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Report from the cultivation demonstrations of the first growing season

Pesonen Liisa, Backman Juha, Jaakkola Ville, Linkolehto Raimo, Kaivosoja Jere, Ronkainen Ari, Suokannas Antti

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NATURAL RESOURCES INSTITUTE FINLAND

Summary

Pesonen Liisa, Backman Juha, Jaakkola Ville, Linkolehto Raimo, Kaivosoja Jere, Ronkainen Ari, Suokannas Antti

Luke

Combined seed drilling is the most common seeding and fertilization method for cereals in Finland. Thus, it is important to introduce the use of recycled fertilizer in this context. Precision farming practices benefit if different nutrients from different fertilizers can be brought together and applied to a site as individual fertilizer mixes.

Liquid form fertilizers are a good alternative as additional nutrient source, since the liquid tanks can be installed fairly freely to the machinery combinations and lead the fertilizers to desired place through hosing. Liquids are also easy and accurate to dose accurately. In some cases, liquid nitrogen fertilizers are applied to the cereal growth as so called split application during the growing season to raise protein content of grain or to minimize nitrogen residues in the soil in those field sites having yield risks. There have not been many liquid fertilizers in the market in Finland to fulfill the need of precision farming, so the possibility to use recycled liquid fertilizers is very interesting.

This report describes the actions taken to demonstrate the use of recycled liquid fertilizers in precision combined seed drilling. Commercially available ISOBUS compatible tractor-combined seed driller system was modified to include liquid fertilizer tanks, pumps, hoses, coulters and ISOBUS controller. The field demonstrations in year 2017 included two precision combined seed-drilling events. The first one was carried out in the spring in Luke Vihti Research farm and the second one in the autumn in Somero in Olli Alikärri’s private farm in the South-West Finland. The demonstrations were disseminated also in field days and KoneAgria farm machinery fair.

Contributers: Junkkari Oy, Epec Oy, Valtra Oy, Suonentieto Oy, Happowa Oy, Lilja Farms Oy, Finnamyl Oy, Envor Group Oy, Jussi Knaapi, Olli Alikärri

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1. Introduction

Combined seed drilling is the most common seeding method for cereals in Finland. The combined seed drilling integrates seeding and fertilizing to the same work task. Both, seeds and fertilizers are placed to the soil few centimeters below the ground level, close to each other. In this way the nutrients in the fertilizer are easily and efficiently available for the growing plants. Combined seed drilling is common in the Nordic farming conditions due to a short growing period. Normally, the cereal growth is fertilized only once, at the seeding time. In some cases, so called split application of nitrogen is used to raise protein content of grain or to minimize nitrogen residues in the soil when there is a risk for the growth to fail.

To demonstrate the use of recycled fertilizers in cereal cultivation, it is important to show how recycled fertilizer can be used in combined seed drilling. Precision farming and site-specific application of nutrients require that at least each main nutrient can be applied individually to each field site (or zone). Since each fertilizer has its own fixed nutrient composition, there is a need to include several different fertilizers to the fertilizer application system. In the Nordic countries, the commonly used fertilizers are granules, and the machinery is constructed to apply them. However, it may be tricky to design several granule fertilizer tanks to these machines. So, liquid form fertilizers are a good alternative as additional nutrient source. Liquid tanks can be installed to the different distances from the application coulters in the machinery construct, since liquids are easy and accurate to dose from different distances using hydraulic pumps and hoses. There have not been many liquid fertilizers in the market in Finland to fulfill the need of precision farming, so the possibility to use recycled liquid fertilizers is very interesting.

The use of liquid fertilizers in combined seed drilling required modification in the machine construct, where liquid fertilizer tanks, pumps, hoses and controllers were added to the commercially available tractor and combined seed-driller system. The seed driller manufacturer provided also a set of coulters that were capable for liquid application.

The field demonstrations in year 2017 included two precision combined seed-drilling events. The first one was carried out in May 2017 in Luke Vihti Research farm and the second one in the autumn 2017 in Somero in Olli Alikärri’s private farm in the South-West Finland.

2. Field demonstration in the spring 2017

2.1. Demonstration site and setup

In the spring 2017 the area of the demonstration field in Luke Vihti Research farm was 25 ha. The field had elevation of 15 meters in the North-South direction, and its soil type varied from clay loam to loamy sand, and organic matter content from 3-6 % to 12-20 %. The field was divided into 16 different sub-fields (or zones) having different yield potential and requirements for nutrients (Figure 1). The sub-fields formed the application zones for the precision fertilizing.

