per treatment. The following treatments were compared:

- Hasorgan 0-0-5 liquid fertilizer (20 l/ha, applied as 15% solution, total 1.16 kg K/ha)
- Kristalon 12-12-36 liquid fertilizer (applied as 5% solution, total 6 kg N/ha, 6 kg P/ha, 18 kg K/ha)
- No liquid starter fertilizer (control)

The trial was planted in a field with very heterogeneous soil conditions in texture, moisture, and organic matter. Each treatment was planted with three replications across the field in order to minimize the effects of heterogeneity in the soil. Planting date was 28th March 2019. All plants were planted at 4.0 cm planting depth, population rate of 100,000 seeds per hectare, and with DeltaForce automatic down force control set to a target down force of 45 kg. The liquid fertilisers were applied during planting using Precision Planting's FurrowJet liquid fertiliser system.

Figure 20. FurrowJet liquid fertilizer system used for planting the trial plot.

Results:

Sugar beets harvested from trial plots fertilized with Kristalon 12-12-36 was more (81.4 t/ha), compared to trial plots fertilized with Hasorgan 0-0-5 (80.7 t/ha) and trial plots without liquid fertilizer application (79.9 t/ha) (Figure 21, top left). Maximum fresh mass yield difference due to application of liquid fertilizer was 2%.

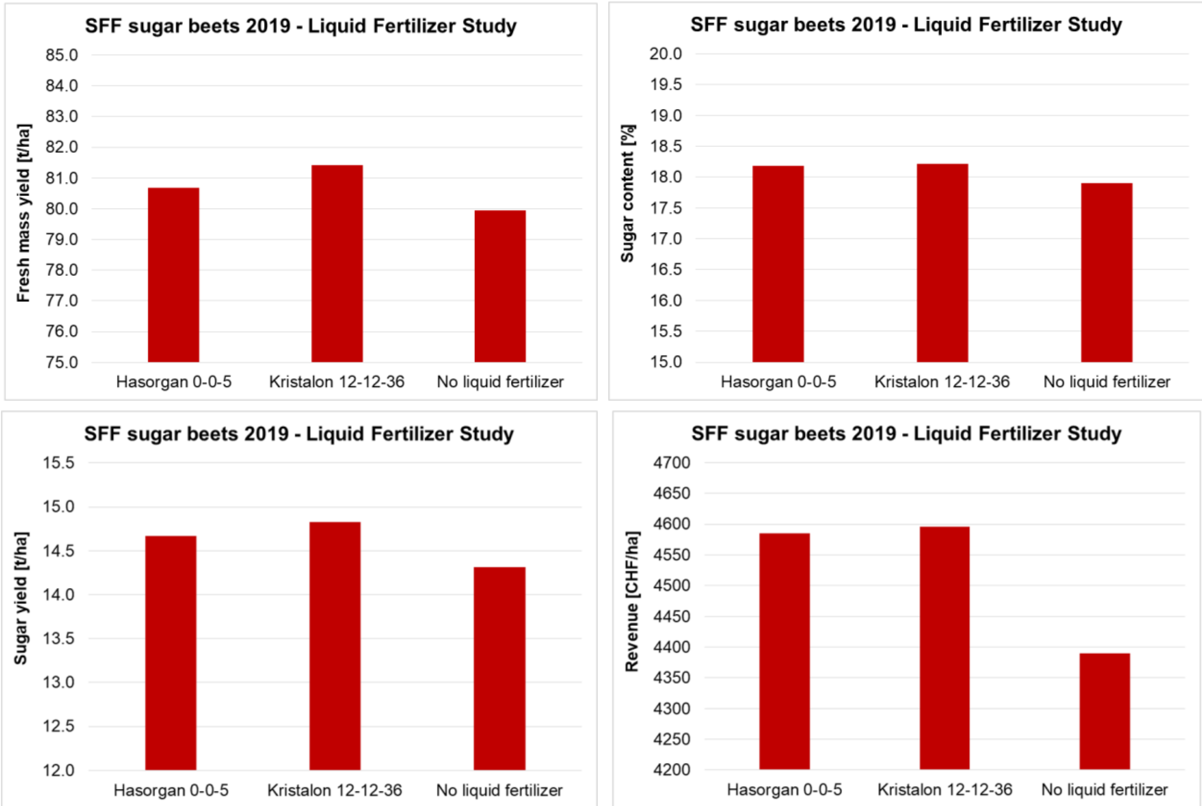


Figure 21. Yields and revenue of the SFF Liquid Fertilizer Study 2019 in sugar beets.

Sugar content was higher in treatments with liquid starter fertilizer, reaching 18.2% for both Hasorgan 0-0-5 and Kristalon 12-12-36, whereas sugar content in trial strips without liquid fertilizer averaged 17.9% (Figure 21, top right). Sugar yield increase due to the application of Kristalon 12-12-36 and Hasorgan 0-0-5 amounted to 0.5 tons/ha (+3%) and 0.4 tons/ha (+3%) compared to the control treatment without liquid fertilizer application (Figure 21, bottom left). The revenue increase due to application of liquid fertilizer on average amounted to CHF 201.5 (CHF 196 per hectare for Hasorgan 0-0-5 and CHF 207 per hectare for Kristalon 12-12-36) compared to the control without liquid starter fertilizer application.

Additional Observations:

Field emergence was measured twice during the trial, 27 and 42 days after planting, in the growth period until the 4-6 leaf stage. The second measurement also comprised investigation of late emergers and juvenile development. We found reduced crop stand in trial plots without liquid fertilizer, however the difference between all the treatments was within 5% (Figure 22).

