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SITES Agroecological Field Experiment (SAFE)

TABLE OF CONTENT

1 SITES

SITES (Swedish Infrastructure for Ecosystem Science) is a national infrastructure for terrestrial and limnological field research funded by the Swedish Research Council, together with the principals of the research stations. SITES aims to promote high-quality research through long-term field measurements and field experiments, and by making data available for everyone. The core of SITES is nine field research stations plus an associated one, that represent a variety of Swedish climate zones and ecosystems, including agricultural land, forests, wetlands, lakes and streams. From north to south Sweden, the stations included in SITES are:

- Abisko Scientific Research Station
- Tarfala Research Station
- Svartberget Research Station
- Röbäcksdalen Field Research Station
- Erken Laboratory
- Grimsö Wildlife Research Station
- Skogaryd Research Catchment
- Asa Research Station
- Bolmen Research Station (associated research station)
- Lönnstorp Research Station

Lönnstorp and Röbäcksdalen represent the agricultural ecosystems.

2 Lönnstorp research station

Lönnstorp is the southernmost station within the SITES infrastructure, and belongs to the department of Biosystem and Technology of the Swedish University of Agricultural Sciences (SLU), in Alnarp. The station consists of a conventionally farmed area of 60 ha at the station, and an area of 18 ha at Alnarp Campus, which was converted to organic farming in 1993 (certified by KRAV). Located in the south-west of Scania and established in 1969, the station has a subject focus on cropping system dynamics and provides research opportunities in ecology, environmental science and agroecology. Researchers utilizing Lönnstorp's facilities are focusing on design, sustainable development and assessment of agroecosystems in conventional and organic farming. The main users of the research station have been researchers from SLU, but other universities, organizations and commercial companies also perform experiments at the station. The station hosts both short and long-term field experiments addressing research question about e.g. cropping systems, reduced tillage, bioenergy crops, greenhouse gas emissions and biogeochemical processes in agroecosystems.

3 SITES Agroecological Field Experiment (SAFE)

The SITES Agroecological Field Experiment (SAFE) infrastructure was established in 2016 in the conventionally farmed area at Lönnstorp research station and is available for many types of studies, e.g. plant and soil ecology, biogeochemistry and agroecology. SAFE is an open infrastructure and can therefore be used by researchers from all over the world. It is also possible to establish smaller experiments within SAFE.

3.1 Experimental design

The SAFE infrastructure is a long-term field experiment and consists of four agricultural cropping systems: a reference (conventionally managed) cropping system, an organic cropping system, an agroecological intensification cropping system, and a perennial cereal cropping system. Each cropping system is replicated four times (blocks A, B, C and D) and the total area of SAFE is 14.2 hectares (Fig. 1). In general, the residues (e.g. straw and beet leaves) are not removed from the field in any of the systems. Modifications for specific research purposes on these systems are allowed, but limited to half of each plot.

The scientific names of the different crops grown in the four systems are compiled in a table annexed at the end of this document (Annex Table 1). The common names are used in the description of each cropping system in this section.

Figure 1: Overview of the four systems of SAFE: reference (conventional) system (REF), Organic system (ORG), agroecological intensification system (AI), and perennial system (PER); repeated in four blocks (A-D).

3.1.1 Reference system

The reference system is a four-year conventionally managed crop rotation. Every block of the reference system is divided into four different plots, each measuring 50 m x 24 m. Hence, every block of the reference system covers an area of 0.48 ha. The rotation includes the following crops: spring barley, winter oilseed rape, winter wheat and sugar beets. A grass legume ley (cover crop) is established after winter wheat. All crops are grown every year (Fig. 2).

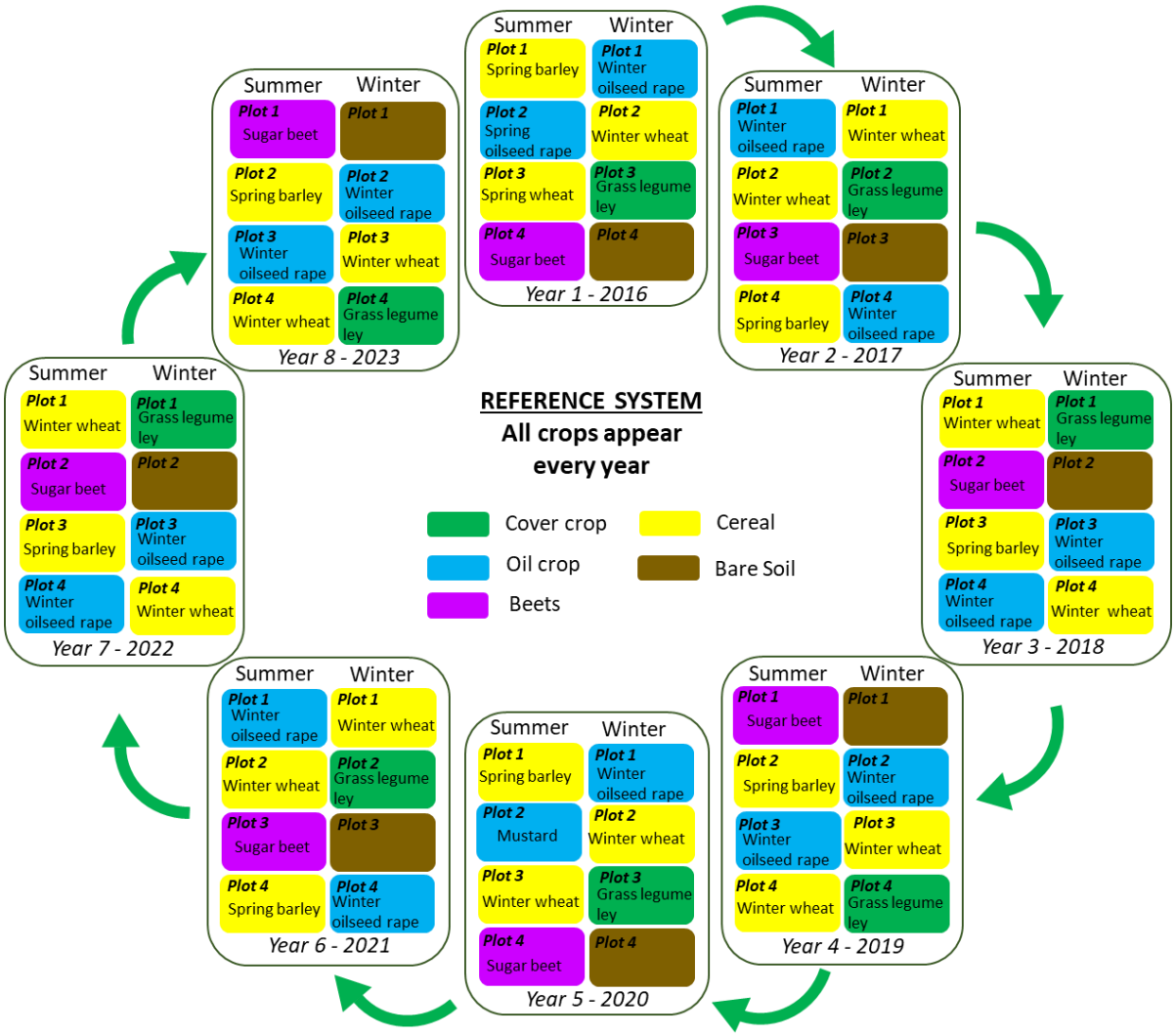

Figure 2: Crop rotation in the reference system.

The reference system is designed to avoid bare soil as much as possible. Therefore, all spring crops are followed by a winter crop and a cover crop is established after winter wheat. Due to the late harvest of sugar beet, no crops or cover crops are established after sugar beet harvest.

The crop rotation used in the reference system is common in conventional farming in south Sweden. The location of this infrastructure (southernmost part of the country) has relatively high yields compared to other parts of Sweden, and this is also the area where the majority of sugar beets are grown in Sweden.

3.1.2 Organic system

The organic system is an eight-year organically managed crop rotation. Every block of the organic system is divided into four different plots, each measuring 50 m x 24 m. Hence, every block of the organic system covers an area of 0.48 ha. The rotation includes the folowing crops: intercrop of lupine with spring barley, winter rye, grass legume ley, sugar beet, intercrop of faba bean with spring wheat, winter oilseed rape, winter wheat and a second grass legume ley (Fig. 3). All the crops are present in the rotation every two years. The grass legume ley is a mixture of 15% tall fescue, 10% of red clover, 5% of white clover, 20% of lucerne, 30% of timothy and 20% of ryegrass.