In the first demonstration, two fertilizers were applied at seeding, one of the recycled liquid fertilizer Bio-Kali (1.3-0.25-4.5) and the other granule NPK fertilizer Yara Mila Y3 (23-3-8). Recycled ammoniumsulphate (AMS) was utilized as foliar N-fertilizer which was applied as split application to the growth during the growing season.

The seed was spring wheat, variety Wellamo, which was applied with constant application rate. There were also two additional containers and controllers for small seed application site-specifically. This opportunity was utilized to seed two different cover crops to the field; one growing deep roots to improve soil structure in wet sites of the field and one developing dense leaves in the sites prone to dry too early in the spring next year.

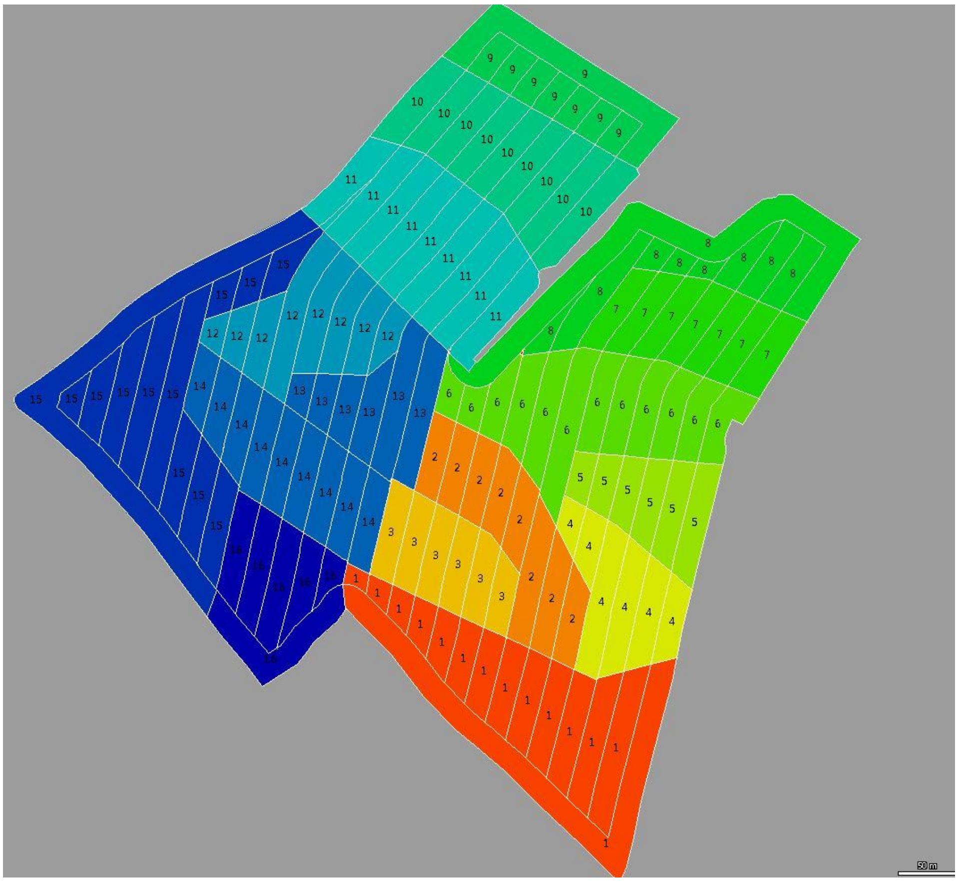

Figure 1. The sub-fields of the demonstration field in the spring 2017.

The demonstration included three different treatments; 1) 'normal' combined seed drilling of wheat with granular NPK fertilizer (Yara Mila Y3) with constant application rate, 2) combined seed drilling with constant fertilizer application, but a part of the NPK fertilizer was replaced with recycled liquid Bio-Kali, and 3) precision combined seed drilling, where fertilizers Bio-Kali and granular NPK fertilizer, as well as cover crop seeds were applied site-specifically to the sub-fields (Table 1). Each treatment consisted of 21 meters wide strips crossing the field side-by-side (Figure 2.) forming treatment zones.

Table 1. An example of two zones (sub-fields) having different target yields and dosage rates of fertilisers, leading to individual nutrient compositions per zone.

