European Association of Remote Sensing Companies

Sentinels Benefits Study (SeBS)

A Case Study

Farm Management Support in Denmark

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Setting the Scene

Jakob peered at the screen on his smartphone. He adjusted the controls and zoomed in on a small area in the north-eastern corner of his field known as *Vandmolle*. The mill had been closed down long-ago but the name stayed as a reminder of the technology of the past. How this contrasted with the satellite image he was looking at today.

He inspected the history and the variations map coming from his Fieldsense app. Snails, it had to be snails again. Last year they had invaded the field next door which belonged to his neighbour. This year they had decided to move south rather than north. His neighbour, Sandi, had talked about it only last week at the local co-operative meeting. She had reported that she did not have the problem this year so far. It was the case, if they had come in his direction

He looked again at the screen which showed the variations in *Vandmolle*. The images coming from the satellite Sentinel 2 showed that the outbreak was still quite small and he questioned whether it would be better to spread the pesticide pellets now or wait to see how the outbreak developed. The weather forecast was for a continued dry spell which would slow their advance, plus he could see on the field history that they had treated the same area for thistles just 2 weeks ago which meant that the snails would not have that as added fodder.

He looked back at the last 4 years history. The snails had last invaded 3 years ago. That time they had not treated with pesticide and had lost a significant area of crop as a result. But then it had been wetter and the snails more aggressive.

On balance he decided to wait a few more days and see. A new satellite image should be available in 2 days time and since the forecast was fine, cloud cover should not be a problem. Spraying the one hectare would cost him €120 in chemicals plus time which could usefully be spent elsewhere on the farm. He reflected that without the imagery he would not even know that the problem was there; Given his neighbours report and the weather conditions it could be a few weeks before he may have noticed and even then it would not be certain that he would scout that area of the farm.

If the attack continued he would lose much more. A hectare of wheat was forecast to sell at around 1000Euro and if he lost 50% of that it would greatly outweigh the cost of treatment. The Fieldsense service was extremely efficient in helping him take these decisions. He returned to the screen and moved to another field, *Lavtfelt*, were there any problems here? Would it be a good time to apply a weedkiller? His digital farm was working better than ever!

1 Introduction & Scope

Poul Jakob, a third-generation farmer in Jutland, welcomes us into his farm office; his dog had welcomed us to the farmyard a few minutes earlier. The magnificent farmhouse, over 500 years old, is situated right next to the golf course for which Poul has leased some 100ha of his land. Poul owns 550ha but leases out the golf-course and farms around 80ha for another owner so is farming 530ha. His primary crop is wheat, but he also grows barley.

Figure 1-1: On-site visit - guided by the farm-dog.

Poul is a typical user of the Fieldsense service which provides digital information to around 100 farmers in Denmark. Fieldsense, the supplier of the service, is a small Danish start-up situated in Aarhus. Unlike many other platforms which provide a full management system for record keeping, action tracking etc, Fieldsense has a really strong focus on information to aid decision making for cereal farmers. Satellite data is the key data source to provide their service.

Data coming from imagery gathered by the Sentinel 2 satellites is processed into stress maps which are overlaid onto the farm field boundaries. If the crop-stress reaches a certain level, then an alert is sent to the farmer. The alert allows the farmer to investigate further the cause of the stress and hence to react.

This provides value to farmers using the service by saving them time on inspections (crop scouting), reducing the use of chemicals and increasing yield by enabling earlier detection of a problem. It also helps farmers gain a “digital picture” of their farm hence improving overall management practices.

Benefits today are modest, but the potential is high. Fieldsense is serving around 3% of the farming land in Denmark devoted to cereals. It is also early on the technology capability curve meaning that much more significant benefits are expected in the future as improved algorithms coupled with machine learning and artificial intelligence allow higher reliability to determine the cause of the stress without farmers scouting (or visual inspections).

Benefits accrue to the farmer through reduced costs of chemicals and time saved. These benefits are very much focused on the farmer although in time some of the benefit may be shared with others in the value-chain. The value-chain may change with time as players who are suppliers to the farmers look to expand their role.

The reduced use of chemicals also has a beneficial environmental impact. Pesticides entering the food chain and drinking water is a problem for countries where farming is intensive as is the case in Denmark. There is even greater potential to reduce the environmental impact where the information service is used to manage fertilizer application – which is not the case today for Fieldsense.

In the case, we have interviewed players at the core of the value chain in order to develop a close understanding of the use of Sentinel data and the impact on farming in Denmark. Fieldsense is just one service in this market and it could be interesting in the future to contrast what is done in Denmark with other countries. The information service forms part of a market sector referred to as precision farming (or increasingly smart farming) which is dedicated more to the farmers themselves. Other information services are more suited to governments, food producers and other parts of the overall food value-chain. These should form the subject of future studies to identify the complementarity between information types.

We wish to thank the following persons for their time spent talking with us to develop the case. In particular, John Smedegaard from Fieldsense who guided us through the agriculture sector and introduced us to a number of the experts we have consulted.

- John Smedegaard, CEO & Founder of Fieldsense
- Poul Jakob, Farmer
- Jens Christian, GeoTeam A/s, consultant agronomist
- Stefan Sherer, CEO & funder of Geocledian
- Peter Ahrendt, Danish Technical Institute.
- Rita Horfarter, SEGES
- Casper Rolighed, Farmer
- Gorm Petersen, Ministry of Education and Science,
- Adam Mollerup, Head of Danish Paying Agency, Ministry of Agriculture
- Jakob Dragsbek, Danish Paying Agency
- Peter Eigaard, Danish Paying Agency
- Johan Scheller, Danish Paying Agency
- Henrik Zeltner, Ministry of Agriculture

2 Farming in Denmark

Farming is going through its own digital revolution driven by economies of scale (as farms get larger) and environmental pressures (to reduce the impact of farming on the environment). Even if Denmark is one of the world leaders in reducing the use of chemicals, further reduction can only have a beneficial impact - provided crop yields are maintained. Larger farms being run with no increase in farm employees, demand greater efficiency which digital technology can deliver. In this chapter, we shall look at the macro-environment of farming in Denmark against which the Fieldsense service is being offered.

2.1 Overview

Farmer's goals around the world are to maximise production whilst minimising cost and at the same time to abide by ever, more-strict environmental regulation. As global demand for food is skyrocketing, there is a continuous push for more efficient and cost-effective operations, further challenged by changing climatic conditions. For Denmark, which has a strong and highly efficient agriculture industry, this is actually good news leading to competitive advantage on the global market. However, it also puts constant pressure on farmers to improve; forcing them to produce more with less and in a more sustainable way. Accordingly, they seek to further mechanize production, allowing them to manage larger areas of crops and more animals, with the same numbers of farm workers.

This being said, farming is a highly complex business with many decisions to be taken each and every day. When and what to sow, when and how much growth retardant to apply, when and how much pesticide/fungicide/fertlizer should be applied? Applications of herbicides, fungicides, pesticides and most particularly fertilizers are all determined by the type of crop, the weather, the spread of pests and diseases and the local soil conditions. On top of that, the interaction between these aspects is difficult to predict.

Accordingly, farming is increasingly (becoming) a highly knowledge-intensive sector, in constant search of monitoring data 'from the field', putting them in context with other sources of impact (like meteorological, soil, ground water level data etc.) and data on human intervention such as localizing tractors and sprayers in the field or for adapting the chemicals being applied to the local conditions.

Satellite data is playing a significant role. Whilst satellite navigation satellites (GPS and Galileo) are enabling better positioning of farm machinery (tractors, sprayers etc.), earth observation satellites can monitor field data in unprecedented ways and volumes. Denmark is a pioneering nation which can leverage on a well-developed (informational) infrastructure as well as an ever-increasing pool of well-educated and technology savvy farmers.

This is where the Fieldsense service comes in, providing farmers in Denmark with up-to-date information on the state of their crops. It is primarily used to programme the spraying or distribution of chemicals and knowing the location and cause of crop-stress to optimize quantities applied which can save farmers both time and money. Assessing these benefits deriving from the availability of satellite data is the core of this case study.

2.2 The Agriculture Industry in Denmark

Agriculture remains a key sector for Denmark even if its importance as measured by its contribution to GDP has been falling steadily. In 1985, it represented 4.9% of total GDP whilst in 2015 this had fallen to 1.3%[1]. The agriculture industry in Denmark provides enough food to feed 15m people compared to the Danish population of 5.7m[2] and exports of the surplus represents 25% of the total value of Danish goods exported of which food directly makes up 17%.