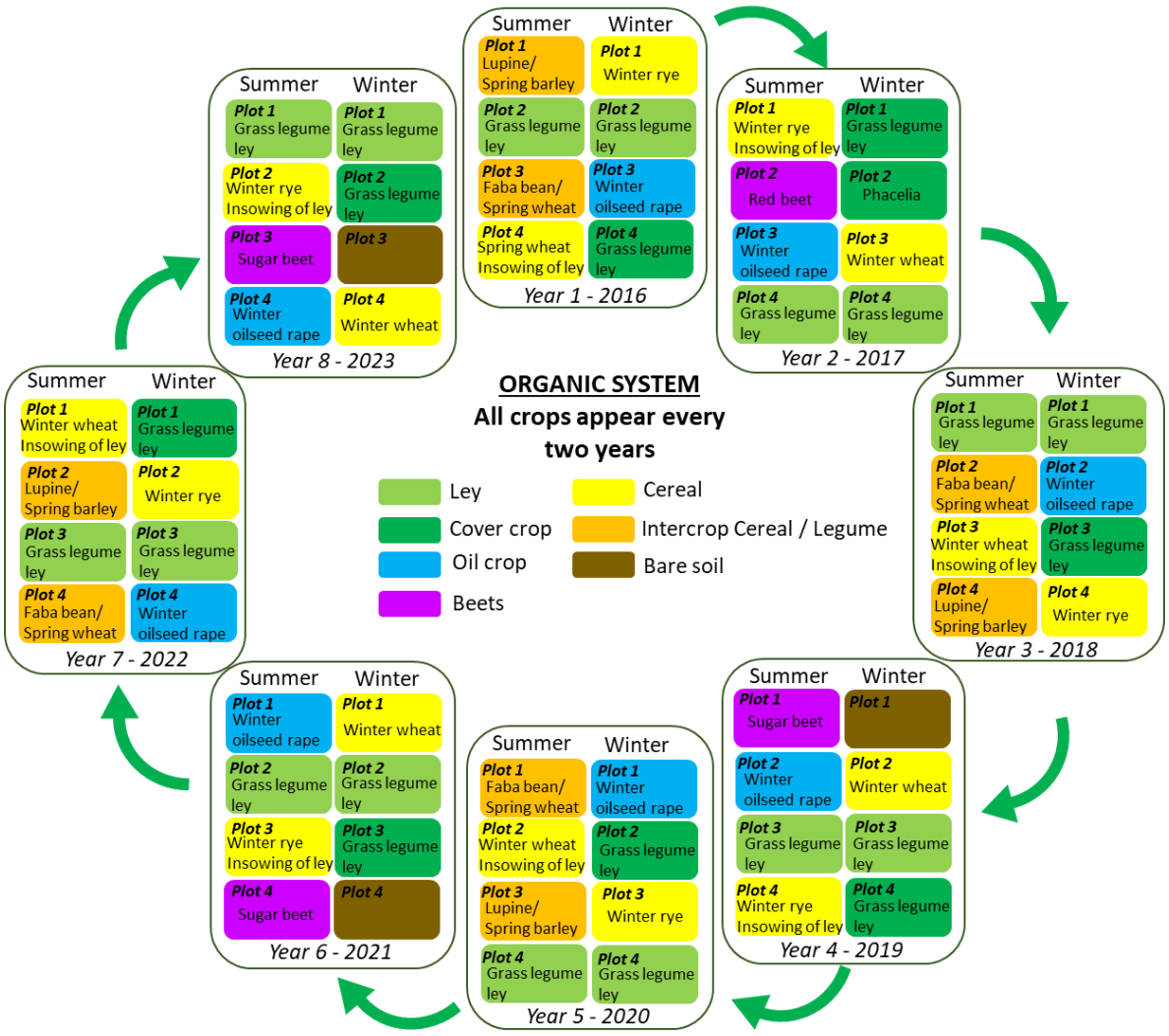

Figure 3: Crop rotation in the organic system.

The organic system is designed to avoid bare soil as much as possible. Therefore, all spring crops (intercrop of lupine with spring barley and intercrop of faba bean with spring wheat) are followed by a winter crop (winter rye and winter oilseed rape), and the winter oil seed rape is followed by winter wheat. The winter cereals (wheat and rye) are also insown with a ley between the cereal rows in the next year's spring. Initially, the design of the rotation included red beet (Fig. 3). However, red beet

presented some challenges that could not be solved and was therefore substituted with sugar beet in 2019. Due to the late harvest of sugar beet (compared to red beet), it is not possible to establish anything following this crop. The two species of each intercrop are sown and harvested at the same time.

3.1.3 Agroecological intensification system

The agroecological intensification (AI) system is an eight-year rotation. Every block of the agroecological intensification system is divided into 15 different plots. Within these 15 plots, four are rows of apple trees (50 m x 2 m), three are rows of hedges (50 m x 2 m) and eight are plots (50 m x 12 m) placed between and outside the rows of apple trees and hedges, where different annual crops are grown (Fig. 4). Hence, every block of the AI system covers an area of 0.55 ha.

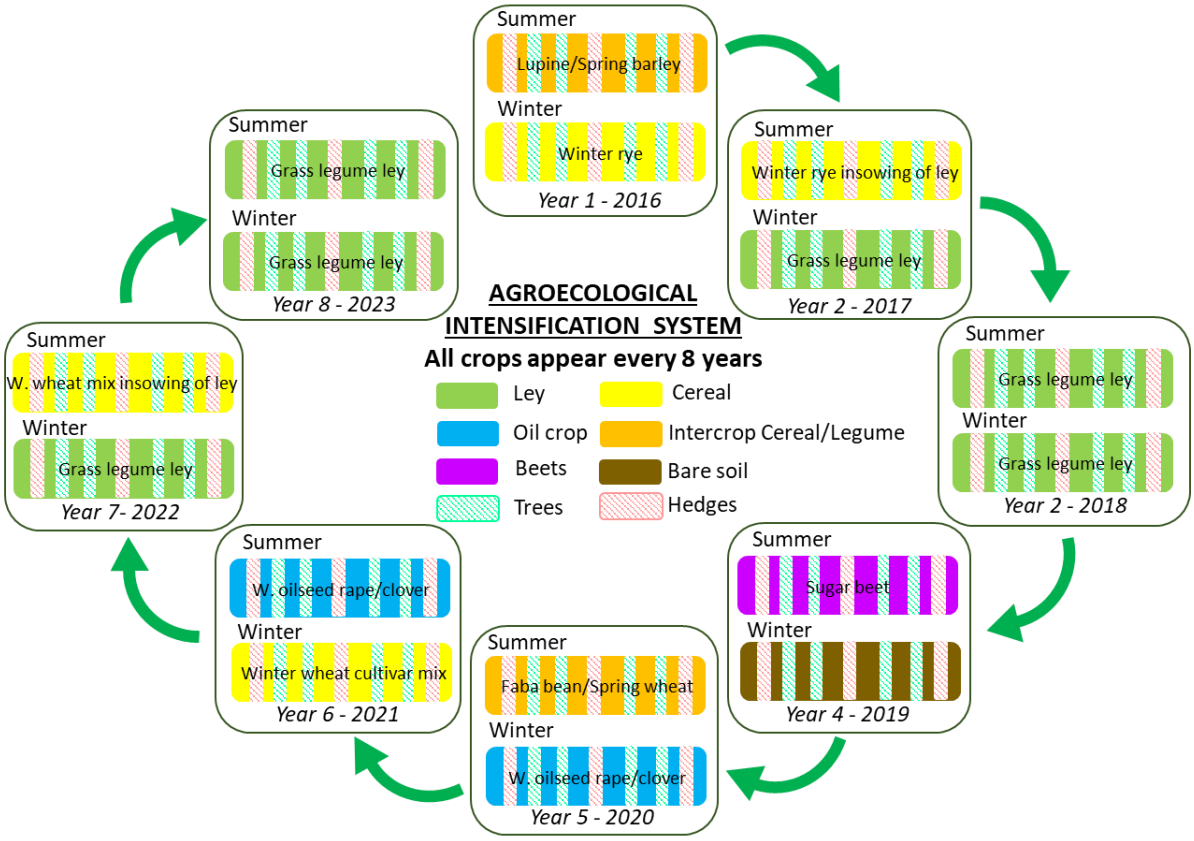

Figure 4: Crop rotation in the Agroecological intensification system.