Zone	Target yield kg/ha	Y3 kg/ha	Bio-Kali l/ha	AMS l/ha	Urea N kg/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha
Hovi 2	6000	522	385	111	250	150	17	59	26
Hovi 5	4500*	261	192	222	250	101	8	30	30

* Cover crop with deep roots

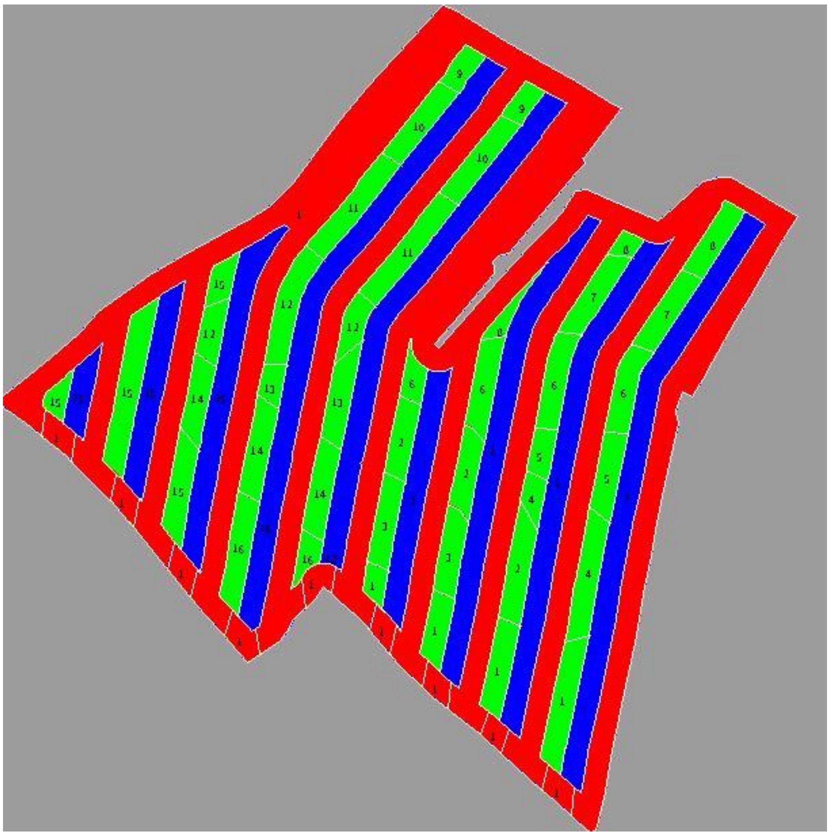

Figure 2. The treatment zones of the demonstration in the spring 2017. Red zones were treated with constant fertilizer application using Yara Mila Y3, blue zones were treated with constant fertilizer application using Bio-Kali and Yara Mila Y3, and green zones were treated site-specifically with Bio-Kali, Yara Mila Y3 and two cover crop seeds (Italian ryegrass and red clover).

2.2. Recycled fertilizers in the demonstration

In the demonstration used fertilizers were Bio-Kali, produced by Finnamyl Oy, and recycled ammoniumsulphate (AMS), produced by Envor Group Oy (Figure 3). Bio-Kali was used as a source of potassium (K) since it contained it 4,5 %. AMS was used as a source of nitrogen (N) and sulfur (S). Further description of the properties of Bio-Kali and AMS is presented in Table 2. There were two kind of Bio-Kali used in the demonstration; so called raw Bio-Kali and pooled Bio-Kali. According to the chemical analyses carried out in the demonstration, raw Bio-Kali's pH was around 5,4-5,6, potassium content 5,4-5,5 % and dry matter content 32 %. Pooled Bio-Kali's pH was 5,4-5,6, potassium content 3,2-3,4 % and dry matter content 17,4-18,5 %. Also, the measured nitrogen and phosphorous contents in the raw Bio-Kali were 1,0-1,1 % N (85-99 % soluble) and 3,7-4,0 % P, when pooled Bio-Kali contained 0,5-11[1] % N (4-74 % soluble) and 0,2 % P (90 % soluble P). Raw Bio-Kali needed more mixing before the use than the pooled one due to stratification (see Figure 4).

Table 2. Properties of Bio-Kali and recycled AMS according to the manufacturers. Figures were used in the planning of the field demonstration.