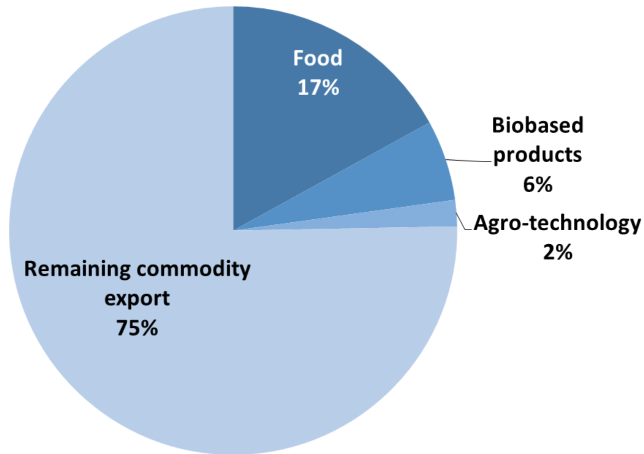

Figure 2-1: Agriculture sector contribution to exports.

The total value of exports of the food sector is DKK159b (€20.6b) in 2015. Of this, pig and dairy products make up almost 30% of the total see Figure 2-2.

The main agriculture "products" are pigs, cattle and cereals but 75% of the cereal production is used for animal feed. Whereas farms were quite integrated 30 years ago, this has changed with much more specialization in either animals or in cereals. The total area of Danish agricultural land is around 2.6 million ha which corresponds to approximately 2/3 of the Danish territory. Cereals covers around 1.5m ha or 57% of this area with grassland accounting for a further 25%; see Figure 2-3.

[1] Danish Statistical Yearbook 2017.

[2] Danish Agriculture: Facts and Figures 2017.

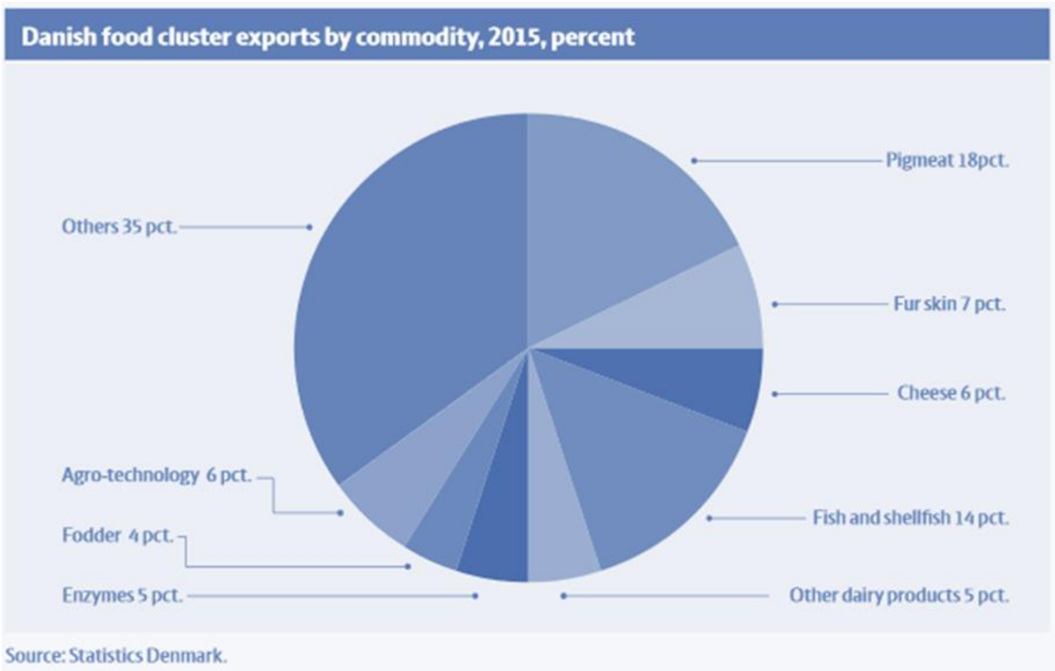

Figure 2-2: Danish food exports by Type

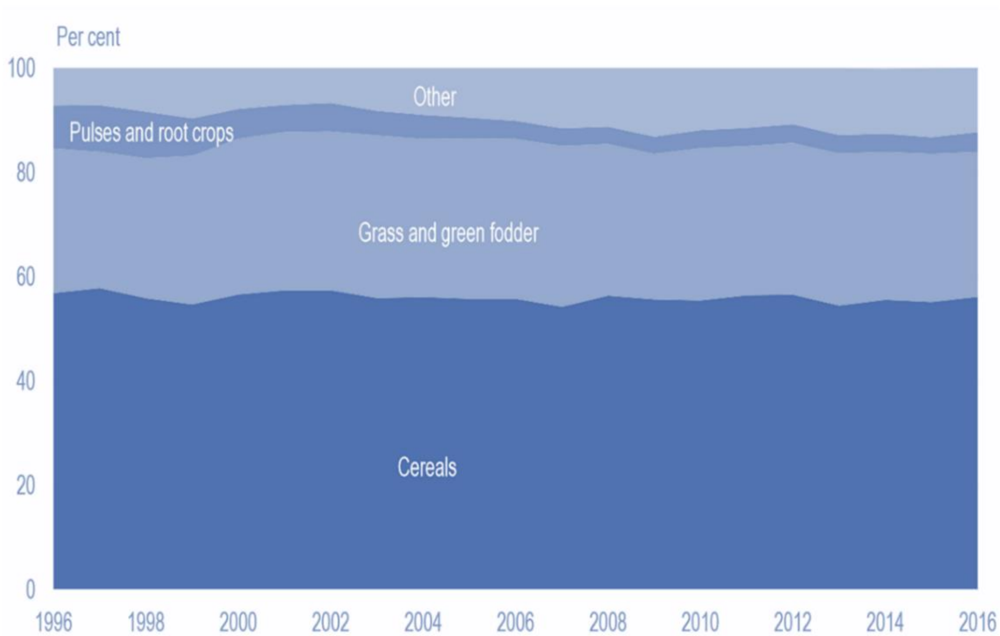

Figure 2-3: Cereals and grassland are over 80% of arable farming in Denmark.

The size of farms has been increasing steadily such that today, the average farm size is 71.9ha up from 30.7ha in 1985. As farm size has grown, so the number of farms has steadily decreased. In 1985 Denmark had around 92,000 farms. Over a period of 30 years this number has been reduced by more than 50 per cent so that Danish agriculture now consists of around 37,000 farms only. Of these 21 per cent have a size of at least 100 hectares where in 1984 only 3 per cent had this size.

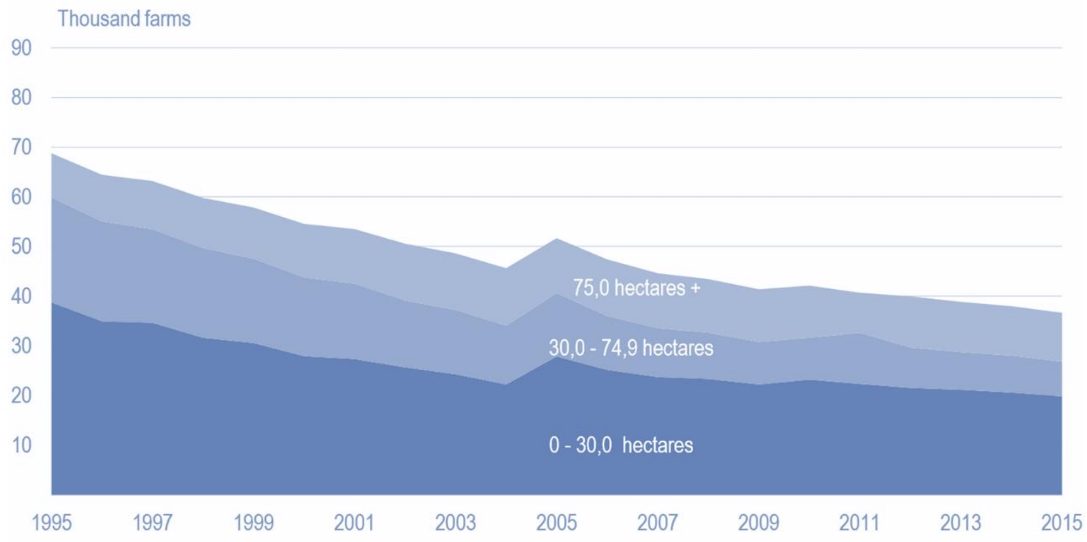

Figure 2-4: Number of farms is shrinking as they grow larger

Even if 79% of the farms are smaller than 100ha, this trend and concentration means that over 1.8m ha or 68% of the Danish farmland is part of farms of 100ha or more – see Figure 2-5. Thus 7,855 (21%) of Danish farms account for 68% of the total farmland. Fieldsense considers that its market today is for farms of 100ha or more but this could extend down to farms of 50ha in the future as the technology becomes even more performant.