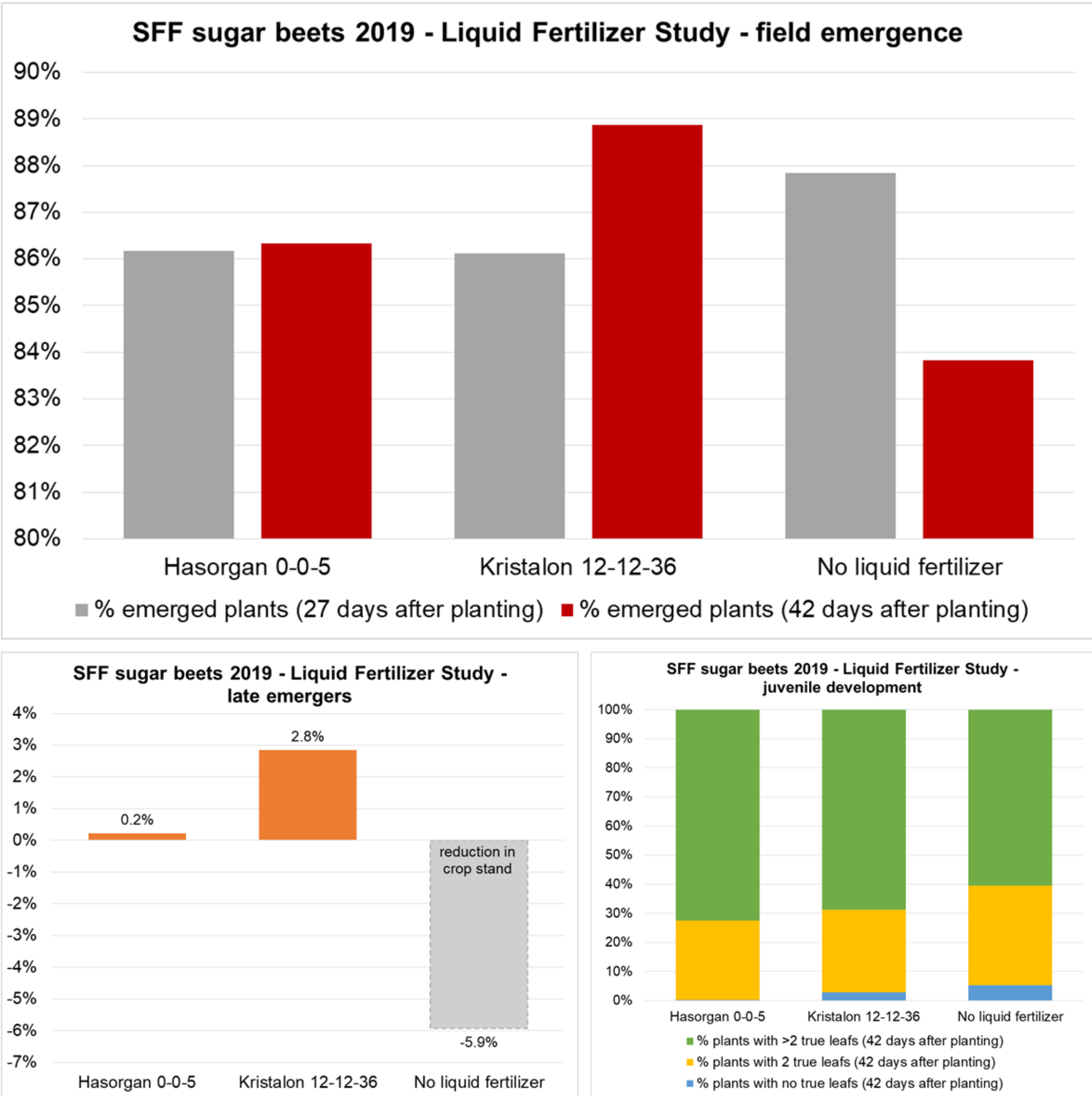


Figure 22. Crop measurement results of the SFF Liquid Fertilizer Study 2019 in sugar beets.

A higher percentage of late emergers was found in the trial plots planted with Kristalon 12-12-36 (2.8%) compared to Hasorgan 0-0-5 (0.2%). In the trial plots planted without starter liquid fertilizer, we observed a reduced crop stand of 5.9%, shown as negative value in the diagram (Figure 22, bottom left).

During juvenile development, sugar beets are more sensitive to growth-enhancers and growth-inhibitors than in later stages of development. Therefore, this phase is of particular importance for the assessment of liquid starter fertilizers that were applied during planting. Our measurements show that the most beneficial juvenile development was found in the Hasorgan 0-0-5 trial plots, indicated by the highest proportion of plants with >2 true leafs (Figure 22, bottom right). Highest proportion of plants with no true leafs at the time of measurement (42 days after planting) was found in the trial plots without liquid fertilizer and indicates a retarded juvenile development, which creates vulnerability for pests and may result in yield losses.

2.2.3. Conclusions from the 2019 sugar beet trial

The results of the 2019 SFF sugar beet trial show:

- Under heavy, heterogeneous soil conditions, automatic down force control with DeltaForce brings a significant advantage by increasing yields.
- Slightly deeper planting depths (up to 4.0 cm) can offer advantages in connection with mechanical weed control (blind harrowing pre-emergence) without loss of yield.
- Increased planted population in sugar beets (150 KS/ha vs. 100 KS/ha) showed no positive effects on yield under local growing conditions.
- The effect of liquid starter fertilizer on juvenile development and yield still needs further investigation, initial results indicate a slight increase in yield (+3%).

Knowledge transfer

The sugar beet trials and the Precision Planting technology used were presented to numerous interested visitors throughout the season as part of the visitor program and at the Swiss Future Farm Days in September 2019 (Figure 23).

Figure 23. Impressions of the sugar beet demonstration plot in summer 2019 at the Swiss Future Farm.

The publications on the 2019 sugar beet trial of the Swiss Future Farm can be accessed under the following links:

- Thurgauer Bauer, 17 May 2019: http://www.vtgl.ch/documents/thurgauerbauer/tb_20_17_05_2019_low.pdf
- Thurgauer Bauer, 23 August 2019: http://www.vtgl.ch/documents/thurgauerbauer/tb_34_23_08_2019low.pdf
- Bild der Wissenschaft 10/2019 – Smartes ackern: http://www.swissfuturefarm.ch/index.php/news-1750/aktuelles/aktuelles-detailseite/smartes-ackern
- Video "Swiss Future Farm: sugar beet trial with Precision Planting": https://www.youtube.com/watch?v=v_0YgjjXh9s&list=PLFyz-rvar2Q5iw2DREtRi129a-mYj9HWgl&index=2&t=56s
- Video "Swiss Future Farm: farm days and trials": https://www.youtube.com/watch?v=StU1MSGiJzo&list=PLFyz-rvar2Q5iw2DREtRi129a-mYj9HWgl&index=4&t=0s

Outlook and next steps

In the 2020 harvest year, the Swiss Future Farm will continue to investigate the effects of different down force settings, planting depths and liquid starter fertilizer applications on sugar beet. The trials will be repeated on additional trial plots in order to compare this year's findings with those of previous years and to derive reliable recommendations for sugar beet growing.

Trial team

The sugar beet trial with Precision Planting was carried out by Nils Zehner, Marco Landis, Florian Abt and Hanspeter Hug in a collaboration between AGCO, GVS Agrar and BBZ Arenenberg. We would like to thank Benoit Blateyron and Isaac Hill of Precision Planting for their expert installation of the FurrowJet liquid fertiliser system as a new component of our planter. Special thanks also go to Ariane Reist and Michael Huber, who gave us active and committed support during their internship at the Swiss Future Farm with the set up, crop measurements and evaluation of the sugar beet trials.

2.3 Trial on stubble cultivation after rapeseed

Objectives

True to the motto "After the harvest is before the harvest", the first important steps towards the next seedbed preparation are already taken during the combine harvest and the first stubble tillage pass:

- Straw and residue management, with the aim of distributing short chopped residues as evenly as possible and promoting rapid decomposition.
- Promoting the emergence of volunteer grain, weeds and grasses.
- The interruption of soil capillarity to preserve the residual moisture in the soil.

In the case of rapeseed, meeting these objectives is a challenge. On the one hand by long stubbles, which provide a perfect survival base for fungal diseases and pests and are only decomposed slowly and with increased nitrogen fixation due to a high C/N ratio. There is also a challenge due to an increased amount of volunteers, which represents about 5% of the yield. This means that an average of 150 to 200 kg/ha of volunteer rapeseed can produce a high weed pressure in crop rotation. Stubble cultivation therefore requires sufficient intensity of cultivation to break up the long stubble and plant residues, but with a shallow working depth to allow as much volunteer rapeseed as possible to germinate.

Study design and applied technology

Following the 2019 rapeseed harvest, a tillage platform was set up to observe the effect of the working depth and tool combinations on the rapeseed emergence. For the tillage comparison, a Horsch Terrano 3 FX cultivator and a Horsch Joker 3 CT compact disc harrow together with a front-mounted Cultro 3 TC knife roller were used. The trial was set up on 9 August 2019, one week after the harvest, in a short window of operation during the rainy summer of 2019. The conditions were borderline due to the high soil moisture, but allowed us to avoid a further weather-related delay. Under normal weather conditions, stubble cultivation would have taken place in the first 24 hours after harvesting. Figure 24 shows the trial design with the different tillage strategies.