Bio-Kali by Finnamyl Oy	**Ammoniumsulphate (AMS)** by Envor Group Oy
• Concentrated potato cell sap, the side product of potato starch industry • Nutrients: – Total N 1,3 % – Soluble N 0,85 % – P 0,25 % – K 4,5 % – Ca 0,04 % – Mg 0,28 % • Dry matter 42 % • pH 4,5-5,6 • Volume weight 1 kg/dm3	• Nitrogen that is stripped from waste waters • Nutrients (35% AMS): – Total N 9% – Soluble N 8,9 % (Ammonium N) – S 10,2 % • pH 7,1 • Volume weight 1,2 kg/dm3

[1] It is obvious that one of the pooled Bio-Kali samples has contained perhaps an extraordinary nitrogen rich clod.

Figure 3. Two AMS (ammoniulsulphate) containers in the middle (light gray or clear colour) and pooled Bio-Kali containers on the right and left (light brown colour).

Figure 4. Bio-Kali containers in storage. The dark containers contain so called raw Bio-Kali (left) and the lighter colored contained so called pooled Bio-Kali (right).

2.3. Machinery and equipment

The work set for the demonstration included ISOBUS compatible tractor, combined seed drill and devices. Combined seed drill was Junkkari M300 Plus, which has four site-specifically controllable containers for inputs; 1 for cereal seed, 1 for granule fertilizer, 2 for small seed (cover crops) or granule micronutrients (Figure 5).

Figure 5. Junkkari M300 Plus combined seed drill with four site-specifically controllable containers; 1 for cereal seed, 1 for granule fertilizer, 2 for small seed or granule micronutrients.

The combined seed drill was equipped with special disc coulters that enabled additional two hoses to be mounted to them for liquid recycled fertilizers application (Figure 6). Liquid fertilizer application required nozzles to the tips of the application hoses in the coulter end. Happowa Oy's nozzles were used in the construct.

Figure 6. Additional hoses for liquid fertilizers (thin white hoses) assembled to the combined seed drill (left). Special disc coulters where liquid fertilizer hoses are attached to, enabling placement application of additional two liquid fertilisers (right).

The additional ISOBUS compatible controllers for liquid fertilizer pumps were constructed by Luke for site-specific application of liquid recycled fertilizers (Figure 7). The controllers were built using Epec 3724 Control Unit and software development tools provided by Epec Oy.

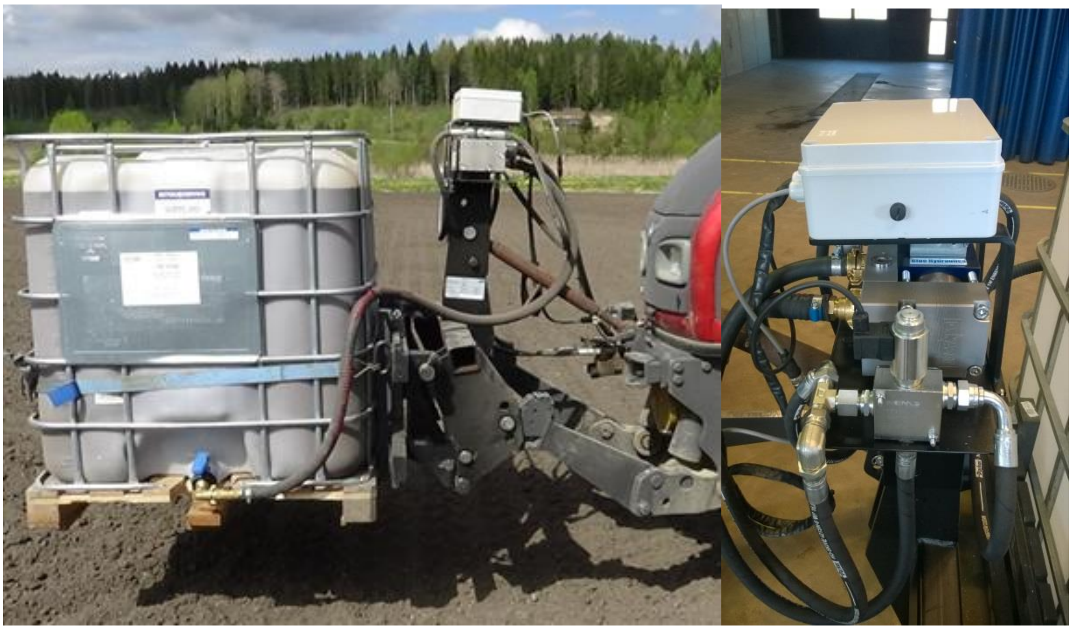

Figure 7. Bio-Kali container in the front of the tractor (left) and the ISOBUS compatible controller (grey box) and liquid fertilizer pump for Bio-Kali application.