The rotation of the annual crops includes intercrop of lupine with spring barley, winter rye, grass legume ley, sugar beet, intercrop of faba bean with spring wheat, winter oilseed rape with alexandrine clover (which is killed by low temperaure in winter), winter wheat and a second grass legume ley (Fig. 4). This eight-year rotation is organically managed and only one crop is grown each season. The AI system is designed to avoid bare soil as much as possible. Therefore, all spring crops (intercrop of lupine with spring barley and intercrop of faba bean with spring wheat) are followed by a winter crop (winter rye and winter oilseed rape), and the winter oilseed rape is followed by winter wheat. The winter cereals (wheat and rye) are also insown with a ley between the cerals rows in the next year's spring. Due to the

late harvest of sugar beet, it is not possible to establish anything following this crop. The species of each intercrop are sown and harvested at the same time.

The hedges in the AI system were planted in 2016, while the apple trees were planted in 2017. The apple tree varieties are Topaz, Aroma and Santana with rootstock M7. Each one of the rows has a total of 17 trees, with six trees of two of the varieties and five trees of the third variety (Annex Table 2). The distance between the apple trees is 3 m. In total, each block has 68 apple trees. Some of the apple trees have been damaged by hares, deer and voles after establishment. These trees have been replaced with apple trees of the same variety but with another rootstock (A2).

The species used in the hedge rows are two varieties of Blue-berried honeysuckle (Ezochi and Stubbaröd), Sea buckthorn, Vosges whitebeam, Black elder, Goat willow and two varieties of Cherry plum (common and Cecilia). The trees and the bigger shrubs were placed in the center of each row with a separation on 1.5 m between each other (Fig. 5). In total, 24 plants of Vosges whitebeam, 24 of Black elder, 24 of Cherry plum and 25 plants of Goat willow were planted per block. The smaller shrubs were placed on both sides of the bigger ones in each row, with a separation on 0.5 m between each other (Fig. 5), with a total of 249 plants of Sea buckthorn and 51 plants of Blue-berried honeysuckle per block planted. Each of the three hedge rows has a different design regarding the distribution of plant varieties.

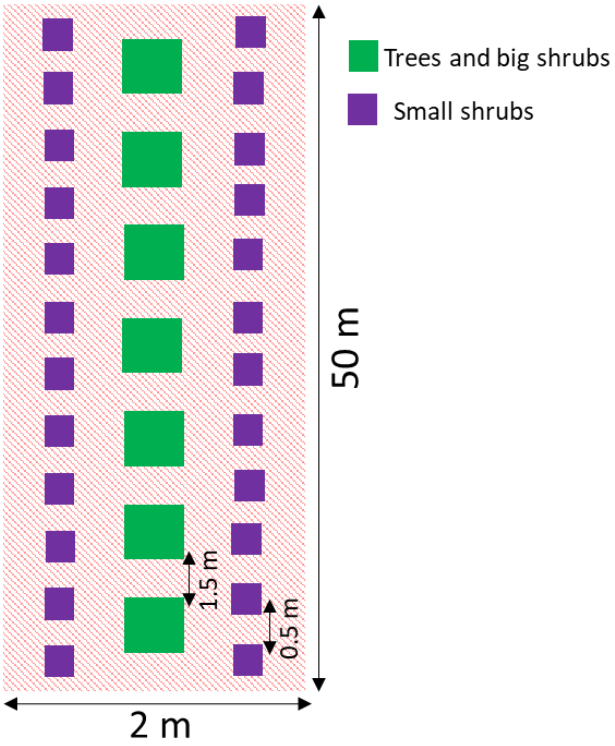

Figure 5: Detail of the distribution of trees and shrubs in the row of hedges in the Agroecological Intensification System.

The implementation of the AI system, widely known as agroforestry, could have several benefits for the cropping system itself and for the surrounding ecosystems. Both shrubs and trees might enhance C sequestration, favor the presence of pollinators, and act as a habitat for organisms providing pest management. Some of the shrubs used in the hedge rows can improve the soil fertility by fixing nitrogen from the atmosphere (in our case the Sea buckthorn). The trees can protect the annual crops from wind, and they might also decrease leaching processes due to their long root system.

3.1.4 Perennial system

The perennial system covers an area of 0.48 ha divided into two plots (50 m x 48 m) in each block. The perennial crops used in this system are intermediate wheatgrass (Kernza®), and an intercrop of Kernza® with Lucerne (Fig. 6). All crops were planted in 2016 and have been harvested once per year. The system provides a model for perennial cereal grain production.

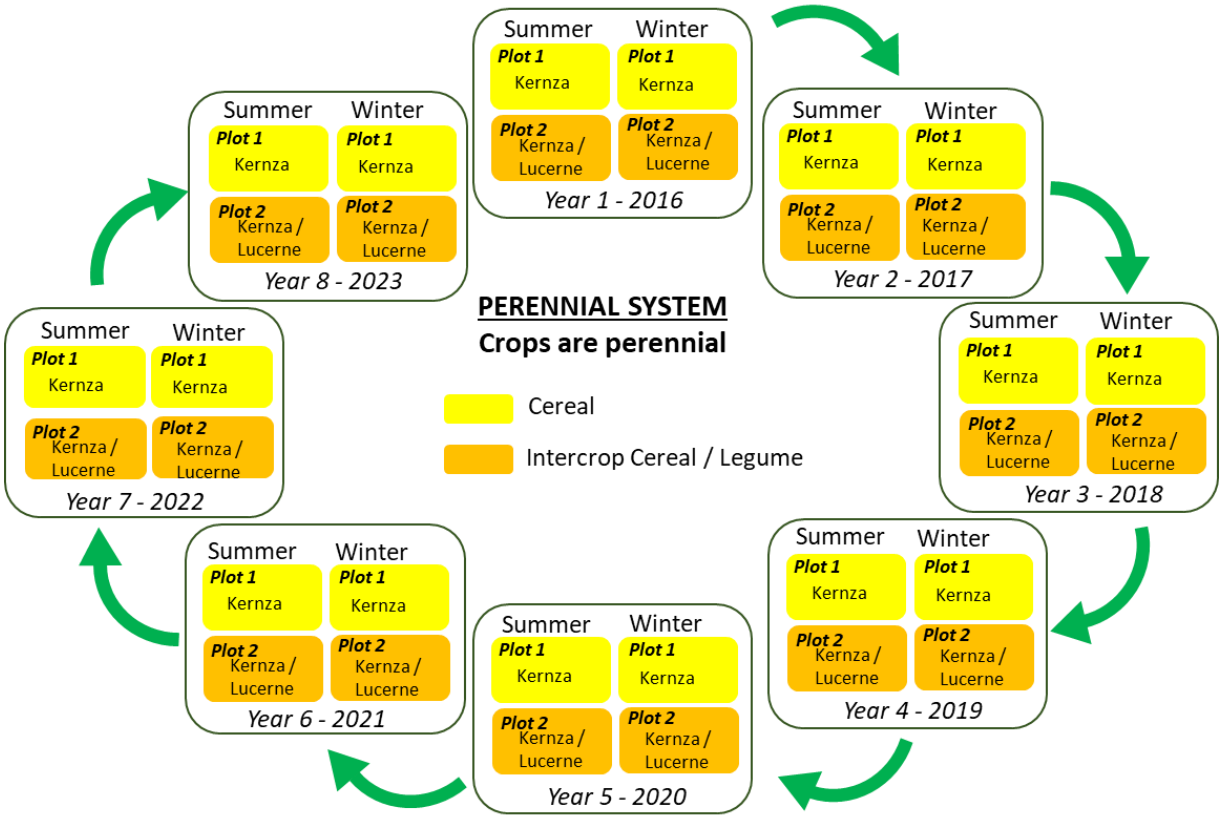

Figure 6: Crop rotation in the Perennial system.

In comparison with the annual cereal systems, the perennial cereal systems might favour C sequestration and soil microbial biomass, prevent nutrient leaching, and be more drought resilient. The intercrop with legume (lucerne) is intended to provide N_2 fixation for improved nitrogen use efficiency.

3.2 Management

3.2.1 Reference system

The management of the reference system resembles a regional contemporary stockless crop production farm, which is a conventional crop rotation without animals in the south of Sweden. This system is fertilized solely with inorganic fertilizers. The spring barley and the sugar beets are fertilized with approximately 120 kg N per ha and year. Depending on the season, the winter wheat is fertilized with between 160 and 200 kg N per ha. The fertilization of the winter oilseed rape is usually applied at two different times: one in autumn (50-60 kg N per ha) and one in spring (150 kg N per ha). YaraMila 27-3-3 (or a similar product) is used in spring barley, winter wheat, and for the spring application of the winter oilseed rape. YaraMila PROBETA is used in the sugar beets and YaraMila RAPS is used for the autumn application of the winter oilseed rape.