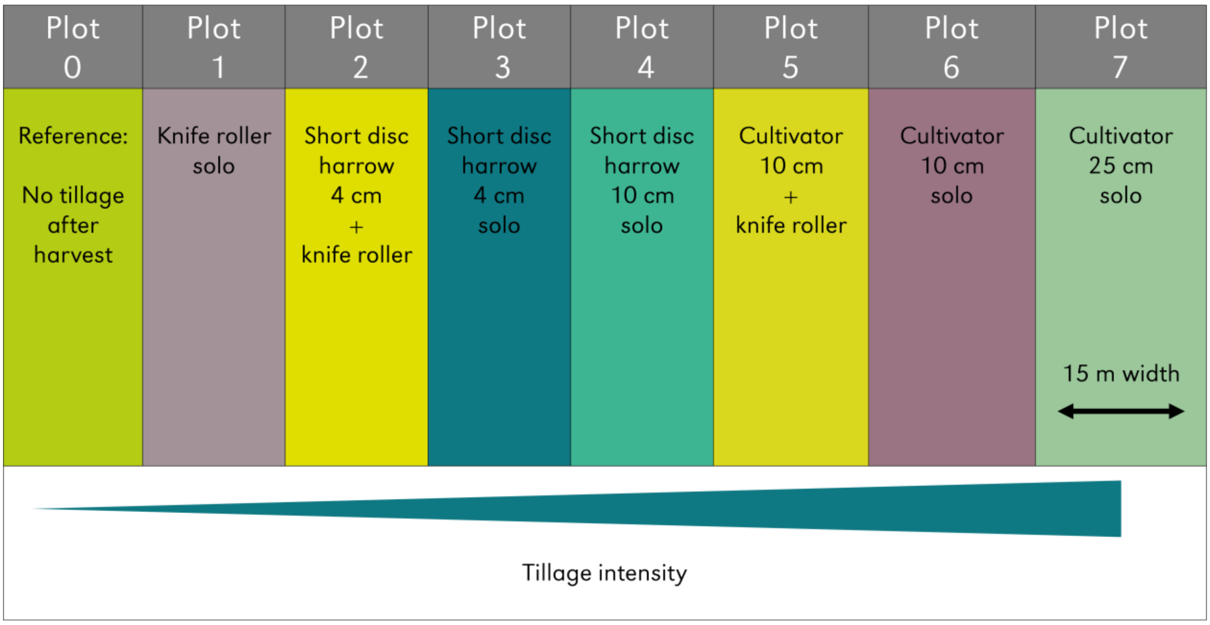


Figure 24. Trial design for stubble cultivation after rapeseed on SFF 2019.

Figure 25. Combinations of knife roller and cultivator (left) and knife roller and compact disc harrow (right) used for the trial plot.

Results

Figure 26 shows the tillage result on the various trial plots. Already when the trial strips were created, we could observe that the cultivator, due to the fact that tines have no cutting action, could produce a strong mixing effect and excellent fine soil production, but could not shred the stubble, regardless of the working depth (plots 6 & 7). A combination with the knife roller can provide the necessary cutting effect and rounds off the work result positively (plot 5).

Figure 26. Tillage result on the trial plots after the trial has been created on 9 August 2019.

This was different with the compact disc harrow, where the cutting effect of the discs was clearly visible. However, there was a difference between the working depths of 10 cm and 4 cm. At 10 cm (plot 4) the stubble could be cut and worked in. At 4 cm (plot 3), on the other hand, as a consequence of a smaller working horizon, we found good crumbling, but with less crumbling of the crop residues. Similar to the cultivator, the combination with the knife roller (plot 2) perfectly complements the working picture: a shallow intensive soil cultivation is coupled with a full-surface cutting action. For plots 2 & 3, a depth of 2 cm was originally intended. However, this depth did not allow the tracks left by the plot harvester to be levelled. It was therefore decided to increase the working depth to 4 cm.

The cutting effect of the knife roller could be shown very well on plot 1. Compared to the 0 plot, it has the advantage that the stubble was chopped down with a clear effect. This means that there is no more evaporation via the stalks and there is no more habitat for fungal diseases and pests. An important aspect of this to maintain a high working speed to ensure the intensity of the cultivation. However, it is easy to see that the knife roller has no soil tillage effect.

On September 20, 2019, the emergence of volunteer rapeseed was compared between the tillage methods. The number of plants per square metre was determined using a square. In the 25 cm deep cultivated plot 7, a number of 25 plants/m^2 could be observed. In the 10 cm deep cultivated plots 4, 5 & 6, a number of 72, 62 and 78 plants/m^2 could be counted, in the 4 cm deep cultivated plots 2 & 3, 98 to 115 plants/m^2 and in plot 1 and reference plot 0 over 120 plants/m^2. As expected, the shallowest worked strips are the ones with the strongest emergence. With deep tillage, in this case 25 cm, the emergence is four times less compared to the trial strip with 4 cm tillage depth. Due to the high amount of precipitation in August 2019, the trial strips without tillage (plots 0 & 1) perform best concerning emergence. In a dry summer, the capillary interruption and the use of residual moisture in the soil would be expected to play a greater role in favour of shallow tillage. An overview of these results is contained in Table 8.

Table 8. Emergence of volunteer rapeseed on the SFF 2019 stubble cultivation trial plot.

Plot	Treatment	Plants/m^2
0	No tillage (control)	>120
1	Knife roller solo	>120
2	Short disc harrow 4 cm + knife roller	115
3	Short disc harrow 4 cm solo	98
4	Short disc harrow 10 cm solo	72
5	Cultivator 10 cm + knife roller	62
6	Cultivator 10 cm solo	78
7	Cultivator 25 cm solo	25

Conclusion: This tillage platform has enabled us to display the following effects:

- ➔ **Less is more!** For rape stubble cultivation, shallow working depths must be preferred. Although we were able to create a good working pattern with the 10 and 25 cm deep variants, the deeper incorporation of the volunteer rape has the effect of greatly reduced emergence dynamics compared to the shallow-worked strips.
- ➔ **A clean cut!** A cutting action is necessary for effective comminution and crumbling of the plant residues. The knife roller is an optimum solution here, whether in solo use or in combination with a short disc harrow or cultivator, provided that the operating speed is guaranteed.

Knowledge transfer

The results of the stubble cultivation trial in rapeseed were presented to the public at the Swiss Future Farm Days in September 2019.

Trial team

The trial plot was set up as part of the Swiss Future Farm Days by the Swiss Future Farm Operating Team under the direction of Nico Helmstetter.

3. Digital data management

3.1 Introduction and objectives

Since 2018, data management at the Swiss Future Farm has been carried out centrally with the NEXT Farming Office software from FarmFacts GmbH. The program is installed locally and has an interface to the tractors on the SFF, which are connected to the TaskDocPro server. The employees at the SFF also document their work via app on their smartphones. On the Swiss Futurre Farm, all operating data is recorded as completely as possible with the following objectives:

- Economic:
    - Identification of cost drivers for the different operations
    - Determination of economic indicators in the famr and field operations and in the farming enterprise
- Labour and agronomic:
    - Simplified organization of (geo)data
    - Fulfilment of the ÖLN and label recording obligations
    - Pooling agronomic data

The measures taken in 2019 to achieve the objectives set in 3.1 are listed below.

3.2 Economic - Contribution margin accounting at crop level

To ensure that the economically relevant data can be recorded as completely as possible at the SFF, FMIS NEXT Farming was selected as the central documentation solution. Task data from the arable and grassland and the livestock operations flow directly into the software via smartphone app. In addition, tasks can also be received from or sent to the machines (see field trial on Variable Rate nitrogen fertilization in Chapter 2.1). Figure 27 shows the internal data flows on the Swiss Future Farm schematically.

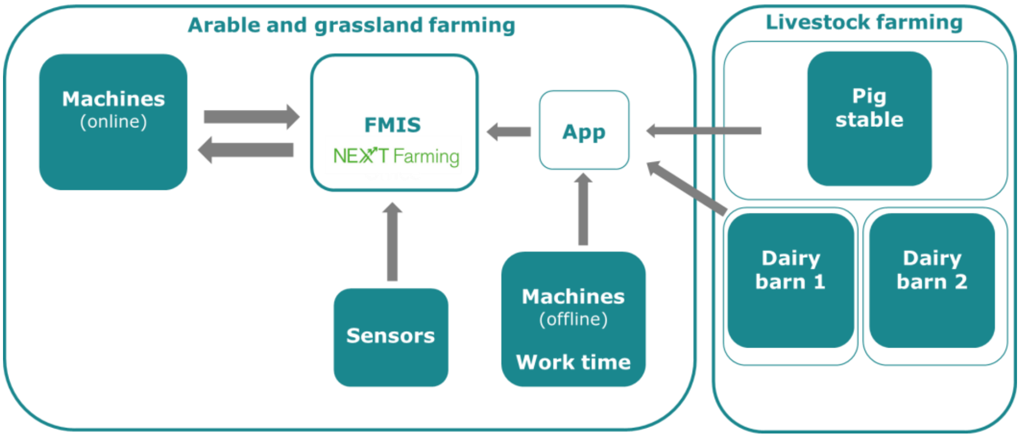


Figure 27. Internal data flows on the Swiss Future Farm.