Tractor of the work set was Valtra T163 which was equipped with ISOBUS functionalities. The user interface of the ISOBUS automation system/machine combination was Valtra's ISOBUS compatible C3000 Task controller (Figure 8).

Figure 8. ISOBUS compatible Valtra C3000 Task controller as a user interface for the machine combination.

The machine combination was put together at Luke Vihti's research premises. While building the construct and programming the liquid fertilizer controller and automated application system, simulation environment was utilized to imitate seeding and fertilization process in the field. Water was used as testing liquid in initial test, but before the actual field work the application rates were calibrated using Bio-Kali (Figure 9).

Figure 9. Programming and testing the liquid fertilizer application system at Luke Vihti.

The first field demonstration in the spring was carried out with just one liquid fertilizer, Bio-Kali, in order to gain experience how the system works in practice (Figure 10). The idea was to make observations during the first field work for further improvements of the system, and before investing to another liquid application system for AMS.

Figure 10. The machinery combination in the first demonstration: ISOBUS equipped tractor, precision combined seed driller and application system for recycled liquid fertilizer (Bio-Kali).

In the second development step the recycled liquid AMS application system was designed. A remark was made that the hydraulic components must tolerate sulphur. The AMS tank and its pump were installed on the pulling shaft of the combined seed-driller. The ISOBUS controller was extended to cover two pumps and it was re-placed to the shaft of the combined seed-driller. The extra hosing with nozzles was assembled to conduct the AMS from the tank to coulters. The AMS application system was utilized in the autumn field demonstration, and it functioned as planned without any troubles (Figure 11).

Figure 11. Recycled liquid AMS tank, pump (under the tank) and the ISOBUS controller (white box) were placed on the pulling shaft of the combined seed-driller.

2.4. Field work

2.4.1. Combined seed drilling in the spring 2017

The actual work in the field took place on the 23^{rd}-25^{th} of May 2017. The seeding/fertilizing plan was first prepared as a GML map, and was then converted to an ISOBUS task file using a converting tool developed by Luke. Other preparations were carried out normally, only exception was to mount the Bio-Kali tank to the front of the tractor and check also the Bio-Kali application and calibration settings in the task controller while doing so for the seeds and granular fertilizer (Figure 12).

Figure 12. Mounting the Bio-Kali tank to the front of the tractor and checking the automation settings in the task controller before starting the actual field work.

The work started by seeding the headland areas first, using only wheat seed and NPK fertilizer with constant application rate. Then, the work proceeded in the field according to the plan from west to east. Automation took care of applying the correct amounts of seeds and fertilizers to each location (Figure 13).

Figure 13. Precision combined seed-drilling with recycled Bio-Kali fertilizer in spring 2017 at Luke Vihti.

The constructed system itself worked surprisingly well right from the beginning when considering that it was the first field trial for the machine combination. ISOBUS as an enabling technology to integrate different machines and devices/components to function as one automation system fulfilled the expectations. As always in field trials, there were some lessons to learn, though. One observation during the work was, that the liquid application system with pumps and hoses had to be flushed with water after finishing the day’s work to prevent drying Bio-Kali liquid to clog the system. Also, any trash or e.g. plant pieces among the liquid may cause harm for the pumps and nozzles. As the machine combination was a collection of machines, devices and services from several contributors set together for the first time, some adjustments had to be made during the first operation day in the field to optimize the performance.

2.4.2. Split application of N as AMS during the growing season

Recycled AMS was planned to be applied as split application during the growing season to some sub-field areas in the demonstration field. As it can be seen from the NDVI map based on drone image taken three weeks after seeding (Figure 14), the growth was not uniformly dense in all parts of the field. So, the need to adjust the nitrogen fertilizing by split application in some parts of the field was realized, as was anticipated based on history data. Three different liquid fertilizers were used for split application: Yara Typpineste, urea and recycled AMS (35%). The fertilizers were applied through a precision sprayer (Figure 15). The used AMS liquid and water relation in the sprayers solution was

1,2:1, and the highest nitrogen doses applied at one spraying task were 20 kg N/ha. The application of AMS with the sprayer functioned well, no difference compared to Typpineste or urea applications were observed. Also, the growth seemed to tolerate AMS application well.