The principles of integrated pest management (IPM) are applied according to the European regulation. In the reference system, herbicides are usually applied every year to all the crops for weed control. Additionally, fungicides and insecticides are applied when needed. Prior to experiment establishment, block A was ploughed to a depth of 25 cm and blocks B, C and D were cultivated with a cultivator to a depth of 12 cm. The field is ploughed every year after harvest of sugar beet and ploughed or cultivated after winter oilseed rape and spring barley. Due to the insowing of ley (cover crop) in the winter wheat, no ploughing or cultivation is performed until January or February the following year.

3.2.2 Organic system

The management of the organic cropping system follows the regulations of the organic agricultural production, which means no use of synthetic pesticides or fertilizers. This system is fertilized solely with organic fertilizers, such as Biofer, and digestate remains from biogas production. Biofer is a commercial product developed by the company Gyllebo Gödning. This fertilizer is based on animal bio-products from conventional and organic slaughterhouses, and the food industry. The digestate is produced by the biogas production company Gasum Jordberga AB. The raw material for the biogas is mainly produced from green mass and residual products from agriculture and the food industry. Winter wheat, winter oilseed rape and sugar beets are fertilized with either digestate or Biofer, equivalent to 30-40 kg N per ha and year. Winter rye is also some years fertilized with the same amount and with the same fertilizers. The decision if the rye should be fertilized or not are based on visual assessments in April. The rest of the crops are not fertilized.

Weeds are managed by harrowing directly after ploughing and again before sowing. In some of the crops, additional harrowing is performed after crop emergence. Pre-emergence flame weeding is performed in the sugar beets and manual weeding is also performed if needed. All plots of the organic system were ploughed (25 cm) prior to the establishment of SAFE. The field is ploughed every year after harvest of sugar beet, winter oilseed rape, faba bean intercropped with spring wheat, and lupine intercropped with spring barley. Due to insowing of ley in the winter wheat and winter rye, no ploughing

or cultivation is performed after harvest of these crops. However, to terminate the grass legume ley, the field is ploughed in January after one season's growths.

3.2.3 Agroecological intensification system

The management of the agroecological intensification system is similar to the organic cropping system, therefore following the regulations of the organic agricultural production, with no use of synthetic pesticides or fertilizers. The agroecological intensification system also follows the fertilization strategy of the organic system, hence applying digestate or Biofer equivalent to 30-40 kg N per ha and year for winter wheat, winter oilseed rape, winter rye and sugar beet. No fertilization is applied to the other annual crops or to the apple and hedge rows. The apple trees are irrigated during spring and summer if needed. No other crops are irrigated.

Weeds are managed by harrowing directly after ploughing and again before sowing. In some of the crops, additional harrowing is performed after crop emergence. Pre-emergence flame weeding is performed in the sugar beets and manual weeding is also performed if needed. The field is ploughed every year after harvest of sugar beet, winter oilseed rape, faba bean intercropped with spring wheat and lupine intercropped with spring barley. Due to insowing of ley in the winter wheat and winter rye, no ploughing or cultivation is performed after harvest of these crops. The grass legume ley is terminated by ploughing in January, after one season's growth.

3.2.4 Perennial system

The management of the perennial system is similar to the organic cropping system, following the regulations of the organic agricultural production, with no use of synthetic pesticides or fertilizers. The perennial system in SAFE is fertilized with the same organic fertilizers as the organic and agroecological intensification systems; Biofer or digestate. Both the sole crop and the intercrop with the legume receive the same amount of fertilizer, equivalent to 30-40 kg N per ha and year.

Row crop cultivation was performed during establishment year (2016) to reduce weed growth. All plots were also ploughed before the establishment of the experiment. No weeding, ploughing or cultivation has been performed since 2016.

3.3 Characterization of the physical, chemical and biological soil properties

In 2015, before SAFE establishment, different physical, chemical and biological characteristics of the soil were determined at 76 evenly distributed sample points (Fig 7.). The area covering all sample points is hereafter named the sample area. The SAFE infrastructure (yellow polygons) was later established within this sample area (Fig 7.).

Figure 7: Overview of the sampling points (AE1-AE76) that were used for characterization of the physical, chemical and biological soil properties (asterisks show points for analysis of nematodes and earthworms). The SAFE infrastructure is highlighted in yellow polygons.

3.3.1 Soil texture

For assessment of the soil texture, 76 different sampling points (Fig. 7) were sampled at three different depths: 0-20 cm, 40-60 cm and 60-90 cm. The texture was determined using mechanical fractionation according to particle size (clay particles <0.002 mm, silt particles 0.002-0.2 mm, and sand particles 0.2-2.0 mm). Larger fractions were disregarded. The soil had on average 69% of sand in the first 20 cm, 67% between 20-60 cm, and 65% in the layer 60-90 cm (Fig. 8). The percentage of clay was similar in the first two soil layers, with 18%, and smaller in the deepest layer, with 17% (Fig. 8). Furthermore, the percentage of silt was 13, 15 and 18% in the 0-20, 40-60 and 60-90 cm soil layers, respectively (Fig. 8). The soil had on average 66.7% of sand, 17.6% of clay, and 15.7% of silt. According to the percentage of the different fractions, the soil can be described as sandy loam soil.

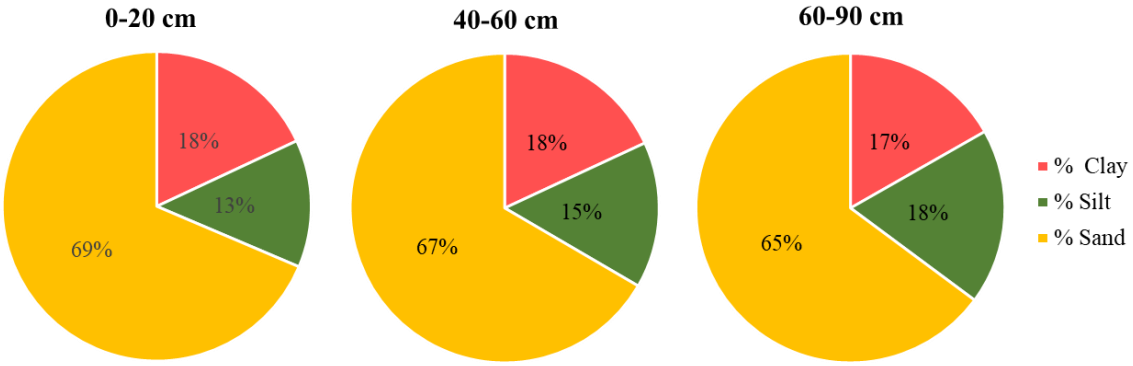

Figure 8: Average soil texture per soil depth within the sample area (Fig. 7).

In the sample area, on the uppermost soil layer (0-20 cm), the variation in the soil texture was small for the silt and sand fractions, with a variation coefficient of 9% and 5%, respectively. For the clay fraction, however, the variation coefficient was larger, with a value of 14%. For the deepest soils layers (20-60 and 60-90 cm), the variation of the soil texture was greater than for the surface layer. The variation coefficient was 23 and 28% for the silt fraction, 10 and 11% for the sand fraction, and 21 and 22% for the clay fraction in the 20-60 cm and 60-90 cm soil layers, respectively.

3.3.2 Nutrient content

The total and available phosphorous and potassium, and the available sodium, calcium and magnesium were determined at 76 points within the sample area (Fig. 7) at four different depths (0-20, 20-40, 40-60, 60-90 cm). The nutrients were extracted from the soil (HCl extraction for P and K; AL-extraction for K, P, Na, Ca, and Mg) and analyzed by Inductively Coupled Plasma (ICP, Optima 7300 DV). The total and available P and the available K were higher in the 0-20 cm soil layer and lower in the other depths, while the available Na, Ca and Mg values were higher in the deepest soil layer (60-90 cm) compared with the other depths (Tab. 1).