On the basis of the operating data recorded in the FMIS, the contribution margins for 2019 for the crops sugar beet, corn, wheat, temporary grassland as well as for the dairy cattle unit were calculated on the SFF. Due to the high level of detail in the recording of operations on the SFF, including the documented costs for operating resources, machinery and labor, it is possible to calculate the contribution margins up to level DB2 (see Table 9).

Table 9. Collection of the relevant parameters for the calculation of process costs and contribution margins in arable and grassland farming.

Item	Parameter	Contribution margin
Benefits total	Crop revenues x prizes, subsidies	
Direct costs	Fuel, seeds, fertilizer, agrochemicals, packaging, cleaning, drying, insurance, other direct costs	Comparable contribution margin (VDB) after calculation of farm unit results
Machine costs	Variable costs	DB1
Labour costs	Working hours x hourly wage, fixed machine costs	DB2

It is currently common practice in Switzerland to calculate the contribution margins up to the level of the comparable contribution margin (VDB) published annually by Agroscope (cf. Schmid et al. 2017). However, this only includes the total benefits less direct costs. The increased level of detail up to DB2 now also allows a comparison of production systems, as machine costs can be explicitly taken into account (see Figure 28).

Table 10. Contribution margin up to level DB2 for the crop winter wheat at the SFF in 2019 (only the areas Grund NFert, Herrenpünt NFert and Schürpünt were taken into account for the calculation, as Fusarium and variety trials were carried out on the remaining area Grund).

		SFF 2019	Reference VDB 2017
Cultivated area	ha	6.1999	3.88
Yield	dt/ha	51.10 (reduced yield on one parcel)	53.1
Benefits (exkl. subsidies)	Fr./ha	2756.70	2673.00
Direct costs	Fr./ha	1161.95	862.00
Comparable contribution margin (VDB)	**Fr./ha**	**1594.75**	**1811.00**
Variable machine costs	Fr./ha	746.40	-
Contribution margin - DB 1	**Fr./ha**	**848.35**	**-**
Labour costs + fixed machine costs	Fr./ha	1843.30	-
Contribution margin - DB 2	**Fr./ha**	**-994.95**	**-**
Subsidies: **Herbicide reduction** **Food security** **Arable land** **Total**	**Fr./ha**	 **250.00** **900.00** **400.00** **1550.00**	
DB 2 plus subsidies	**Fr./ha**	**555.05**	

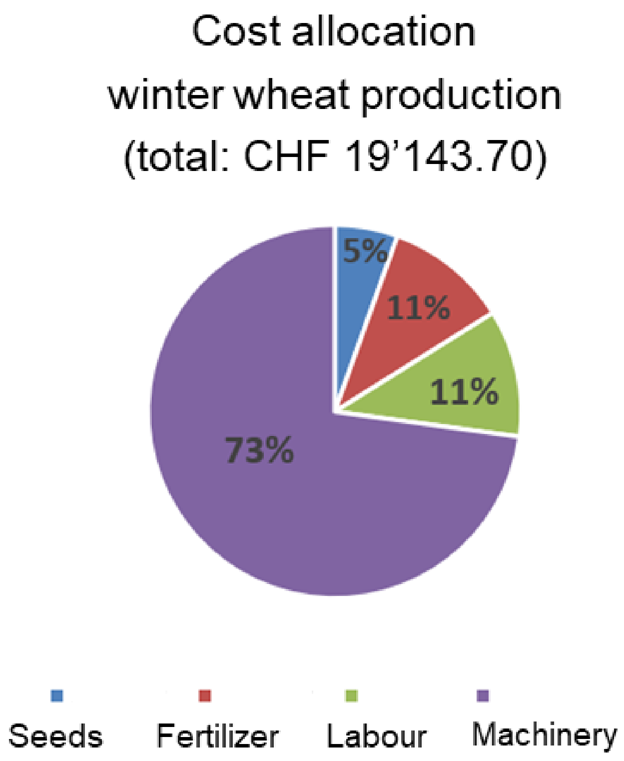


Figure 28. Allocation of process costs for winter wheat production.

3.3 Labour and agronomic - data organisation

3.3.1 Simplified organization of (geo)data

In the field of labor economics, the aim is to document as efficiently as possible and to exchange data for Precision Farming applications simply between FMIS and tractor. For documentation, the NEXT Farming Mobile Job App is used, which is directly connected to the FMIS and installed on every employee's smartphone. The tractors used for Precision Farming applications (Fendt 516, Valtra N174, Valtra T174, MF5713S) have a server connection to the FMIS. This allows data such as field boundaries, waylines and prescription maps to be exchanged wirelessly between the machine and software. The FMIS serves as a master data set in which the current field boundaries and waylines are always available and can be transmitted to additional tractors if required (Figure 29).

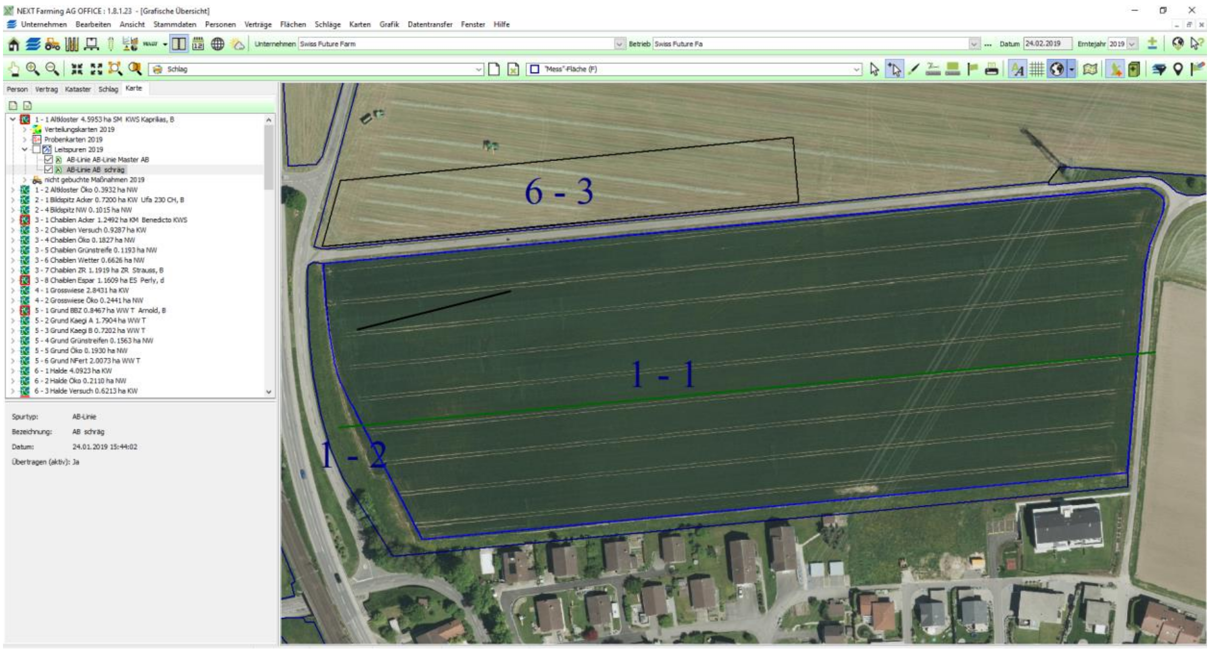


Figure 29. Central administration of field boundaries and waylines in FMIS.