	Agricultural area, 1.000 ha.				Number of holdings			
	2000	2013	2014	2015	2000	2013	2014	2015
Without cropland					800	1.668	1.531	1.868
Less than 5 ha.	4	3	1	3	946	764	483	419
5-10 ha.	60	56	56	56	8.457	7.803	7.835	7.506
10-20 ha.	164	99	100	99	11.188	6.928	6.942	6.490
20-30 ha.	161	98	93	98	6.531	3.973	3.799	3.535
30-50 ha.	353	170	166	170	9.017	4.392	4.264	4.018
50-100 ha.	763	389	375	389	10.891	5.400	5.216	4.945
100-200 ha.	715	657	657	657	5.351	4.616	4.567	4.408
More than 200 ha.	421	1.157	1.204	1.157	1.360	3.285	3.315	3.447
Total	2.647	2.628	2.652	2.628	54.541	38.829	37.952	36.636
Average size of holding, ha					48.5	67.7	69. 9	71.9
Source Statistics Denmark								

Figure 2-5: Growing size of farms in Denmark

Even if the farms are growing, the number of workers on each one is not, and mechanization has driven greater efficiency. This now becomes coupled with digital technology and smart farming has become the mantra.

2.3 Farm Management Practices and Challenges in Denmark

Farming in Denmark, as in other EU member states is mainly controlled under EU regulation. This includes many of the environmental considerations that impact strongly the way that farmers work.

> *The production of food and agricultural products is highly regulated. Most of the regulation is based on EU regulation, and often these rules are interpreted and implemented strictly in Denmark, leading to even higher standards. The areas of regulation include hygiene, animal welfare, the use of medicine, pesticides and fertilizers etc.*[3]

Hence farmers are driven by two pressures:

- To maximize production whilst minimizing costs
- To satisfy regulatory requirements including those for the environment.

Productivity is key in the Danish food and agricultural cluster. From farm to fork, all processes are optimized, and resources used efficiently. Continuous innovation in many areas puts Denmark in the lead of productivity; advances in agro-technology to improve fertilizer and chemicals use lead to greater efficiency in the fields.

The Danish food and agricultural cluster works hard to ensure that production is sustainable and has shown that economic growth is possible while at the same time reducing resource use. From 1990 to 2014, the value of agricultural production increased by 22%. In the same period, nitrogen loss was cut by 43%, the phosphorus excess went down 83% and greenhouse gas emission decreased by 16%.

Farmers are faced with many daily decisions which are complex, often without right answers (!) and which depend on the type of crop being grown. For example, the growth pattern and management of potatoes is very different to that of wheat; the former put on leaf very rapidly and hence have a steep change in vegetation index compared to wheat so that fertlizer, growth and irrigation needs are very different. Crop information services like Fieldsense need to adapt to these differences to be fully useful to the farmer and this is reflected in the evaluation made of the economic benefit.

Diseases, such as scab, stripe rust, Septoria tritici blotch, Septoria nodorum blotch and various root rots, cause some losses each year. Spraying with fungicides is common practise to control these diseases[4]; Boscalid and Triazole are the two most commonly used fungicides. Rates to apply depend

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[3] Source: Danish Agriculture and Food Council; Facts and Figures.

[4] Wheat in the World; B.C Curtis. http://www.fao.org/docrep/006/y4011e/y4011e04.htm

on many factors but early and precise application is the goal - aided by the information coming from Fieldsense.

Pests, such as birds, mites and snails all cause crop damage and should be dealt with in different ways. Treatments are sometimes liquid requiring sprays, or pellets requiring scattering. The effective area to be treated is limited by the equipment ie the length of booms dictates the minimum area to be covered whilst the separation of spray head or distributor influences the precision of application.

Planning of the planting is a key factor. Crop rotation has long been a primary question for farmers to address and is no less true today. Winter wheat can be planted after a spring crop. Harvesting takes place in July and August and new planting should take place soon afterwards. Availability of labour and maybe farm machinery will affect the dates. If the new crop is planted early, then often a growth inhibitor will be applied to ensure that the plants put on growth in their root system avoiding too much top development before the winter which is vulnerable to adverse weather. It also provokes stronger and sometimes shorter, stems hence increasing the resistance of the plants to adverse weather conditions[5].

Growth inhibitor may also increase the yield by a small amount, but the cost can be high and outweigh the gains. Hence, such decisions are well-balanced and, since precise meteorological conditions are unknown, also a gamble if not a risk. The ultimate use of the crop may also determine the practices adopted. If wheat is used for animal feed, then a high protein level is sought to attract a higher price. This requires a specific pattern of growth

And, last but not least, all of these decisions are influenced by the weather!

2.4 The Socio-environmental Context

Regulation of chemical use plays a very strong role in farming practices. A pesticide is a chemical substance used in agriculture to kill or limit organisms which are considered 'pests' because they might endanger agricultural crop output; pesticides can be subdivided into categories e.g.: fungicides (against fungi), herbicides (against plants considered to be 'weeds'), and insecticides (against insects)[6]. The use of pesticides plays an important role in agricultural production by ensuring less weed and pest damage to crops and a consistent yield. However, their use can have negative environmental impacts on water quality, terrestrial and aquatic biodiversity (persistence and toxic effects on non-target species, etc.), and pesticide residues in food may also pose a risk for human health[7].

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[5] Plant Growth Regulators for Wheat. TopCrop Manager September 2015. https://www.topcropmanager.com/cereals/plant-growth-regulators-for-wheat-17806

[6] Eurostat: http://ec.europa.eu/eurostat/statisticsexplained/index.php/Glossary:Pesticide

[7] Agri-environmental indicator - pesticide risk, Eurostat, http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_pesticide_risk

The environmental risks of pesticide use vary considerably from one pesticide to another, depending on the intrinsic characteristics of their active substances (toxicity, persistence, etc.) and use patterns (applied volumes, application period and method, crop and soil type, etc.). Measuring the real use of pesticides would allow a better estimate of risks by crop and region for different compartments of environment and for human health[7]. At the moment, harmonized statistical data on use of pesticides are not available on a European scale: under regulation (EC No 1185/2009 concerning pesticide statistics[8]), data deliveries on the agricultural use by crop each five years started in 2015, but the data remains fragmented[7]. Nevertheless, Member States annually monitor pesticide residues relative to European maximum residue limits (MRLs) and in 2014 over 97% of the around 83 000 samples analyzed fell within the legal limits [4]. Cases exceeding this, observed during the annual monitoring activities, are more often found in foods imported from outside the EU (6.5 % of the samples from third country in 2014 contained residues that exceded the permitted concentrations), but some residue problems can also be assigned to European agriculture (1.6 % of the samples in 2014)[7].

As a result of their potential toxicity, often even at very low levels, the application of pesticides in EU is strictly controlled by Community legislation since 1991 (by national legislation prior to 1991)[9]. Policy control measures in the EU are driven by the objectives of protecting human health and the environment (consumers, operator safety, protection of water quality and biodiversity)[9]. The 2009 EU Directive on the Sustainable Use of Pesticides aims to reduce impacts on human health and the environment[10]. To this end, Member States established National Action Plans including quantitative objectives, targets, measures and timetables. These plans should promote low-pesticide-input pest management and non-chemical methods, including both integrated pest management and organic farming.

The contamination of surface waters with pesticides is managed under the 2000 EU Water Framework Directive[11].