The variation in the soil nutrient content was smaller in the surface soil layer (0-20 cm) than at the other depths. The variation coefficient was smaller for the total K (13%), total P (23%), available Mg (24%), available K (32%), and available Na (35%). However, for the available P (59%) and available Ca (73%), the variation was much greater. The deepest soil layers showed a large variation in terms of soil nutrient content. On average, for the soil layers 20-40, 40-60 and 60-90 cm, the variation coefficients was 20% for the total K, 29% for the available K, 31% for the total P, 36% for the available Na, 72% for the available P, and 77% for the available Mg. With regard to the available Ca, it showed the greatest variation in the 20-40 and the 40-60 cm soil layers, with an average variation coefficient of 174%, while in the deeper layer the value dropped to 77%.

Table 1: Content (average ±SD) at different soil depths of total phosphorous (P tot; HCl-P), total potassium (K tot; HCl-K), available potassium (K av; AL-K), available P (P av; Al-P), available sodium (Na av; Al-Na), available calcium (Ca av; Al-Ca) and available magnesium (Mg av; Al-Mg) in the sample area.

Nutrient	Depth	mg 100 g^{-1}			Nutrient	Depth	mg 100 g^{-1}		
P tot	0-20 cm	48.0	±	10.82	Na av	0-20 cm	2.13	±	0.75
	20-40 cm	33.7	±	9.94		20-40 cm	2.45	±	0.91
	40-60 cm	27.5	±	8.22		40-60 cm	2.24	±	0.84
	60-90 cm	36.1	±	11.60		60-90 cm	3.08	±	1.06
K tot	0-20 cm	145	±	19.1	Ca av	0-20 cm	320	±	233
	20-40 cm	134	±	22.0		20-40 cm	489	±	850
	40-60 cm	146	±	33.2		40-60 cm	955	±	1676
	60-90 cm	148	±	31.1		60-90 cm	3268	±	2516
K av	0-20 cm	10.33	±	3.28	Mg av	0-20 cm	7.78	±	1.86
	20-40 cm	5.87	±	1.73		20-40 cm	7.10	±	5.28
	40-60 cm	5.09	±	1.35		40-60 cm	9.32	±	8.81
	60-90 cm	4.87	±	1.57		60-90 cm	22.81	±	14.21
P av	0-20 cm	8.32	±	4.93					
	20-40 cm	4.58	±	3.50					
	40-60 cm	3.53	±	2.47					
	60-90 cm	3.80	±	2.68					

3.3.3 pH

The soil pH (H_2O) was determined at 76 points within the sample area (Fig. 7), at four different depths (0-20, 20-40, 40-60, 60-90 cm). The soil pH in the first two layers of the soil (0-20 and 20-40 cm) was similar, with values 6.7-6.9, while in the deepest soil layers it increased significantly to a value of 7.4 in the layer 40-60 cm and to a value of 8.1 in the layer 60-90 cm (Fig. 9). The pH values were quite homogenous over the entire sampled area, with a variation coefficient of 6% in the first two soil layers (0-20 and 20-40 cm), 8% in the 40-60 cm soil layer, and 5% in the deepest soil layer (60-90 cm).

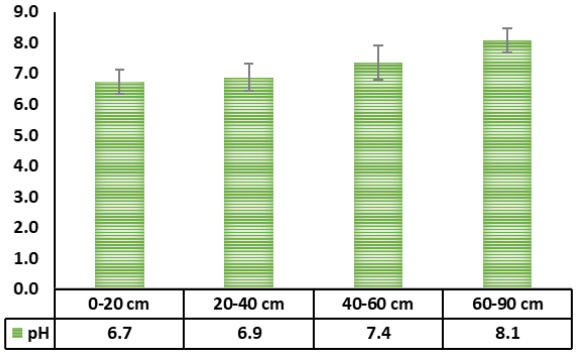

Figure 9: Average value ± SD of the soil pH within the sample area.

3.3.4 Nematodes

The number of nematodes was analyzed in the 0-30 cm soil layer of 24 selected samples from the initial 76 (Fig. 7). Nematodes were extracted using the standard procedure with Baermann funnels through which the organisms are driven down the funnel into collection cups by the use of a heat source. On average, 66 nematodes were found per gram of dry soil, and a total of 50 different genera were identified. The most abundant group was the herbivores, representing 41% of the total nematodes (Fig. 10), with five genera that were practically present in all the sampling points: Merlinius, Tylenchorhynchus, Helicotylenchus, Pratylenchus, and Paratylenchus. The group of bacteria feeders also represent an important proportion (36%) of the nematodes (Fig. 10), with 18 genera present. Some of these genera appeared in almost all the sampling points (Rhabditidae, Acrobeloides, Cephalobus, Chiloplacus, Eucephalobus, Monhysteridae, Plectus, Anaplectus and Alaimidae), while others only appeared in a few sampling points (Cervidellus, Acrolobus, Heterocephalobus, Drilocephalobus, Panagrolaimus, Wilsonema, Cylindrolaimus, Achromadora and Prismatolaimus). The root and facultative fungal feeders represented 12% (Fig. 10) of the total nematode, with eight genera, but only one of them was present in all the sampling points (Filenchus); the other genera were only present is some of the soil samples (Coslenchus, Lelenchus, Aglenchus, Tylenchus, Tylenchidae indet., Boleodorus, Psilenchus). The fungal feeder nematodes represented 9% of the total (Fig. 10) and six genera were detected; three of these were present in almost every soil sample (Ditylenchus, Aphelenchus and Aphelenchoides), while the rest were only present in 11 (Diphtherophora), three (Tylencholaimellus), and one (Dorylaimellus) soil samples. The omnivorous nematodes represent only 2% of the total (Fig. 10) but eight different genera were detected (Mesodorylaimus, Prodorylaimus, Qudsianematidae indet., Thonus, Eudorylaimus, Epidorylaimus, Aporcelaimidae and Dorylaimoides); any of them were present in all the samples. Finally, the predator nematodes were found occasionally in our soil samples, representing 0.5% of the total (Fig. 10) with four genera detected, of which two were rare (Seinura and Mylonchulus); the other two were detected in half of the samples, but in small amounts (Clarkus and Anatonchus).

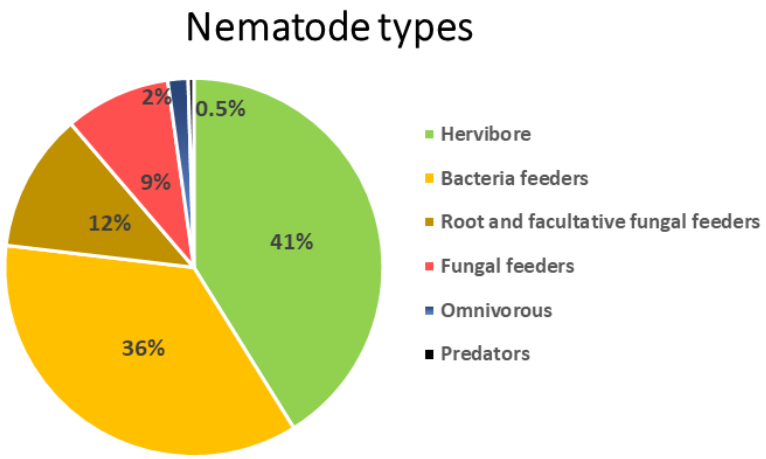

Figure 10: Percentage (on average) of the different types of nematodes within the sample area

3.3.5 Earthworms

For the earthworm characterization, we used the 24 selected points used for the nematode characterization (Fig. 7). The soil samples were taken with a wooden frame of 30 x 30 cm and to 0-30 cm depth. The soil was carefully hand sorted and larger pieces broken up, since earthworms can be in a resting state, curled up in small 'caves' that they make for that purpose. Earthworms were extracted using the standard procedure with Tullgren funnels through which the organisms are driven down the funnel into collection cups by the use of a heat source. All worms found were first washed with water, and then placed into a jar with 70% alcohol for storage.

Most of the earthworms detected (83.5%) were juveniles of the genus Aporrectodea, which were present in all the samples but one (Fig. 11). Species from the same genus were present in some of the samples*:* *Aporrectodea caliginosa*, *Aporrectodea longa*, *Aporrectodea rosea*, and *Aporrectodea caliginosa.* Juveniles from the genus Lumbricus were also detected, but the specie *Lumbricus terrestris* was only found in one of the samples. On average, we found two species per sample, a biomass of 12 g of earthworm m^{-2} and an abundance of 149 individuals per m^2.