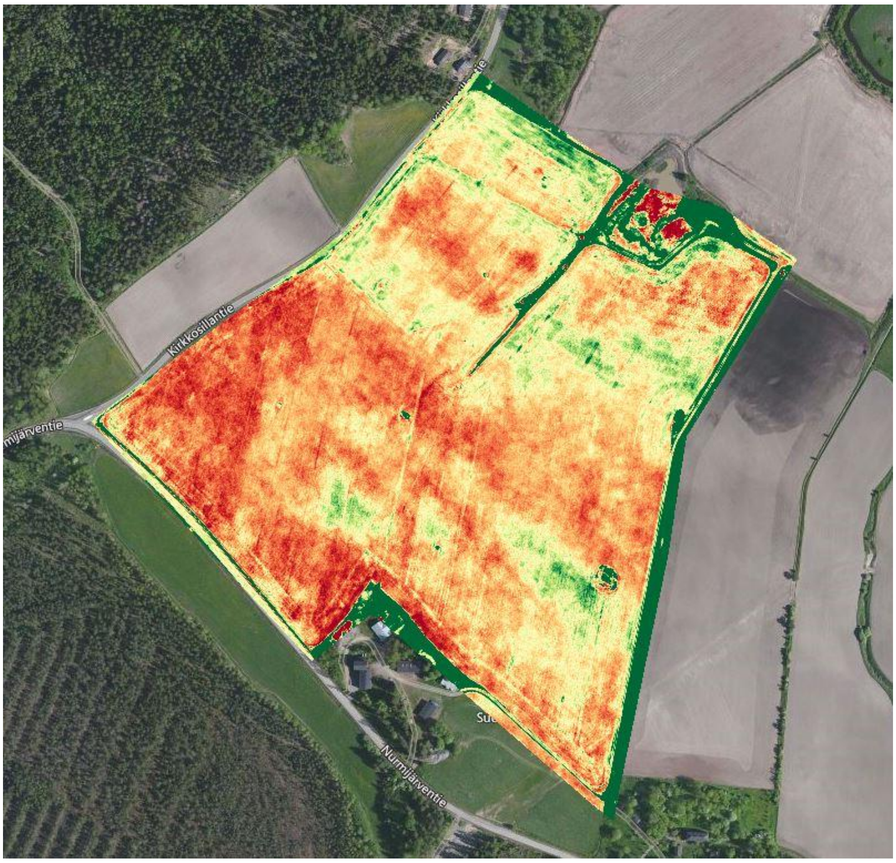

Figure 14. Classification of biomass coverage in the demonstration field in the 15th of June 2017 (20 days from seeding). (Picture: Jere Kaivosoja, Luke)

Figure 15. Precision sprayer used in the demonstration to apply recycled AMS (ammoniumsulphate) as split application of nitrogen.

3. Field demonstration in the autumn 2017

3.1. Demonstration setup

The second field demonstration was carried out in the autumn by seeding winter wheat in a private farm in Somero, the South-West Finland. The field size was 5 hectares, comprising two sub-fields (zones) (Figure 16). The soil type in the field was clay loam, but clay in the northern sub-field was heavier than in the southern sub-field. Also, the organic matter content was estimated to be higher in the southern sub-field. It was noticed from the soil analyses results that there were insufficiencies in micronutrients in the sub-fields. Thus, additional two micronutrient fertilizers were included to the demonstration, to be applied from the 'small seed' tanks of the combine seed drill. As a whole, winter wheat seeds, liquid fertilizers Bio-Kali and AMS, and three granule fertilizers one phosphorous for (Startti P) and the two for micronutrients (Yara HeVi3 and GreenCare Syksy) were applied and controlled at the same time.

The planning of the field task was made in collaboration with the farmer. The 'fertilizer cocktails' per sub-field were planned to contain the most suitable nutrient combinations (Figure 17). The planning needed several iterations, and also some compromises such as a little too high sulphur doses to the southern sub-field. Commercial software AgriSmart was used to prepare the prescription map for the task and to further convert it to an ISOBUS task, to a format that the ISOBUS compatible automation system of the machinery was able to read (Figure 16).