3.3.2 Fulfilment of ÖLN and label recording obligations

The ecological performance certificate (ÖLN) is a minimum standard for environmentally friendly agriculture in Switzerland. Compliance with the ÖLN is a prerequisite for a farm to receive direct federal payments (state subsidies). Digital recording is intended to reduce the documentation effort by allowing entries to be made in the field via app. After the start of digital recording at the end of 2017, the first ÖLN inspection was carried out at the SFF in 2019. The digital recordings corresponded to the required level of detail and could be presented to the inspector in printed form for review. Practitioners wishing to access the digital recording should note that they should always be able to access their digitally stored data. It is therefore essential that a regular data backup is carried out and that a copy of the data is available as a PDF on the computer or in printed form so that it can be presented to the inspector on the day of the inspection in the event of any technical problems.

3.3.3 Pooling agronomic data

In winter 2018/2019 a georeferenced soil sampling was carried out at the SFF in cooperation with the company bodenproben.ch and the soil laboratory of BBZ Arenenberg. For this purpose, the areas were divided into homogeneous field sections based on historical soil maps (Agroscope Reckenholz 1977) and satellite-based soil zoning (data set by AgriCircle AG and Vista GmbH). The sampling paths for the soil sampling were then placed in these subplots. The data were then transmitted digitally as shape files to bodenproben.ch. On the sampling device the sampling points were read in and automatically controlled. 20 samples were taken from each subplot and combined to a mixed sample for analysis in the soil laboratory of BBZ Arenenberg. Figure 30 shows the subdivision of the Grosswiese field in Tänikon based on the historical soil map, the soil zoning via satellite and the assessments of the long-standing operational staff. The results of the sampling are summarized in Figure 31.

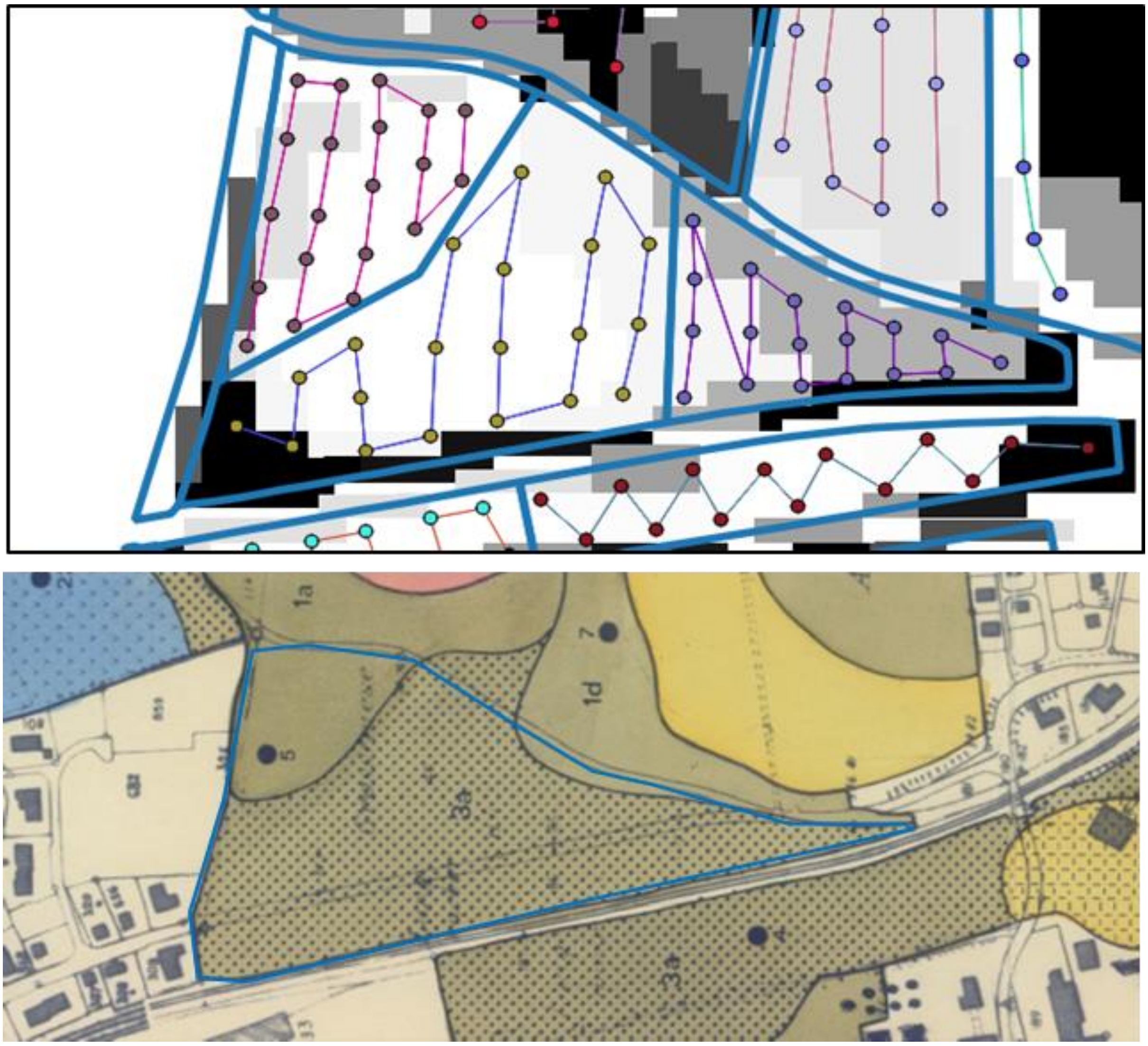


Figure 30. Subdivision of the Grosswies field into three subplots including paths for sampling (picture above) and historical soil map from 1977 (picture below).