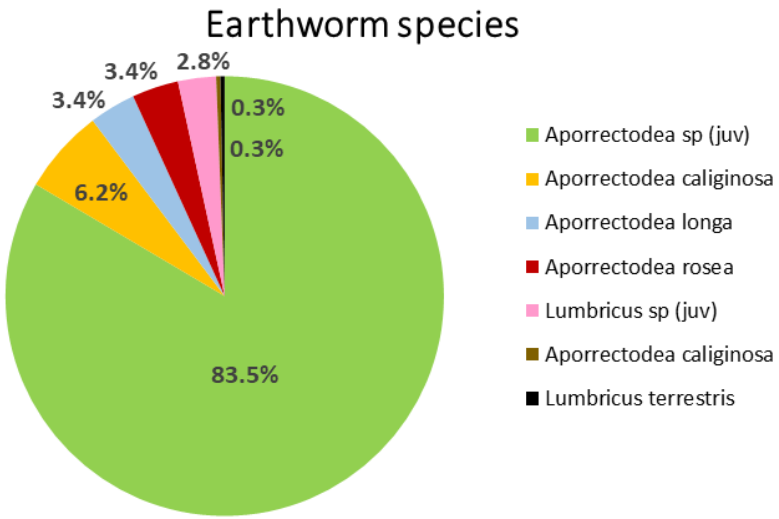

Figure 11: Percentage of earthworm species abundancy within the sample area.

3.3.6 Mesofauna

The soil mesofauna was analyzed in the first 0-30 cm of the 76 soil samples collected in the experimental area (Fig. 7). The soil mesofauna was extracted from the soil samples using Tullgren funnels with an underlying collecting vessel and a lamp that provides the actual extraction. The animals which live in the soil pores strive away from the lamp and down into the collecting vessel.

Each soil sample had, on average, one species of oribatida and four different species of collembola. The abundance was 1,056 individuals of oribatida per m^2 and 4,179 individuals of collembola per m^2. Within the oribatida, the most abundant species were *Ramusella insculpta, Tectocepheus velatus, Oppiella nova* and *Microppia minus*, representing 44.6, 21.5, 14.2 and 11.2% respectively of the identified individuals (Tab. 2). With regard to the collembola, the most abundant species was *Mesaphorura yosii*, representing 25.5% of the identified individuals, together with *Protaphorura armata*, *Parisitoma notabilis, Folsomia fimetaria* and *Isotomiella minor*, representing 12.7, 11.0, 10.9 and 8.9% of the identified individuals, respectively (Table 3).

Table 2: Mesofauna (% of oribatida) in the sample area.

Oribatida	%
Suctobelbidae	2.1
Brachychthoniidae	0.4
Oppiella nova	14.2
Ramusella insculpta	44.6
Microppia minus	11.2
Tectocepheus velatus	21.5
Ceratozetes thienemanni	4.7
Banksinoma lanceolata	1.3

Table 3: Mesofauna (% of collembola) in the sample area.

Collembola	%
Brachystomella parvula	0.2
Mesaphorura yosii	25.5
Protaphorura armata	12.7
Onychiurus jubilarius	0.1
Willemia intermedia	5.6
Micranurida pygmaea	0.1
Ceratophysella denticulata	0.8
Stenaphorura quadrispina	0.7
Friesea mirabilis	2.9
Pseudanurophorus binoculatus	0.1
Proisotoma minuta	7.5
Isotoma viridis	3.1
Pogonognathellus flavescens	0.1
Orchesella bifasciata	0.9
Lepidocyrtus lignorum	1.9
Folsomia fimetaria	10.9
Folsomia spinosa	0.1
Folsomia quadrioculata	1.9
Parisitoma notabilis	11.0
Isotomiella minor	8.9
Vertagopus cinereus	2.7
Megalothorax minimus	0.2
Sphaeridia pumilis	0.1
Sminthurinus elegans	1.6
Sminthurus viridis	0.4

3.3.7 Apparent electrical conductivity

A non-destructive mole sensor was used to estimate the apparent electrical conductivity, EC_a, in the sample area (Fig. 12). This parameter can give an indication of the soil's physical and chemical properties, such as clay soil texture, moisture content, salinity, cation exchange capacity, bulk density and soil organic matter content. Texture variations usually overshadow water content differences in such a way that the relative variation pattern is fairly constant if measurements are made at different times in the same place, but with different water contents. The values in the sample area were between 60 and 75 mS/m and were slightly higher in the area were blocks B and D were established.

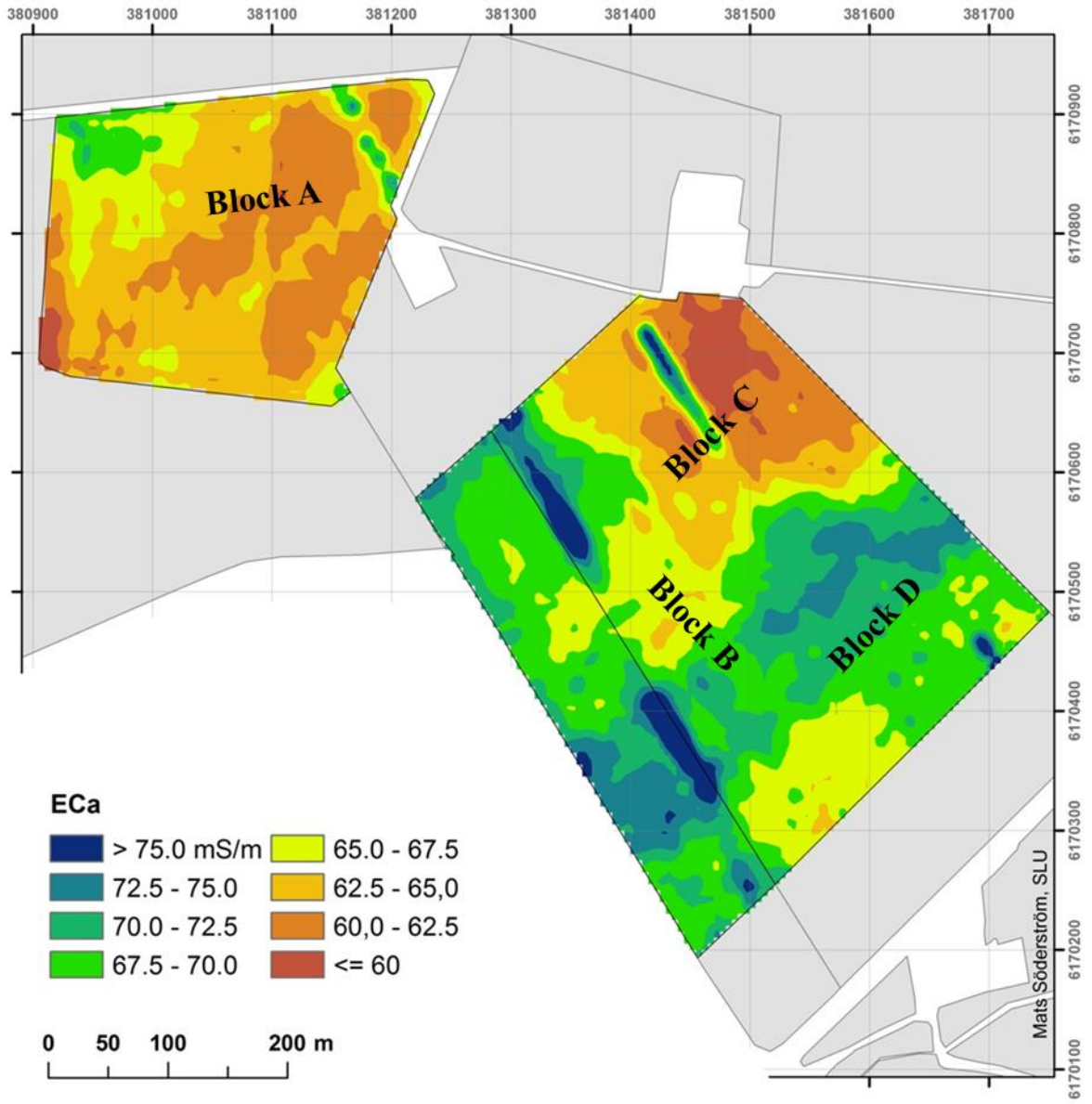

Figure 12: Map of apparent electrical conductivity in the sample area.

3.3.8 Thorium-232

A non-destructive mole sensor was used to estimate the amount of Thorium-232 in the sample area. Thorium-232 gives a response only from the topsoil and is usually very well correlated to the clay content. This natural radionucleotide can also be used as an indicator of phosphate fertilization, since the addition of phosphate rocks modifies the natural abundance of radionucleotides in the soil. The quantity of Thorium-232 was quite homogenous in the sample area (Fig. 13).