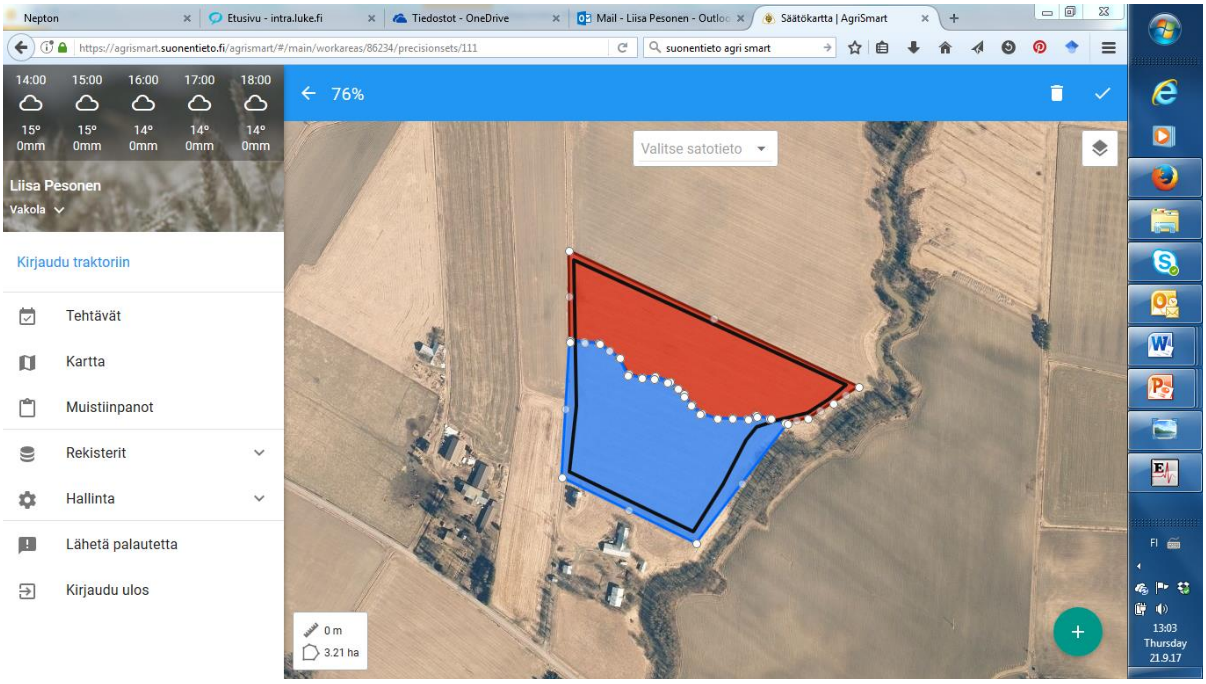

Figure 16. The demonstration field divided into two sub-fields in Somero in the autumn 2017. Picture is a screenshot from Suonentieto's AgriSmart cultivation planning application.