Denmark is among EU Member States which in addition to controls on impacts (e.g. the 1998 Drinking Water Directive[12]) have introduced pesticide taxes – a specific measure to restrict the use of pesticides[9]. The relative amount of pesticides sold in Denmark, Figure 2-6, is only about 0.5% of the total EU quantity (where Spain, France, and Italy together account for about 55% of EU total)

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[8] Regulation (EC) No 1185/2009 of the European Parliament and of the Council of 25 November 2009 concerning statistics on pesticides

[9] Pesticide sales statistics, Eurostat, http://ec.europa.eu/eurostat/statistics-explained/index.php/Pesticide_sales_statistics.

[10] Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides.

[11] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

[12] Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption.

and Denmark's major share of pesticides are fungicides/bactericides (25%), and herbicides/haulm destructors/moss killers (75%), according to data for the year 2014[9]. In terms of pesticide sales by country's utilized agricultural area (UAA), Denmark is among the EU countries with the lowest values (below 1 kg/ha of UAA), see Figure 2-7 which is substantially lower than 3 kg/ha of UAA (and more) of the largest consumers (Spain, France, and Italy), whereas intensive use of pesticides in Malta and Cyprus is above 9 kg/ha of UAA[9].

Whilst overall sales of pesticides have remained fairly constant at just under 400,000 tonnes per annum, the pesticide sales in Denmark decreased from 2011 to 2014[13]. A new tax on pesticides was introduced in Denmark in 2013 which has encouraged the reduction but also may have encouraged farmers to stockpile in 2012 so exaggerating the reduction.

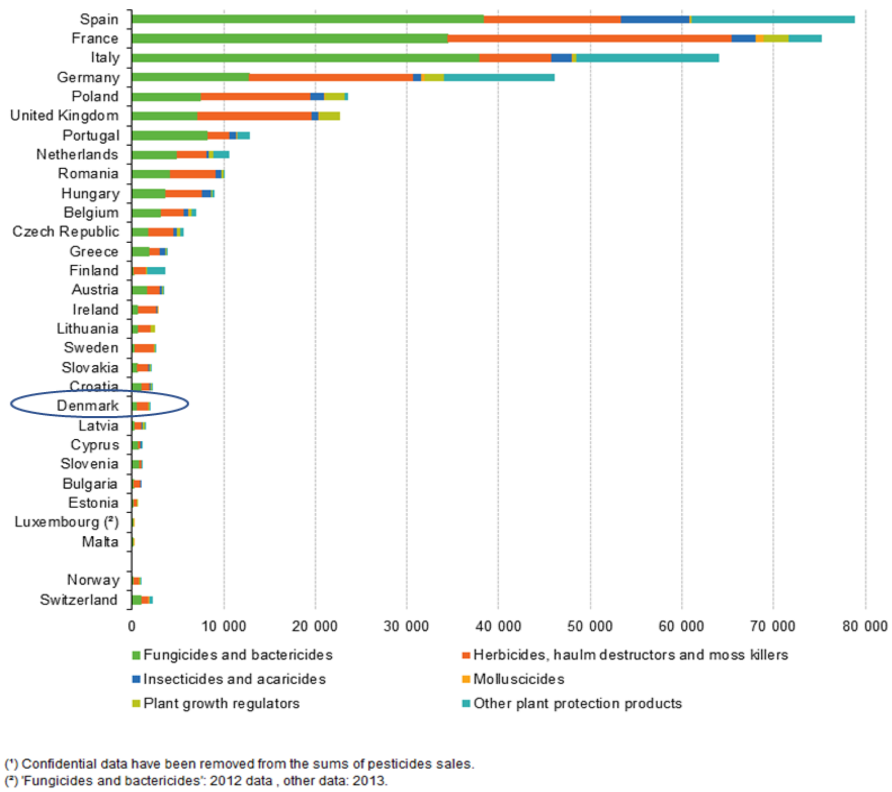
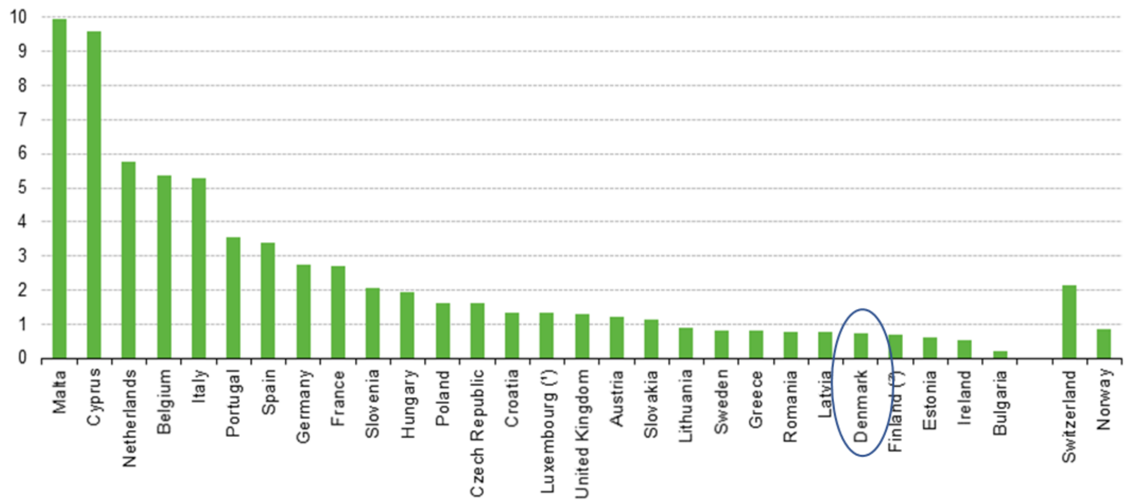


Figure 2-6: Comparison of pesticide sales in 2014, (Eurostat)

In Denmark, the most commonly utilized herbicide is glyphosate (round-up) and the mostly used fungicides are boscalid and triazole[14].

13 Agri-environmental indicator – consumption of pesticides, Eurostat, http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_consumption_of_pesticides

14 Working communication on the SeBS Project with Geoff Sawyer, SeBS Project Manager, December 2017.



Note: Confidential data have been removed from the sums of pesticides sales. Data on total UAA from 2013.
(¹) 'Fungicides and bactericides': 2012 data , other data: 2013.
(²) Urea is used only in forestry and is excluded from the total pesticide sales.

Figure 2-7: Use of pesticides (Kg per ha) in 2014, Eurostat

While the chemical safety information does not list health effects of long-term or repeated exposure to glyphosate, effects of short-term exposure include severe irritation of eyes and mild irritation of skin. Moreover, carrier solvents used in commercial formulations may change physical and toxicological properties[15]. The substance is toxic to aquatic organisms, and despite it does enter the environment under normal use, great care should be taken to avoid any additional releas[15].

Triazole is a whole family of fungicides and is not covered in this document. As it concerns boscalid, it is practically nontoxic to terrestrial animals, is moderately toxic to aquatic animals on an acute exposure basis, and according to the United States Environmental Protection Agency (US EPA) estimate, the potential ecological risks are low[16]. Boscalid is persistent and has low mobility in soil, however, it may move to surface water through spray drift and runoff of soil and suspended sediments[16]. Boscalid is classified by US EPA as suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential[16].

[15] International Program on Chemical Safety, Chemical Safety Information from Intergovernmental Organizations, http://www.inchem.org/documents/icsc/icsc/eics0160.htm

[16] Boscalid, Pesticide Fact Sheet, Office of Prevention, Pesticides and Toxic Substances, United States Environmental Protection Agency, July 2003,

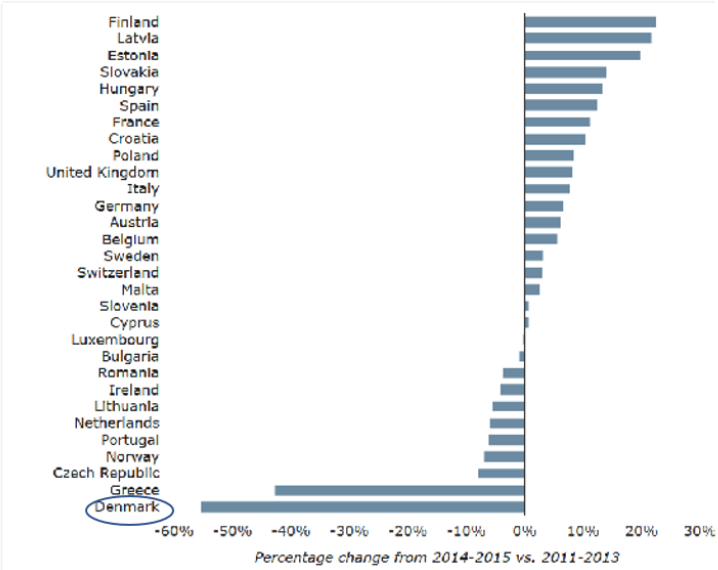


Figure 2-8: Changes in sales of pesticides in EU Member States (tonnes of active ingredients)

In summary, even though the current situation with pesticides use in Denmark is fully compliant with legislative requirements and the values of residues are well below prescribed thresholds, a further potential reduction of pesticides' use in Denmark would have a positive effect on environment and human health especially when seen from the perspective of risk avoidance. Even though this positive impact is hardly quantifiable, it should not be neglected.