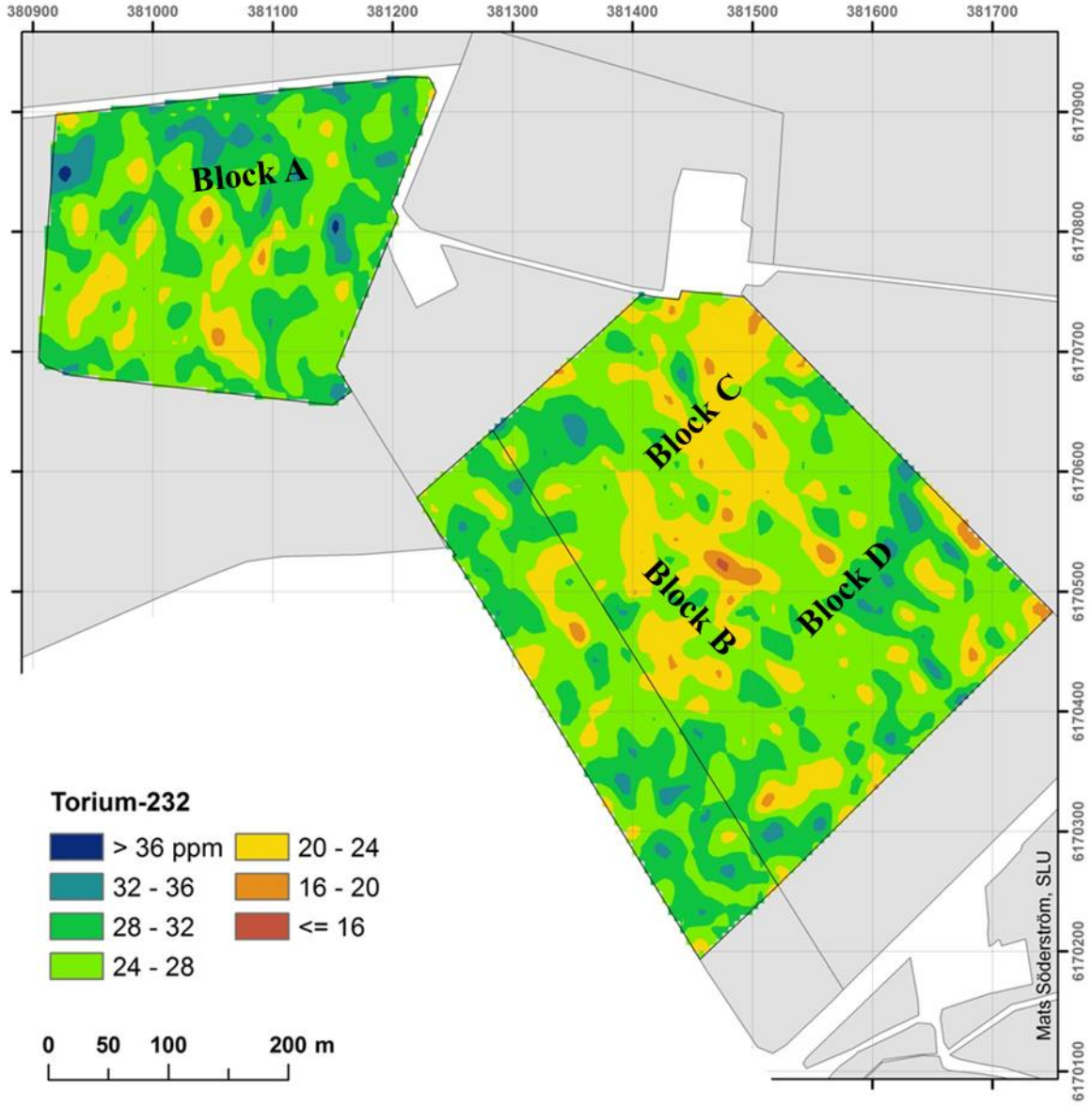

Figure 13: Map of the amount of Thorium-232 in the sample area.

3.4 Measurements and assessments

3.4.1 Crop sampling

3.4.1.1 All crops except sugar beet

The crops are sampled just before harvest every year. The sampling is performed in the part of the plot where modifications are not allowed. In the reference, organic and perennial systems, samples are taken from four different places within each plot using a 50 cm x 50 cm frame. All plant material within these four frames is cut at a height of about 10 cm and combined to one sample per plot. In the agroecological intensification system, one sample is taken from each sub-plot between the apple and hedge rows using a 50 cm x 50 cm frame, eight in total. All plant material within each frame is cut at a height of about 10 cm and considered as one sample. The samples are further divided into crop species and weeds. In the case of grass legume ley, the samples are divided into grasses, legumes and weeds. The plant samples are dried at 60ºC for 72 hours. The cereals, oilseed rape, faba bean, Kernza and lupine samples are threshed to separate seeds from the rest of the sample. The total dry weight of each sample fraction is noted, and the yields are calculated. The total amount of C and N is analyzed in all sample fractions using a FLASH 2000 elemental analyzer (Thermo Scientific).

3.4.1.2 Sugar beet

The sugar beets are sampled just before harvest every year. The sampling is performed in the part of the plot where modifications are not allowed. In the reference and the organic systems, two rows with lengths of 8 m (7.68 m^2 in total) are sampled in each plot. The total number of beets are counted in each sample area (7.68 m^2). The beets within the sample area are harvested and the leaves and the necks are removed before transportation to Örtofta sugar factory for further analyses. The fresh weight of the leaves and the neck are noted and both fractions are dried at 60ºC for 72 hours. The total dry weight of each sample fraction is noted. In the agroecological intensification system, one row with a length of 4 m is sampled in each of the sub-plots between the apple and hedge rows, eight in total. Four subplots are combined into one sample (7.68 m^2 in total), hence, two combined samples per block.

3.4.2 Soil sampling 2019

The soil was sampled in the SAFE infrastructure in January 2019 (all plots in the reference, organic and perennial systems, and three plots in the agroecological intensification system) with regard to pH (H20), total N, total C, organic C, total K (HCl-extraction), available K (AL-extraction), total P (HCl-extraction) and available P (AL-extraction). An ICP Avio 200 was used to analyze P and K, and TruMac CN was used to analyze C and N. The results from 2019 are summarized in annexed Table 3. Soil from this sampling occasion has been stored.

3.4.3 Spectral measurements

Lönnstorp is involved in SITES' Spectral thematic program. Within this program, the SAFE infrastructure is monitored with phenocams, fixed sensors and drones.

- Phenocams: here are three different phenocams mounted on a 10 m tower, which is located between the two plots of the perennial system in block A (Fig. 1). These cameras are oriented at different angles and positions, covering the four cropping systems of SAFE (Block A). The cameras take pictures every 30 minutes.

- Fixed sensors: There are three NDVI sensors (two upwelling and one downwelling) mounted on the 10 m tower that is also used for the phenocams. Additionally, two NDVI sensors are mounted on a mobile 4 m tower (one upwelling and one downwelling). The 4 m tower is located in the reference system of block A and is moved every autumn to follow the winter wheat crop. The sensors take measurements every 10 minutes.

- Drone: Regular flights are performed over the whole SAFE area. The drone has RGB and multispectral cameras. The drone takes pictures with a high degree of overlapping, which allows the generation of orthomosaics, point clouds and digital surface models where the altitude is included.

3.4.4 Weather data

There is an automatic weather station at SITES' Lönnstorp research station. The weather station provides the following data:

- Air temperature at 0.2 and 1.5 m above ground level. Measured once per minute and averaged over the preceding 15 minutes.

- Relative humidity of air (%) at 0.2 and 1.5 m above ground level. Measured once per minute and averaged over the preceding 15 minutes.

- Precipitation (mm) at 1.7 m above ground level. Sum of readings over the preceding 15 minutes.

- Wind speed (m s^{-1}) and wind direction. Wind sensor set at 1.8 m above ground level. Measured once per minute and averaged over the preceding 15 minutes.

- Maximum reading of winds speed at 1 minute sampling intervals (m s^{-1}).

- Soil temperature. Soil Temperature Sensor at -0.05 m and -0.2 m below ground level. Measured once per minute and averaged over the preceding 15 minutes.

- Incoming shortwave radiation (W m^{-2}) at 1.3 m above ground level. Measured once per minute and averaged over the preceding 15 minutes.

- Air pressure (hPa). Barometric Pressure Sensor at 1.2 m above ground level. Measured once per minute and averaged over the preceding 15 minutes.