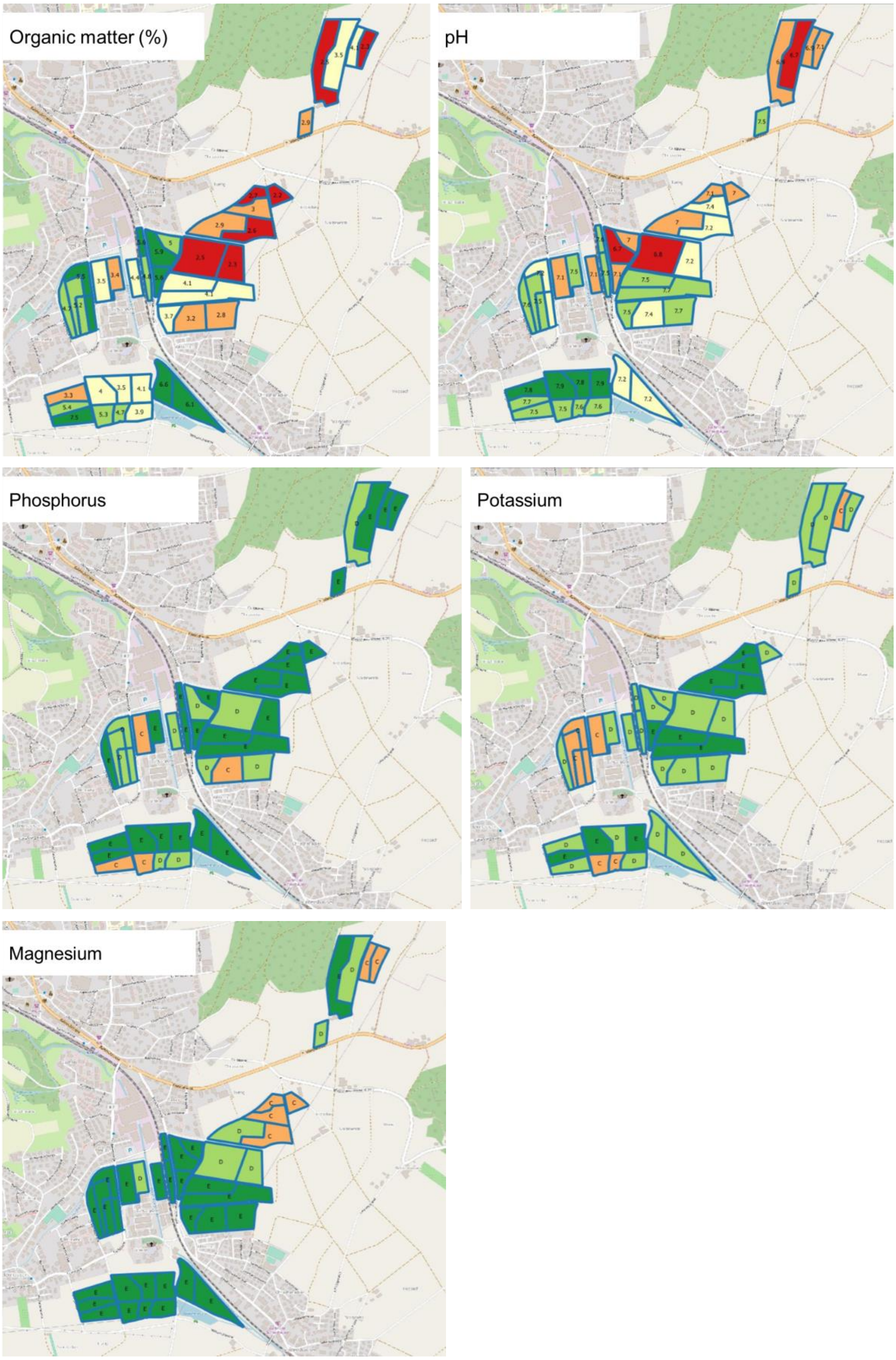


Figure 31. Results of the soil samples for the sampled subplots for organic matter, pH, phosphorus, potassium and magnesium.

Soil organic matter consists of plant and animal detritus at various stages of decomposition, provides numerous benefits to the physical and chemical properties of soil, hence, the amount of soil organic matter and soil fertility are significantly correlated. The ranges described in Table 11 apply for interpretation of organic matter content found in the soil sampling.

Table 11. Interpretation of organic matter content

Percentage	**< 2.0 %**	**2.0 - 3.0 %**	**3.0 - 4.0 %**	**> 4.0 %**
Rating	Low	Medium	High	Very high

The results show that lower organic matter content was found on light soils with higher content of sand in its texture and on fields with long-term arable farming use, where intensive tillage was applied, which enables faster decomposition and thereby reduces the organic matter level in the soil. Contrary, high and very high organic matter content was found on heavy soils with high clay content and long-term usa as permanent grassland and pasture.

The soil pH describes the acidity or alkalinity in soils and is a major parameter for plant nutrient availability by influencing the chemical forms and reactions of different nutrients. The optimum pH range for most crops is between 5.5 and 7.5. An interpretation of results based on the ranges described in Table 12 shows that most fields can be characterized as alkaline, which is due to the high share of calcaric brown earth as a dominating soil type. Neutral and slightly acidic soils where found on fields with higher content of sand in the soil texture and long-term intensive tillage practice.

Table 12. Interpretation of soil pH

Value	**<6.8**	**6.8 - 7.2**	**>7.2**
Rating	Acidic	Neutral	Alkaline

Considering the content of plant-available nutrients phosphorus, potassium, and magnesium, an interpretation based on the classification scheme in Table 13 shows that most soils are enriched with these nutrients due to long-term cattle and pig slurry application from the farm's livestock production unit and locations with fertilization trials in the past. Only a minor share of the agricultural area has lower, sufficient nutrient contents, predominantly on fields with intensive arable farming use and regular nutrient removal by the harvested crop.

Table 13. Content classes for plant-available nutrients phosphorus, potassium, and magnesium

Classification	**A**	**B**	**C**	**D**	**E**
Content	Poor	Moderate	Sufficient	Storage	Enriched

3.4 Telemetry systems

The SFF machine fleet is equipped with telemetry units and connected with AGCO Connect. This allows permanent remote localization, performance monitoring, and indication of maintenance status for all connected machines (Figure 32).

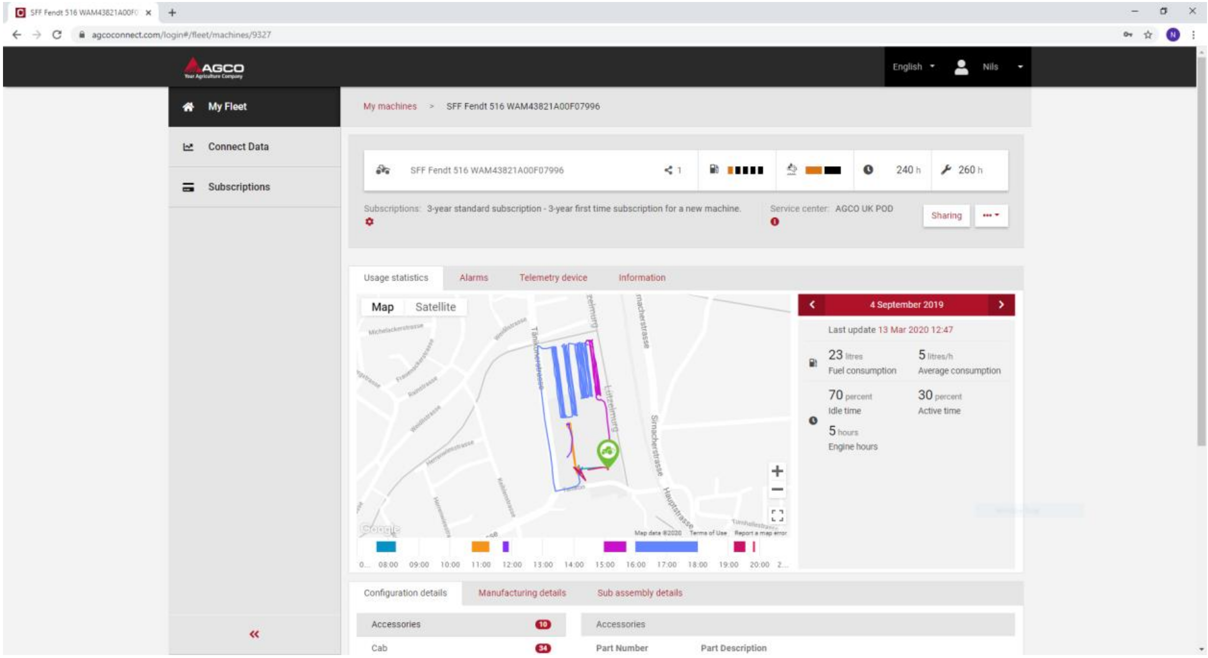


Figure 32. AGCO Connect user interface with machine localisation and performance monitoring.

Knowledge transfer

The basics of data management and practical application examples were presented to the public throughout the year as part of the regular visitor program and at the Swiss Future Farm Days in September 2019.

Parties involved

The Operating Team is responsible for data management at the SFF. The georeferenced soil sampling was carried out in cooperation with the company bodenproben.ch and the soil laboratory of BBZ Arenenberg.

References:

Schmid D., Hoop D., Renner S., Dux-Bruggmann D., Jan P. (2017): Zentrale Auswertung von Buchhaltungsdaten - Betriebszweigergebnisse : Stichprobe Referenzbetriebe und Stichprobe Betriebsführung. Agroscope, Tänikon.