2.5 Organic Foods

Since we are looking at a service which impacts on the use of pesticides and other chemicals, it is worth a quick word on the place of organic farming in Denmark. Not strictly relevant for the case since organics avoids the use of any chemicals relying on natural methods to control pests and weeds, it is still an important trend in Denmark which shows the sensitivity of the issue to the general public.

Organic does not mean no use of fertilisers, pesticides or herbicides but that only naturally occurring forms should be used. Support to early detection ie by using the Fieldsense service, is just as, if not more, important for an organic farmer as it is for non-organic ones.

In 2017, approximately 9% percent of Danish farmland is cultivated organically, and Danish consumers buy more organic food than any other Europeans. Proportionally, the organic market in Denmark is the biggest in the world, with organic food making up 9.6 percent of the total retail food market in 2016[17]. With the growing demand, Denmark imports significant quantities of organic produce and, to counter this, there is an increase of hectares being devoted to organic farming.

[17] Danish Agriculture and Food Council: http://agricultureandfood.dk/danish-agriculture-and-food/organic-farming

3 The Use of Satellite data

3.1 Summary

Fieldsense is a service supplied by start-up company to farmers and agronomists in Denmark. The service includes crop monitoring to help farmers get a clear view of their crop performance and to detect and manage crop threats and prescription maps to optimise the application of chemicals. The information is supplied via a web-platform to subscribing farmers and consultants.

The system allows farmers not only to see changes in their fields indicating the condition of the crop but also to assemble and compare with historical data. Alerts are made when certain changes are detected so that the farmer can investigate further. Machine learning is being introduced which will guide the farmer as to the problem which has been detected whether it is due to disease, pests or other causes ie drainage or pipe-bursts.

Sentinel 2 imagery is used to map the vegetation and especially how it is changing with time. Each pass over Denmark is processed to provide an easily assimilated vegetation map which lies at the heart of the system. Other data is being added coming from in-field sensors which provide the local conditions (rainfall, air and soil temperatures, winds, humidity etc).

3.2 The Service - Fieldsense

Information from Fieldsense is used to support key decision making by farmers and especially the quantity and timing for the application of chemicals. The farmer enters his fields of interest in the portal and Fieldsense offers them an activity map of each field which is a measure of the crop growth. It can provide a variable rate map[18], also called a prescription map, to control the distribution of chemicals or fertilizer by the farm machines. Today, around 50,000ha of crop land is being managed with the aid of the Fieldsense service. This is growing quite quickly as a major sales drive is engaged.

Satellites capture images of the farmers' fields several times a month. By focusing on specific wavelengths of light, FieldSense analyzes the photosynthetic performance and provides detailed insights into the cellular activity of the crops, giving a new perspective on their growth.

When crops are under stress, their growth activity decreases. FieldSense detects small variations in activity by automatically running analyses each time new imagery is available. Once an issue has been detected, subscribers receive a notification telling them exactly where action is needed.

[18] A Variable Rate Map (VRM) shows the prescribed or planned application of fertilizer or chemicals to a field based on the location in that field.

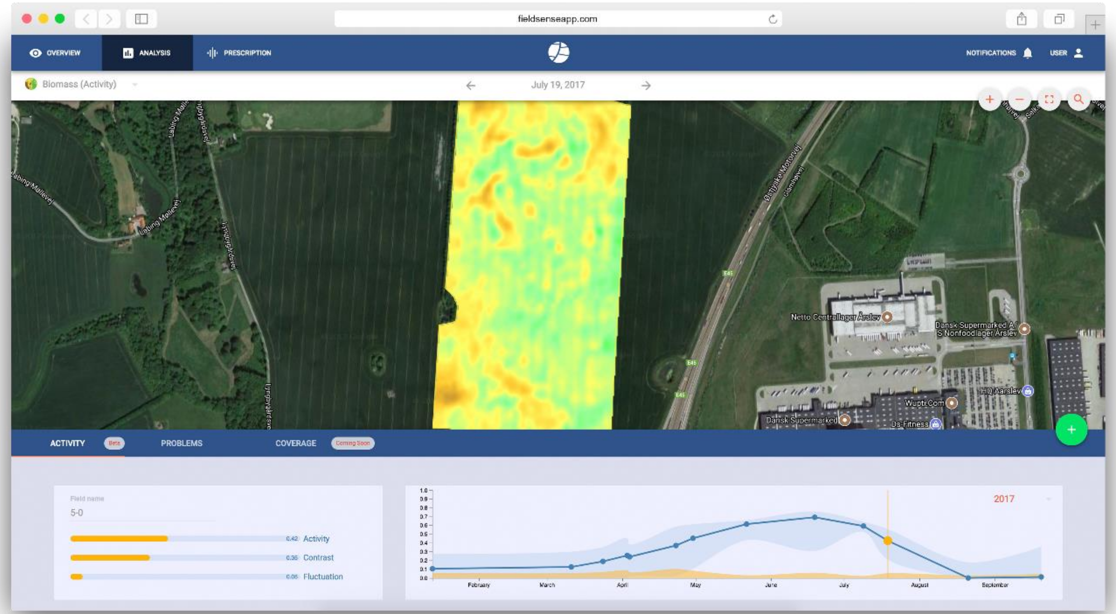


Figure 3-1: Screenshot of the Dashboard of Fieldsense service

Figure 3-1 shows the typical screen used by farmers to assess his fields. The field highlighted is showing the biomass activity where strong green indicates good vegetation growth. The imagery is taken from the selection available which can be scrolled through on the page and shows the evolving conditions for the field as shown on the occasion of each satellite overpass. A historic plot of measurements is shown at the bottom of the screen offering both mean and variation for the measured vegetation index. Three key indicators are shown in the box to the left and plots of each of these to the right. These allow a farmer to see the evolution of his crop with time.

Historic data is now available to the farmer for the last 4 years. This allows problems to be identified and forms the basis for the alert system. As the database develops, and more years' data are acquired, so the precision of the analysis will improve in the future. Ultimately, the expectation is that a highly reliable indicator can be given to identify the cause of the crop stress.

Fieldsense now provides an alert to the farmer when a variation is considered to present an issue. The history of the activity is used to characterize the issue and to recommend a remedy to the farmer. Issues can be due to pest attack ie snails, weed growth ie thistles, disease ie leaf blight or may be due to watering (over or under watering) or simply meteorological ie storm damage.

2016

2015

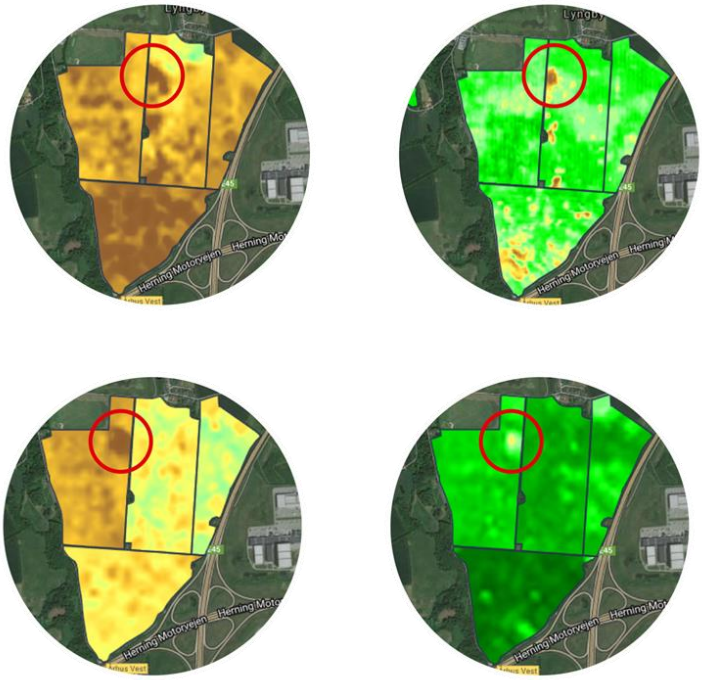


Figure 3-2: Example of crop stress (snail attack) over 2 years

The example in Figure 3-2 shows two similar areas of crop stress caused by a snail attack. The snails live in the hedges and in 2015 emerged on one side into the crop and in 2016 they emerged on the other side. Such a picture is characteristic of snails and is easily recognizable by an expert. The goal of Fieldsense is that this becomes recognizable automatically such that there is a high degree of confidence and treatment can be planned without even a field visit. One this goal has been achieved for most of the possible causes of stress, then the full potential of Fieldsense will be realized.