3.5 Access to data

Data from SITES and the SAFE infrastructure are available via SITES' data portal https://data.fieldsites.se/portal/ or by contacting the station managers.

3.6 Appendix

Table A1: Common and scientific names of the different crops used in SAFE.

Common name	Scientific name
Alexandrine clover	*Trifolium alexandrinum*
Apple	*Malus pumila*
Barley	*Hordeum vulgare*
Black elder	*Sambucus nigra*
Blue-berried honeysuckle	*Lonicera caerulea*
Cherry plum	*Prunus cerasifera*
Faba bean	*Vicia faba*
Goat willow	*Salix caprea*
Intermediate wheatgrass	*Thinopyrum intermedium*
Lucerne	*Medicago sativa*
Lupine	*Lupinus albus*
Mustard	*Brassica nigra*
Oilseed rape	*Brassica napus ssp. napus*
Phacelia	*Phacelia tanacetifoli*
Red clover	*Trifolium pratense*
Red beet	*Beta vulgaris*
Rye	*Secale cereale*
Ryegrass	*Lolium perenne*
Sea buckthorn	*Hippophae rhamnoides*
Sugar beet	*Beta vulgaris ssp. vulgaris var. altissima*
Tall fescue	*Festuca arundinacea*
Timothy	*Phleum pratense*
Vosges whitebeam	*Sorbus mougeotii*
Wheat	*Triticum aestivum*
White clover	*Trifolium repens*

Table A2: Location of the apple tree varieties used in SAFE in the Agroecological Intensification System.

Block A				Block B			
Row 1	Row 2	Row 3	Row 4	Row 1	Row 2	Row 3	Row 4
Aroma	Topaz	Topaz	Topaz	Santana	Aroma	Aroma	Aroma
Aroma	Aroma	Topaz	Topaz	Aroma	Aroma	Aroma	Topaz
Aroma	Aroma	Aroma	Topaz	Aroma	Aroma	Topaz	Topaz
Santana	Aroma	Aroma	Aroma	Aroma	Topaz	Topaz	Topaz
Santana	Santana	Aroma	Aroma	Topaz	Topaz	Topaz	Santana
Santana	Santana	Santana	Aroma	Topaz	Topaz	Santana	Santana
Topaz	Santana	Santana	Santana	Topaz	Santana	Santana	Santana
Topaz	Topaz	Santana	Santana	Santana	Santana	Santana	Aroma
Topaz	Topaz	Topaz	Santana	Santana	Santana	Aroma	Aroma
Aroma	Topaz	Topaz	Topaz	Santana	Aroma	Aroma	Aroma
Aroma	Aroma	Topaz	Topaz	Aroma	Aroma	Aroma	Topaz
Aroma	Aroma	Aroma	Topaz	Aroma	Aroma	Topaz	Topaz
Santana	Aroma	Aroma	Aroma	Aroma	Topaz	Topaz	Topaz
Santana	Santana	Aroma	Aroma	Topaz	Topaz	Topaz	Santana
Santana	Santana	Santana	Aroma	Topaz	Topaz	Santana	Santana
Topaz	Santana	Santana	Santana	Topaz	Santana	Santana	Santana
Topaz	Topaz	Santana	Santana	Santana	Santana	Santana	Aroma

Block C				Block D			
Row 1	Row 2	Row 3	Row 4	Row 1	Row 2	Row 3	Row 4
Topaz	Topaz	Topaz	Santana	Santana	Santana	Aroma	Aroma
Topaz	Topaz	Santana	Santana	Santana	Aroma	Aroma	Aroma
Topaz	Santana	Santana	Santana	Aroma	Aroma	Aroma	Topaz
Santana	Santana	Santana	Aroma	Aroma	Aroma	Topaz	Topaz
Santana	Santana	Aroma	Aroma	Aroma	Topaz	Topaz	Topaz
Santana	Aroma	Aroma	Aroma	Topaz	Topaz	Topaz	Santana
Aroma	Aroma	Aroma	Topaz	Topaz	Topaz	Santana	Santana
Aroma	Aroma	Topaz	Topaz	Topaz	Santana	Santana	Santana
Aroma	Topaz	Topaz	Topaz	Santana	Santana	Santana	Aroma
Topaz	Topaz	Topaz	Santana	Santana	Santana	Aroma	Aroma
Topaz	Topaz	Santana	Santana	Santana	Aroma	Aroma	Aroma
Topaz	Santana	Santana	Santana	Aroma	Aroma	Aroma	Topaz
Santana	Santana	Santana	Aroma	Aroma	Aroma	Topaz	Topaz
Santana	Santana	Aroma	Aroma	Aroma	Topaz	Topaz	Topaz
Santana	Aroma	Aroma	Aroma	Topaz	Topaz	Topaz	Santana
Aroma	Aroma	Aroma	Topaz	Topaz	Topaz	Santana	Santana
Aroma	Aroma	Topaz	Topaz	Topaz	Santana	Santana	Santana

Table A3: Content (average ±SD) at different soil depths of total phosphorous (P tot; HCl-P), available phosphorous (P av; AL-P), total potassium (K tot; HCl-K), available potassium (K av; AL-K), total N (N tot), total C (C tot), organic C (C org) and pH in the different SAFE systems 2019.

		0-20 cm			20-60 cm			60-90 cm		
REF	P av (mg 100 g-1)	10.39	±	3.46	4.76	±	1.73	3.29	±	1.88
	P tot (mg 100 g-1)	52.46	±	8.91	32.90	±	6.43	33.22	±	8.10
	K av (mg 100 g-1)	10.92	±	1.85	7.77	±	1.19	8.94	±	1.39
	K tot (mg 100 g-1)	144	±	16.24	144	±	15.77	168	±	34.09
	N tot (%)	0.17	±	0.02	0.08	±	0.01	0.03	±	0.01
	C tot (%)	1.67	±	0.23	0.87	±	0.22	1.12	±	0.69
	C org (%)	1.65	±	0.22	0.77	±	0.14	0.32	±	0.10
	pH	6.70	±	0.49	7.52	±	0.64	8.31	±	0.31
ORG	P av (mg 100 g-1)	8.68	±	6.29	5.17	±	4.86	3.89	±	2.92
	P tot (mg 100 g-1)	50.71	±	15.20	37.38	±	17.96	37.41	±	10.50
	K av (mg 100 g-1)	11.58	±	3.26	8.21	±	1.17	9.29	±	1.18
	K tot (mg 100 g-1)	148	±	13.38	147	±	10.67	173	±	26.96
	N tot (%)	0.16	±	0.02	0.08	±	0.02	0.03	±	0.01
	C tot (%)	1.62	±	0.16	0.84	±	0.22	1.02	±	0.54
	C org (%)	1.60	±	0.15	0.76	±	0.12	0.34	±	0.06
	pH	6.77	±	0.48	7.39	±	0.48	8.35	±	0.26
AI	P av (mg 100 g-1)	8.29	±	3.96	4.08	±	1.27	2.92	±	1.27
	P tot (mg 100 g-1)	47.56	±	7.40	30.52	±	3.86	35.85	±	0.60
	K av (mg 100 g-1)	11.36	±	0.93	7.07	±	2.01	9.12	±	1.09
	K tot (mg 100 g-1)	158	±	14.52	160	±	15.08	166	±	12.11
	N tot (%)	0.17	±	0.03	0.09	±	0.04	0.02	±	0.01
	C tot (%)	1.66	±	0.24	0.96	±	0.38	1.44	±	0.42
	C org (%)	1.65	±	0.24	0.88	±	0.39	0.46	±	0.24
	pH	6.96	±	0.26	7.78	±	0.41	8.57	±	0.09
PER	P av (mg 100 g-1)	8.95	±	4.05	4.46	±	3.19	2.65	±	2.21
	P tot (mg 100 g-1)	49.65	±	10.89	32.82	±	11.35	36.45	±	5.34
	K av (mg 100 g-1)	13.05	±	3.46	8.12	±	0.95	8.48	±	1.34
	K tot (mg 100 g-1)	153	±	15.36	144	±	11.91	158	±	19.14
	N tot (%)	0.17	±	0.02	0.07	±	0.01	0.02	±	0.01
	C tot (%)	1.72	±	0.18	0.89	±	0.24	1.56	±	0.74
	C org (%)	1.69	±	0.16	0.65	±	0.09	0.32	±	0.06
	pH	6.98	±	0.63	7.62	±	0.71	8.50	±	0.24