4. Public Relations

4.1 Visitor program

Public relations work at the Swiss Future Farm was again accorded great importance in the 2019 operating year, and the Operating Team offered numerous groups from practical agriculture, politics, business, education, consulting and the press an insight into Smart Farming activities at the SFF. In 2019, a total of 3180 guests were welcomed to the Swiss Future Farm at around 100 events, of which 2384 were participants in the public visitor program. A pleasing response was that practical farmers made up the largest proportion of visitors with around 900 attendees. The Swiss Future Farm was also visited by a total of 796 participants in training and education programs, with BBZ Arenenberg students making up the largest group of participants at around 300 persons. The interest shown by visitors and training participants repeatedly underlines the need for and importance of training opportunities in the field of modern agricultural technologies. As a further component of knowledge transfer at the Swiss Future Farm, a total of around 100 publications were made available to the public as articles in the agricultural and general press and in the Social Media.

Figure 33. Impressions from the Swiss Future Farm visitor program 2019.

4.2 Renewable Energy and Electric Mobility Exhibition

On March 21, 2019, the exhibition on renewable energies and electromobility in agriculture was inaugurated in the Innovation Barn at the Swiss Future Farm. The Canton of Thurgau's government council took the opportunity at the IBK conference to present the energy promotion program adopted by the cantonal council in spring 2019 and the promotion of electromobility. Throughout the year, new innovations and interested circles joined the exhibition. In addition to electric mobility, tractor manufacturer Valtra provided the biomethane-powered tractor from the Weihenstephan Research Institute in Freising near Munich for the exhibition. In this context, Markus Zeifang from the SCCER BIOSWEET research competence centre, which links 13 Swiss university institutes and is supported by the Swiss government, was also present as an exhibitor. Zeifang, together with the company Apex, presented a "biomethane filling station for farms". SCCER BIOSWEET sees great opportunities at the versatile Tänikon farm to use biogas to generate electricity and heat as well as biomethane fuel.

Figure 34. The energy exhibition was able to address a broad public.

The organizations MBRsolar AG and the energy trade organization of the St. Gallen Regional Association of the Canton of St. Gallen used the exhibition to present their activities in the field of renewable energy. This includes first-hand information on the potential for energy saving, biogas production, wind and solar energy. The BBZ Arenenberg will also reorganize and increasingly expand its energy consulting services as of 2020. The heating company Heim from Aadorf presents the domestic production of electricity and heat energy with a combined heat and power unit. Regional wood chips are used as the energy supplier for the cogeneration plant.

Massive energy savings possible

The Tänikon Energy Exhibition attaches great importance to saving energy: using exhibits, it was calculated how, for example, the electricity requirement can be reduced by half compared to the conventional heat lamp with new piglet nest boxes. A clear sign that an energy check on the house or farm is worthwhile by far. "In addition to this, the combination systems of vertical small and low wind systems as well as solar systems with storage possibilities also fit", explained Hans Rüdlinger from the company Newgreentec. "These ensure self-sufficient electricity production, especially in remote buildings." Hanspeter Neukomm reported on the activities of the organisation "Schaffhauser Landenergie" in front of his self-built small biogas plant. Neukomm built a biogas plant on his farm 40 years ago and is considered a pioneer in this field. This is also true of his home town Thayngen, where he has three biogas plants. Two of them supply a large, privately built heating network in cooperation with the municipality and private heat consumers.

Agricultural equipment relies on various energy sources

On a farm there are numerous machines that need to be driven. Here too, the exhibition showed various approaches to solutions. "Small devices such as a yard loader or a fruit-growing lift work perfectly with e-mobility. It's a different story for a tractor pulling a plough through the field," said Nicolas Helmstetter of GVS Agrar Landtechnik. Alternative energy sources such as methane gas are in demand here. The manure of a dairy cow provides 919 cubic meters of methane per year, which means that an 80 HP tractor, for example, can be driven for about 130 hours per year. The Swiss Future Farm already has an electrically driven farm loader and a small electric transport vehicle in operation.

Figure 35. Christian Eggenberger of BBZ Arenenberg (right) welcomes the construction experts of the Agridea construction conference at the Innovation Barn in Tänikon.

4.3 Swiss Future Farm Days 2019

At the 1st Swiss Future Farm Days from 20 to 21 September 2019 at the Swiss Future Farm in Tänikon, everything revolved around sustainable agriculture. Information was provided at various practical stations and in the Innovation Barn on the topics of mechanical weed control with harrow and camera-controlled hoe, stubble cultivation in rapeseed, Controlled Traffic Farming, Variable Rate nitrogen fertilization and renewable energy production and electro-mobility.

For the SFF Farm Days, after the grain harvest, a demo area was set up with sugar beets and various mechanical weed control strategies were demonstrated directly in the field. Also under the motto "After the harvest is before the harvest" a harvested rapeseed field was located at another practical station, where different strategies and methods for stubble cultivation were demonstrated. The aim was to prepare the field for the next harvest in the best possible way.

An important resource in agriculture is the soil. In order to work it gently, it makes sense to always use the same tracks, especially for large machines. For this reason, the concept of "Controlled Traffic Farming" was presented at a practical station during the Farm Days under the direction of Agroscope. Initial trials are showing good results. The trials will be continued at the SFF from the 2020 season onwards.

Innovation and exchange

Despite the good harvest weather, the exhibitions in the "Smart Farming Technology Hall" and the "Innovation Barn" were pleasingly well attended. In the first, the Farming-Simulator game was presented, for which a Swiss Future Farm map as gaming environment has been available for free download since autumn 2019. In addition, interesting suppliers from the drone, software and sensor technology sectors were on site, including bodenproben.ch, Remote Vision, Barto, ADA-EDA, Farmfacts and Pessl Instruments. Numerous exhibits on the subject of electric mobility and renewable energies in agriculture were part of the innovation drive. The "International Straw Bale Arena" also took place in these premises. Here, informative discussions were held with producers, consumers and marketers on the topics of agriculture, robots and consumers, and effective conclusions were drawn.

The past year has shown that the Swiss Future Farm has also established itself as a venue for events. The SFF Farm Days proved once again that the public interested in the topic of digital agriculture and that a good exchange platform is needed.

Figure 36. Impressions of the Swiss Future Farm Days 2019.

4.4 External presentations by representatives of the Swiss Future Farm

In 2019, the Swiss Future Farm was again a sought-after speaker on topics relating to Smart Farming technologies and sustainability in agriculture. At events in Switzerland and abroad, inputs from day-to-day business and further experience could be exchanged. The following is a summary of the external appearances:

12 February 2019 - International Corn Information Ring (IMIR Meeting) in Aesch (CH)
At the internationally attended general meeting Florian Abt spoke on the subject of digital technologies in corn production, among other topic around Precision Ag.

12 March 2019 - Agridea conference of farming communities in Tänikon (CH)
The meeting of the operating communities took place in 2019 at the Swiss Future Farm in Tänikon. In addition to a tour of the farm, Florian Abt presented the opportunities offered by digitisation for joint ventures. Josias Meili from Strickhof, for his part, spoke about the dangers. Afterwards, a draft concept for the use of digital technologies was drawn up in a joint workshop.

29 March 2019 - Austrian Innovation Day for Agriculture in Althofen (AT)
On March 29, 2019, the province of Carinthia, together with the LFI Austria, the agricultural college Althofen and the Chamber of Agriculture of Carinthia invited to the Innovation Day Agriculture 4.0 in Althofen. Florian Abt presented the Swiss Future Farm and the chances of Smart Farming technologies in an input presentation to a large number of practitioners, associations and politicians.

Figure 37. Florian Abt during the input presentation in Althofen (AT)

21 May 2019 - Nefertiti - European DemoFarm Network in Brussels (BE)

On May 21, 2019, Nils Zehner gave an input presentation at the annual conference of the European Network for Demonstration Farms in Brussels, presenting the work and challenges at the Swiss Future Farm. In the panel discussion that followed, Nils Zehner represented the view of small-scale Swiss agriculture and a manufacturer of agricultural machinery engaged in demonstration farms.

Figure 38. Nils Zehner (2nd from left) during the panel discussion in Brussels.