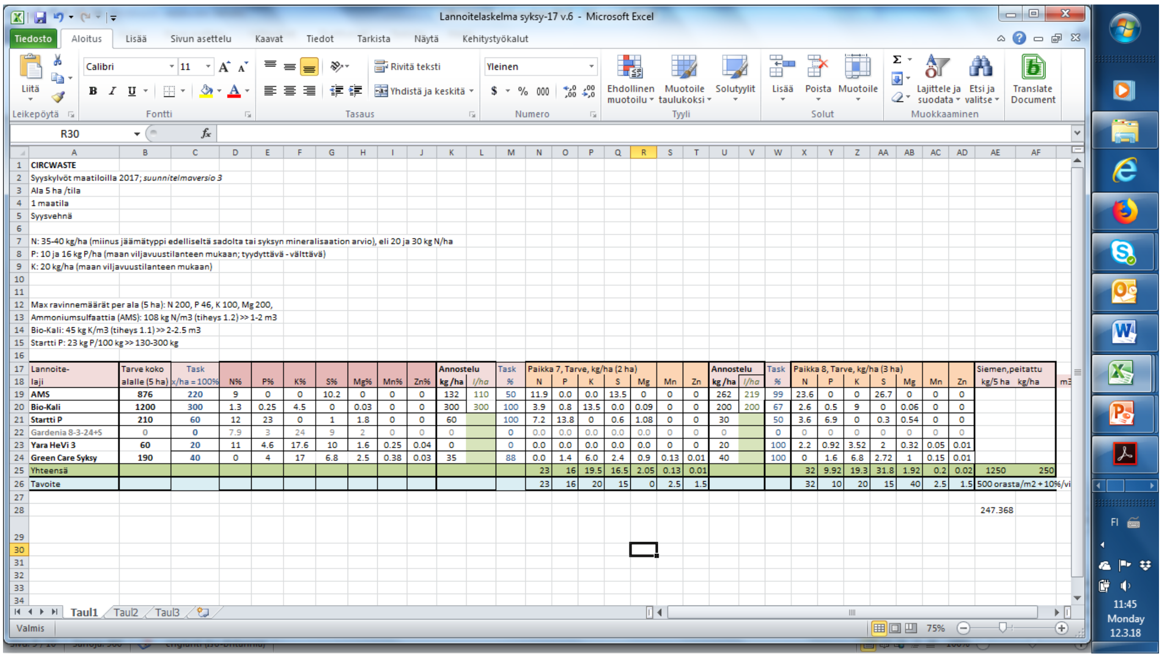

Figure 17. Iterative planning of sub-field specific 'fertilizer cocktails' for the field demonstration in the autumn 2017.

3.2. Field work

The actual field demonstration took place in Somero, Olli Alikärri's field on the 23rd and 25th of September. The field was still a little too wet for seeding on the 23rd. So, it was the day when preparations for the actual seeding were made, and the machinery with all added functionalities was introduced to the audience on the site. Only a small part of the field was seeded to demonstrate the functionalities in action. The rest of the field was seeded after two days, on the 25th of September. The machinery is shown in Figure 18.

Figure 18. The machinery combination used in the field demonstration in Somero in the autumn 2017.

Working in the field was challenging due to very moist soil conditions. However, the machinery and the built precision application mechanisms of recycled liquid fertilizers worked well. It was noticed the tractor hydraulics was used on the upper limit of its capacity (lifting of coulters and two fertilizer pumps), due which the headland turns and starting a new driving line had to take place in a lower speed than in normal seeding. The recycled liquid fertilizers were consumed the planned amounts in the demonstration, which indicates that the application functioned correctly.

4. Dissemination

There were only few guests following the field demonstrations on the site, since the time was busy time for farmers in their own fields. Thus, photos were taken and videos recorded about the seeding and fertilizing actions in the field, and presentations were prepared to be shown to farmers and other interested parties later.

So, the system was presented to the audience as power point presentations in two field day events; Västankvarn field day in Inkoo on the 6th of July and Etelä-Savo field day in Mikkeli on the 10th of August 2017, and in KoneAgria farm machinery fair on the 12th-14th of October 2017.

In KoneAgria, the video introducing the whole procedure of precision combined seed-drilling with recycled liquid fertilizers from planning to field operation was showed to the fair's audience. In addition, the filed work was demonstrated by simulating it utilizing a platform, which was borrowed from Luke's ISOBUS laboratory (Figure 19). The simulation showed on the map how machinery combination moved in the field while working, and how the controllers commanded the application pumps and actuators according to the location of the combination on the map. The audience was able to monitor the process and e.g. sub-field-specific machinery and application settings through Task Controller.

Figure 19. Presenting precision seed-drilling with recycled liquid fertilizers to KoneAgria audience using Luke's simulation environment.

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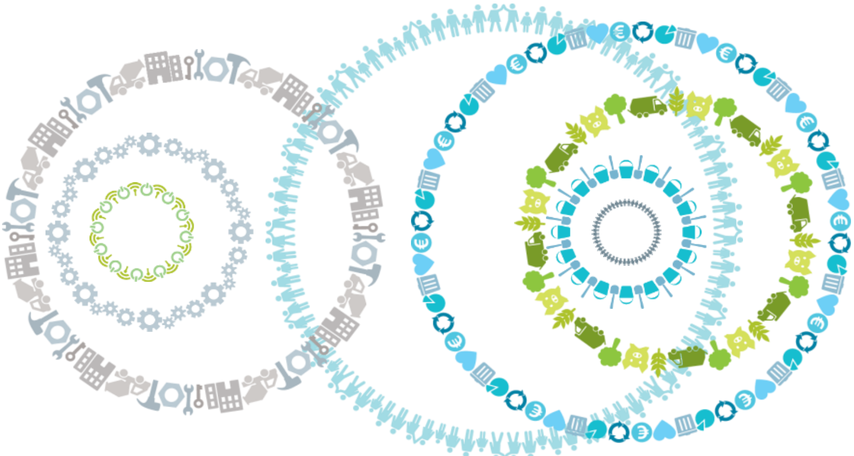

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Natural Resources Institute Finland
Latokartanonkaari 9
FI-00790 Helsinki, Finland

tel. +358 29 532 6000