Early detection of an issue can avoid bigger problems later. Without Fieldsense, the farmer would be relying on scouting - where a farmer is walking the fields to assess crop condition - to detect the problem. However, only a small fraction of the area of large farms can be monitored in this way. A farmer such as Poul is spending around 3 hours per week on crop scouting throughout the growing season.

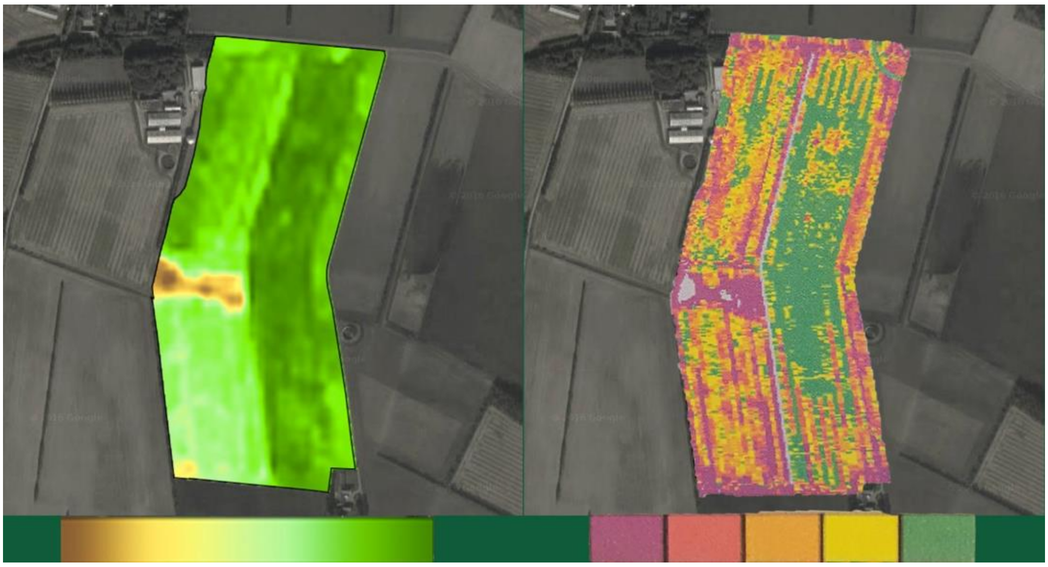


Figure 3-3: Contemporary biomass activity and stress map of the same field.

Figure 3-3 shows the same field in biomass extent and the variations (right side). It illustrates two key issues. There is a marked divide down the middle of the field. It turned out that this was due to the farmer having stopped distributing fertilizer because it had started to rain. The right-hand side was treated earlier than the left side. The impact is more vegetation on the right side than on the left side. With the evidence presented by the imagery, the farmer can better identify and plan the next actions to take.

The second effect in the field is the brown area showing up in the biomass extent - also visible in the variations map. In this case, a drainage pipe was blocked and the area was wetter than the rest of the field. Again, identification through the Fieldsense service can allow earlier detection and treatment than would otherwise be the case.

3.3 The Role of the Satellite Data

One of the primary features of FieldSense is its ability to show multiple types of Earth observations. These observations are usually represented as a “map type” or “map layer”. There are three different map types in FieldSense; (1) biomass activity, (2) variations, and (3) visible light (regular RGB photos).

Optical imagery taken by Sentinel 2 is used to generate maps which indicate the state of the vegetation in the image. Clearly, Fieldsense will not disclose the exact algorithm which they are using but it is based upon the very familiar NDVI[19]; which we can describe for those who are not familiar with the term or technique.

[19] NDVI = Normalised Difference Vegetation Index.

NDVI is a classical technique which allows the amount of vegetation to be measured. It is a simple but powerful algorithm using the properties of the green leaves to absorb or reflect light. The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 µm) for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 µm). The more leaves a plant has, the more these wavelengths of light are affected, respectively.

Sentinel 2 measures the energy reflected in visible and infra-red bands from which the NDVI can be calculated for each pixel. A description of NDVI and the scene classification of which it is part see the Sentinel 2 user guide[20] and for a more detailed guide to vegetation indices[21].

A key process to be applied before the NDVI can be calculated is to filter out all areas covered by cloud. A cloud mask is produced such that these and the areas which are shadowed by the cloud can be identified. Clearly, clouds can be a problem in Europe and over Denmark which has the impact of reducing the effective coverage which is possible.

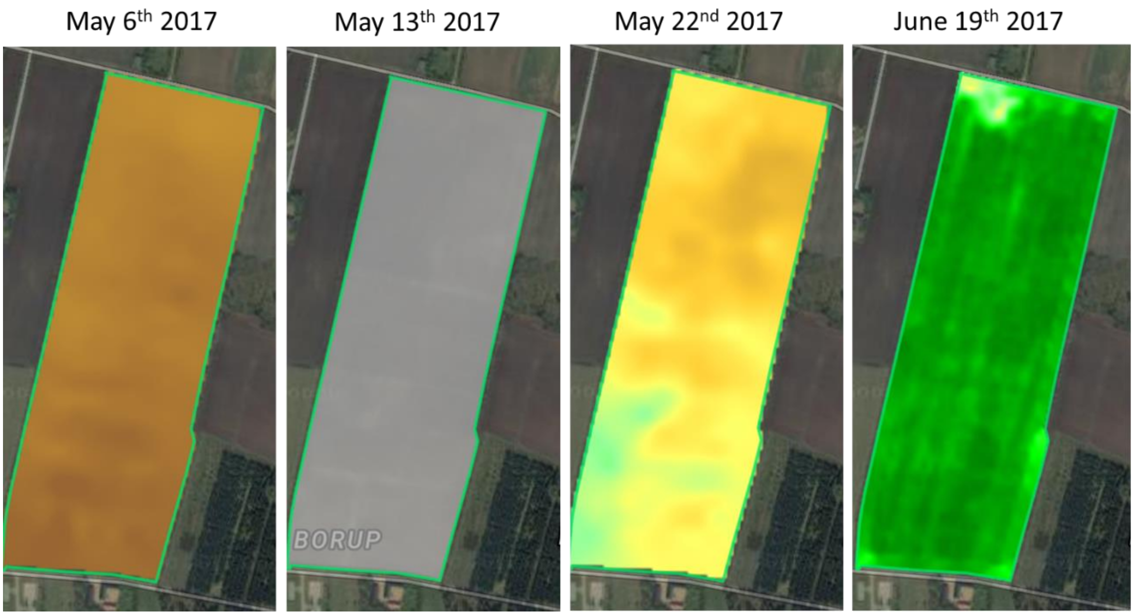


Figure 3-4: Biomass Activity Evolution in satellite imagery

Figure 3-4 shows the evolution over 6 weeks of the biomass in one field. The image of 13th May was cloud covered and masked out. The other images show the progressive crop growth during the fastest time of the growing season.

Other factors which must be taken into account are the field boundaries since the farmers are interested in the crop stress in their own fields. Some information services rely on cadastral driven

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[20] Sentinel 2, level 2A Algorithm Overview.

[21] Twenty Five Years of Remote Sensing in Precision Agriculture: Key Advances and Remaining Knowledge Gaps. David Mulla, University of Minnesota. April 2013

boundaries but these are not always available or are costly and field edges can be discriminated in the images. Fieldsense gives farmers the capability to correct their field boundaries manually in their account.