27 July 2019 - FarmingSimulator Farmcon 19 in Harsewinkel (GER)

From 27 to 28 July 2019 the presentation of the new FarmingSimulator version LS19 took place in Harsewinkel at the company Claas. During the event the winner of the Modding Contest was chosen, who programmed a map interface for the Swiss Future Farm. Nils Zehner moderated the award ceremony and introduced the Swiss Future Farm in a presentation in front of filled halls.

Figure 39. Nils Zehner at the award ceremony of the Mod Contest at Farmcon 19.

08 October 2019 - Agroscope agricultural economics conference in Tänikon (CH)

The 42nd Agroeconomic Conference at Agroscope in Tänikon focused on the topic of "Economic activity in the field of tension between market and politics". Florian Abt gave a presentation on the possibilities of digital data management for economic farm management.

22 October 2019 - Annual meeting of the Charter Association for the Digitisation of Agriculture and Food in Zollikofen (CH)

At the end of October, the Charter Community for the Digitisation of Agriculture and Food met for its annual meeting in Zollikofen. In front of representatives of the industry, including politicians, and in the presence of Federal Councillor Guy Parmelin, Florian Abt outlined the current status and current obstacles in agricultural data networking.

Figure 40. Florian Abt (2nd from left) at the panel discussion with representatives of the FOAG, Identitas and data protection officers of the canton of Berne on the networking of agricultural data.

4.5 Engagement in the PFLOPF project

Between 2019 and 2026, the project "Optimization and reduction of agrochemical use with Precision Farming technologies" - abbreviated as PFLOPF (in German): Pflanzenschutzoptimierung mit Precision Farming - is running in the cantons of Aargau, Thurgau and Zurich. The project aims to achieve agrochemical savings of at least 25 percent using technology-based measures. In the project, Swiss Future Farm provides expert support for the procurement and use of the technologies. Christian Eggenberger, member of the Swiss Future Farm Operating Team, is the strategic project manager in PFLOPF.

4.6 Involvement in the project Fachmedium digitale Technologien in der Landwirtschaft (DiTeLa)

The Swiss Future Farm is part of the project group for the development of a specialist medium for digital technologies in agriculture in Switzerland. The specialist medium is being developed together with experts and will be published and distributed by edition-lmz. The specialist medium is to be used in tertiary education, in consulting, in farm management school and for self-study.

4.7 Farming Simulator integration

The Farming Simulator is an internationally acknowledged computer game for simulation of machinery operation and farm management (https://www.farming-simulator.com). For the current version Farming Simulator 19 and on occasion of this year's Farming Simulator mod contest, the Swiss Future Farm Special Award was implemented as a category that was awarded at the FarmCon19 gaming convention. The reference material for creation of the Swiss Future Farm map (pictures, drone videos, field boundaries, topographic landscape model) was provided on the basis of the Smart Farming activities of the SFF Operating Team. As a result, the Swiss Future Farm is available as a Farming Simulator gaming environment for download: https://www.farming-simulator.com/mod.php?mod_id=135531

Figure 41. Impression from the Swiss Future Farm map for Farming Simulator 19.

5. Training and education

5.1 GVS Agrar Academy

GVS Agrar AG founded the Agrar Academy on 27 June 2019 as an educational platform for the employees, sales partners and customers of the GVS Agrar Group. The technical advances in agricultural equipment require consistent and practice-oriented further training opportunities at all levels. Here at the Swiss Future Farm there is a unique opportunity to learn and experience Agriculture 4.0 in theory and practice. The theoretical knowledge can also be directly applied in practice thanks to the state-of-the-art infrastructure. Customers of GVS Agrar AG expect the sales advisors to have in-depth knowledge of Smart Farming. Various training courses are already planned for the 2020 season for all AGCO brands distributed by GVS Agrar. The training courses are modular and contain theoretical elements as well as practical application to enable sales advisors and customer service technicians to meet the customers' expectations.

Figure 42. Foundation of GVS Agrar Academy on the Swiss Future Farm on 27 June 2019.

GVS Agrar AG also uses the Swiss Future Farm location for dealer conferences, machine presentations and sales events. In 2019, all AGCO brands were represented at the SFF with a wide variety of events. The Fendt sales team carried out dealer training for the Swiss dealer network. The Valtra demo tour, which was held at various locations in Switzerland, also stopped over at the Swiss Future Farm to show the Valtra product range in the best light. In August, Massey Ferguson haytools dominated the farm area as part of a training session organized for the Swiss Massey Ferguson dealer network (Figure 43).

Figure 43. Impressions of GVS Agrar events at the Swiss Future Farm 2019.

5.2 Lessons BBZ Arenenberg

Also in 2019, part of the elective subject Agricultural Engineering and Energy in Basic Education as well as the Agricultural Engineering module of the Farm Management School was again held at the Swiss Future Farm. Students and prospective farm managers visited the SFF in January and March for half-day classes on Smart Farming. The topics covered included the basics of satellite navigation, the application of guidance systems, the use of ISOBUS, the integration of sensors in herd management and the use of agricultural software.

Figure 44. Students of the BBZ Arenenberg at practice stations at the SFF.

6. Outlook

For the 2020 season, a major trial focus is on mechanical weeding strategies. In addition, the influence of different settings of down force, planting depth and liquid starter fertilizer on juvenile development and crop yield will be investigated in sugar beets. In a winter wheat trial, the effect of Variable Rate nitrogen fertilization based on aerial imagery on the yield is being investigated using a scientific study design.

For information on upcoming events, please visit our website **www.swissfuturefarm.ch**.

Acknowledgement

The Operating Team of Swiss Future Farm would like to express its gratitude for the committed support in the 2019 harvest year. Special thanks go to:

- SFF Senior Sponsors
- SFF Steering Team
- GVS Service Teams Balterswil, Koblenz, Schaffhausen
- GVS Marketing Team
- BBZ Team Arable Farming Consulting
- BBZ Team Regional Development
- BBZ Farm Operations Team Tänikon
- AGCO Fuse EME Team
- AGCO Agronomy and Farm Solutions Team
- Precision Planting, Tremont, IL, USA
- Agroscope Team Tänikon
- Ariane Reist (university intern, ETH Zurich)
- Michael Huber (university intern, ETH Zurich)

and all visitors and friends of the Swiss Future Farm!

Links

Homepages:
www.swissfuturefarm.ch
https://www.agcocorp.com
https://arenenberg.tg.ch
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https://www.youtube.com/channel/UCzsEm9mMLs0X_lT3MoaCJXQ

Swiss Future Farm Video Chronology 2019:
https://www.youtube.com/watch?v=eSimgzyRTpw
https://www.youtube.com/watch?v=ulDthqDAuys&t=17s
https://www.youtube.com/watch?v=_4Ts89CJtl4&t=130s
https://www.youtube.com/watch?v=wgb_KJALYA8&t=29s
https://www.youtube.com/watch?v=YOYg1YJSfIM
https://www.youtube.com/watch?v=YO0VnLdC6vw

FarmingSimulator Swiss Future Farm map:
https://www.farming-simulator.com/mod.php?mod_id=135531

Imprint

Authors:
Dr. Nils Zehner, Florian Abt, Marco Meier, Nicolas Helmstetter

Swiss Future Farm
Tänikon 1
CH-8356 Ettenhausen
info@swissfuturefarm.ch
www.swissfuturefarm.ch

Operating Team:
Dr. Nils Zehner (AGCO), Florian Abt (BBZ Arenenberg), Christian Eggenberger (BBZ Arenenberg), Marco Landis (GVS Agrar, until Oct 2019), Marco Meier (GVS Agrar, since Nov 2019), Raphael Bernet (BBZ Arenenberg)

Steering Team:
Dr. Bernhard Schmitz (AGCO), Martin Huber (BBZ Arenenberg), Markus Angst (GVS Agrar), Nicolas Helmstetter (GVS Agrar), Bernhard Müller (BBZ Arenenberg)

Executive Board:
Steve Clarke (AGCO), Ueli Bleiker (Canton of Thurgau), Ugo Tosoni (GVS Group)