Once the NDVI has been calculated it shows a measure of the leaf volume in each pixel. In ideal circumstances this will then be homogeneous across a crop in a field. The variations map enhances the variations in biomass activity on a field specific scale. This has the benefit of making similar-looking green shades of the biomass activity map more distinct. However, since this map is field specific, it is not possible to compare fields to one another and it is used to indicate where there is stress on a crop within a field.

The history of the in-field variation and knowledge of the field itself can be used over time to build up a stronger picture. Using artificial intelligence techniques Fieldsense will provide increasingly more sophisticated products in the future. The goal will be to link all the processes together in an automatic processing chain. Hence a problem is detected by Fieldsense which alerts the farmer and provides the variable rate map directly for uploading to the relevant farm machinery. The farmer only has to validate the process.

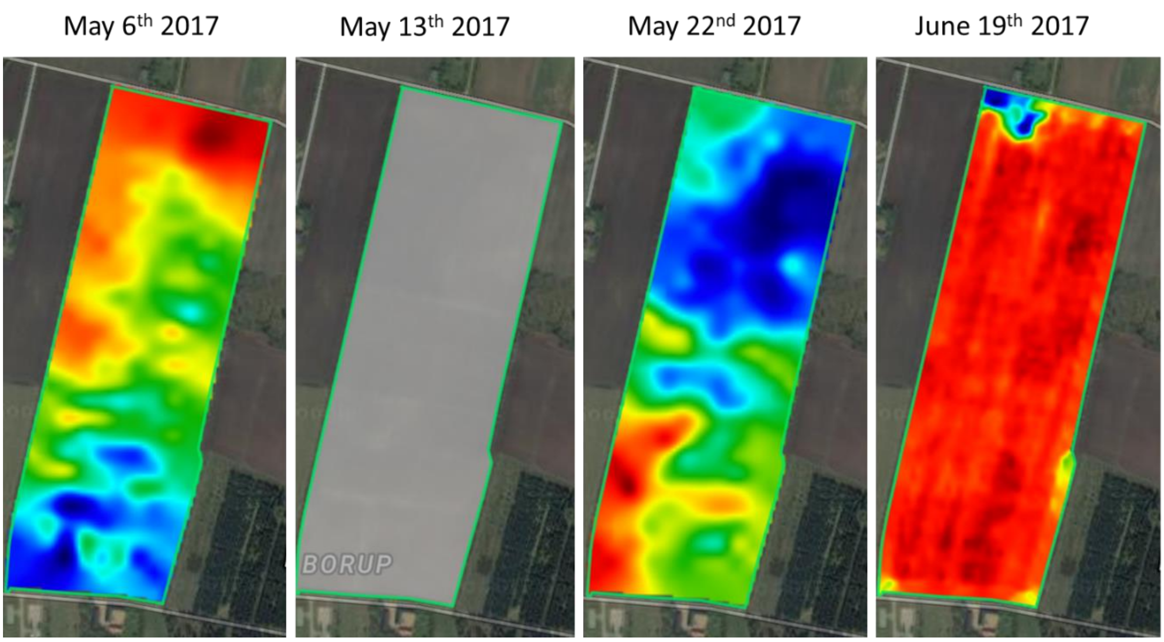

Figure 3-5: "Variations" or Stress Map of the same field over time.

In Figure 3-5 is shown the stress map (called variations in the Fieldsense terminal) for the same field and same period as for Figure 3-4. The area to the top left in the map of 19th June may be something to investigate. A decision could depend on historic information and knowledge of the farm conditions ie wet corner of the field, specific growing conditions etc.

4 The Value Chain

Having covered the service and the macro environment it is embedded in, we will now look into its impact on the value chain it functions in: what parties are in there and what subsequent effects does the availability of Fieldsense cause in their interactions? In this chapter we look at the role each is playing in the value-chain whilst in the next chapter we shall look at the value being created.

4.1 Description of the Value-chain

Central to our methodology – in this case study as well as past and future ones - is the value-chain stemming from the use of the satellite data. It is the basis for the analysis of the value generated by the availability of the Sentinel data. The value chain features a set of 'tiers' representing subsequent users of satellite-based services (and their subsequent users and so on). Each tier connects to a different form of information (packaged in the form of a service), which can still be related to the Sentinel data[22].

The value-chain associated with this case is shown in Figure 4-1. It starts with tier 1 (the service supplier, which supplies the farmers and their consultants - the agronomists. Farmers produce is sold to tier 3 (food producers as well as other farmers for livestock feed who then, via the distributors, like supermarkets, sell their output to tier 5 (the end beneficiaries, being the citizens and consumers in Denmark and beyond since large parts of the production are sold as exports.

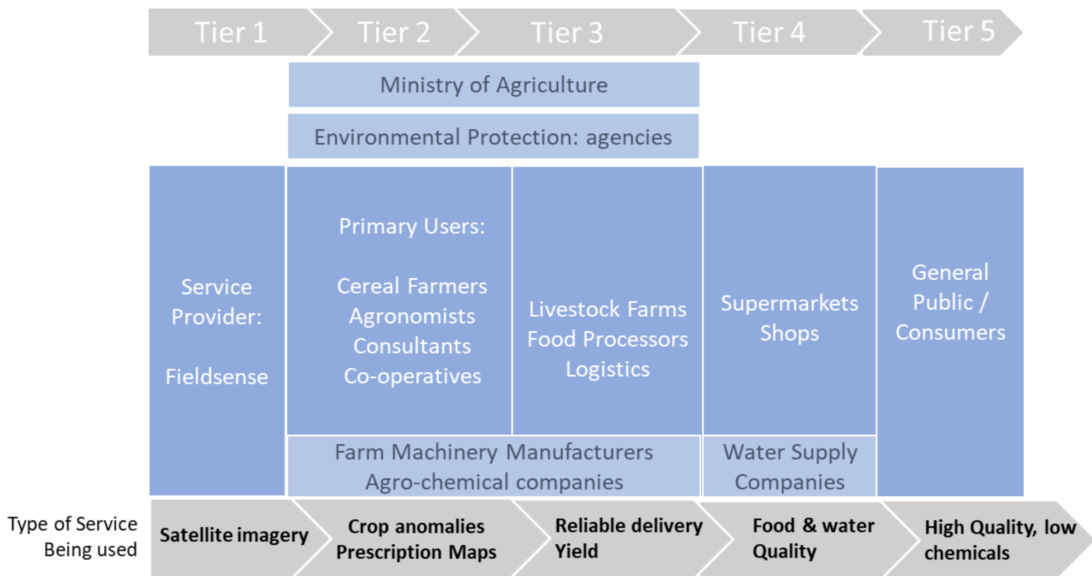

Figure 4-1: Farming in Denmark Value Chain.

[22] Annex 2 contains further details on the concept of the value chain and our methodology.

4.2 Value-Chain Actors & Other Stakeholders

4.2.1 Service Provider (Tier 1)

Fieldsense[23] is a young, start-up company formed in 2015 by a group of 6 computer scientists, farmers and business developers who have the objective to develop easy-to-use decision-support solutions for the agricultural industry. The decision to launch the company was taken following the success of the founders at the Copernicus Masters[24] competition in 2014. From the 6 initial founders, the company has grown in its 2 years of existence to employ 12 people today.

Fieldsense analyse Sentinel 2 data to generate information products so providing digital services for farmers through web access and IoS and Android mobile platforms. Formally, called CEPTU, Fieldsense also gathers, integrates and analyses data from other sources. A small, remote, in-situ measurement tool has been developed to improve the service offered. This contains several sensors to provide key, localised conditions. It is also being sold as a second line of business.

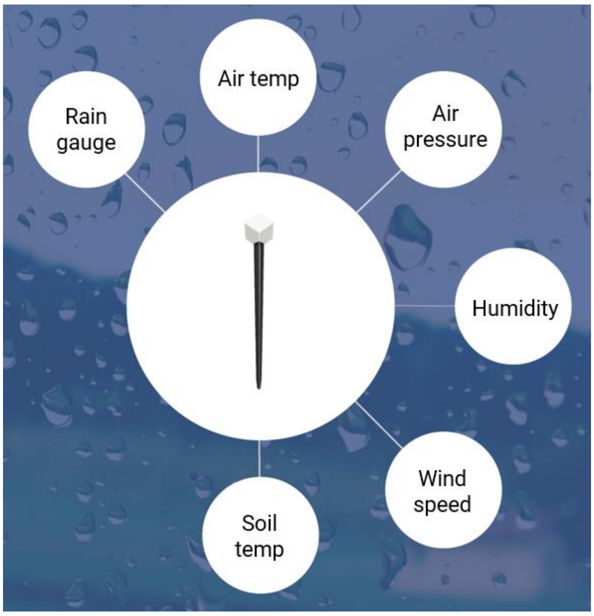

Figure 4-2: In-situ measurement tool from Fieldsense

This is not the only way in which Fieldsense has adapted its business model as it has developed; even within the timeframe of this case. When our analysis started, the satellite image maps were being provided by Geocledian; a micro company in Germany processing satellite data. Interestingly, Fieldsense found it more advantageous to develop its own processing capability, integrating the image processing and map generation into their own processing chain. Now, they even start to develop business by providing this service to others. This backward integration is not only a measure of the skill of the company but also of the dynamism of the market it is operating in.

In the meantime, Geocledian are also now starting to offer an agriculture service of their own – Ag!Knowledge. As a start-up specialized in designing and providing geospatial cloud services, Geocledian's goal is "*to provide high quality, easy-to-use and low-cost information products based*

23 Fieldsense: https://site.fieldsenseapp.com/

24 Copernicus Masters is an international competition which awards prizes to innovative solutions for business and society based on Earth observation data.

on satellite data and other sources." As a team of remote sensing experts with a strong research background they seek other ways to exploit their skills such as the new agriculture service.

Both Fieldsense and Geocledian are expanding as a result of being able to use the free and open Sentinel data.

4.2.2 Farmers, Agronomists, Consultants (Tier 2)

a) Farmers

The primary users or beneficiaries of the Fieldsense service are the farmers who use it directly to inform and help them with farm management. They also share it with their advisors: the agronomists or consultants. However, other players in the value chain can also benefit from the availability of farm information and this is a sector which is rapidly evolving.

It is important to realize that the increasing availability of data, including (services based on) satellite data, impact heavily on the traditional role of the farmer. Having much more land and crop to look after, the modern farmer has turned into a tech-savvy manager with a small staff which work in the fields. Whilst the farmer will decide what action to take and when, he will mostly be in his office directing the operations. The trend towards larger farms which we discussed in section 2, is both a driver of and a consequence of increasing digitalisation and connectivity.

This means that the farmer is not directly viewing his fields and crops on a daily basis; even the workers will only visit a field when there is a task to be performed. The farm workers are not skilled to recognise disease or plant problems which is why a system like Fieldsense can deliver so much value. Satellites can provide imagery on a sufficiently regular basis that anomalies can be detected, without having to be in the field. And this is only the beginning; in the near future tractors are expected to drive themselves, relying on in-situ sensors on-board, providing additional data so complementing that coming from the satellites.

b) Agronomists/Consultants

As even the farmer is not expert in all aspects of crop management, when needed, they turn to an agronomist; sometimes referred to as a consultant. Their advice may range from technical assistance regarding the farm machinery to use and especially new technologies being incorporated into it such as variable rate spraying, digital rate maps, positioning and automatic controls, or it may concern the type of crop to plant and when to do so, the incidence and treatment of disease or pests on crops.

Two categories of agronomist exist in Denmark; private and independent ones such as Jens Christian who works for GeoTeam As, and those (the majority) working for the DLBR[25]. DLBR is a co-operative structure consisting of 31 consulting companies distributed throughout the country. The

[25] DLBR is the Danish Agriculture Advisory Service. https://www.dlbr.dk/

DLBR companies are owned by Danish farmers, which also make up the majority of customers. The companies are locally-based and provide expert advice to the farmers.

Each farmer has the right to call upon 3 hours of agronomist expertise from the DLBR each year as benefit for part of their annual fees (subscriptions). Farmers also meet regularly (weekly during the height of the growing season) in local groups to exchange on their experiences. This allows news on diseases or pest outbreaks to be conveyed and shared quickly as well as the efficacy of different treatments.

c) Co-operatives

Many of the organisations in Denmark concerned with agriculture and food products are co-operatives - a well-recognized legal structure. It makes for a more dynamic and integrated sector and is surely one reason for Danish competitive advantage in the sector. Three co-operatives are particularly relevant to the Fieldsense case: SEGES which provides an advisory service to farmers and is often referred to as a farmers' union, Danish Agro and DLG. As such, co-operatives are a strong feature in the Danish agriculture sector and, as reported by the Danish Agriculture and Food Council:

> *The major food enterprises in Denmark are farmer owned co-operatives. With today's professional daily management, they are among the world's largest exporters of safe, high-quality food and agricultural products. Profits are returned to the own-ers – the farmers. It is voluntary to join a co-operative, and the companies are controlled by the members. The basic principle is "one farmer - one vote", irrespective of farm size and production volume*[26]*.*

The Danish Agriculture & Food Council (DAFC) represents the farming and food industries of Denmark including companies, trade and farmers' associations. Over 90% of Danish farmers are members of the DAFC. SEGES offers services to farmers and the local advisory service (DLBR) such as research in farming practices, advice on farm management, deliver IT solutions on farm management and host the huge databases with farm data (Registration of animals, crops, fertilizer and pesticide use). It has the goal to ensure[27] that Danish farmers have access to and can deploy the latest technology and knowledge as quickly and as efficiently as possible. SEGES is also the primary body to advise government policy on farmers views, it offers services to farmers such as advice on farm management and it sponsors research into farming practices.

Since 2016 SEGES and the Danish Ministry for Agriculture has offered the use of CropSat for free to all farmers (in 2017 there was 7.300 users and in 2018 it is 7.500 users). With CropSat farmers can create application maps (variable rate maps) for fertilizer and pesticide use on basis of biomass measured form Sentinel-2. To push the interest for CropSat and precision farming, SEGES also send out to all farmers application maps with a suggestion for distribution of the first nitrogen in oilseed

[26] Danish Agriculture: Facts and Figures. Danish Agriculture and Food Council.

[27] Danish Agriculture and Food Council http://agricultureandfood.dk/

rape (7.500 fields in 2017 and 12.500 fields in 2018). The maps can be altered according to local knowledge in CropSat or the complementary SEGES program CropManager. In the free part of CropManager farmers can also follow the growth rhythm of their crops and benchmark the (biomass) between fields and up against the average of their neighbours fields with similar crops. CropManager and CropSAT both use data from Sentinel-2 in their application with data coming from Sinergise (an EO service provider based in Slovenia).

DLG and Danish Agro are 2 large, farmer-owned co-operatives established to provide bulk buying of products and services. Both have developed strongly as commercial businesses with operations and sales outside of Denmark in addition to their core goal to supply Danish farmers.

Both companies are seeking to extend their role as suppliers and it would be consistent with business models in other situations that they start to first use and maybe to supply the service to their clients. DLG and Danish Agro both compete and co-operate; specializing in different aspects of the farm supply business.

A consequence of this macro structure in Denmark and indeed elsewhere in the farming industry, is that new and improved techniques and technologies can spread quickly throughout the sector. All three of the co-operatives have a wide reach into the Danish farming sector with SEGES having almost all Danish farmers as partners. As Fieldsense develops its capability, take up in its core market should be strong.

a) Researchers

Aarhus where Fieldsense is located is an important centre for agriculture research and innovation. Agrotech which is a unit of the Danish Technological Institute provides research services to all players in the value chain. This includes the timing and effectiveness of different chemicals to be used, impacts of crop rotations and advice on the use of growth retardants. Much of the research is undertaken on behalf of the farmers' union SEGES.

4.2.3 Farm Machinery, Agro-chemical businesses (Tier 2 & 3)

Information on crops is also of great importance for the suppliers of the chemicals being used and the sellers of farm machinery. Today, Fieldsense is not yet being used by either farm machinery or chemical suppliers. However, as we close the case, we understand that some discussions are taking place.

In some other countries these two sectors supplying the farmers have become actively involved in acquiring and selling data linked to the farms and their crops. For both sectors it is about understanding their market. Some also provide the information gathered back to the farmer as a tool to help keep their business. This is a different business model but shows the potential for the large agro-businesses to become involved in the value chain.

The interest of both the agro-business and the suppliers of farm machinery is somewhat similar. Both see the attraction to gather the data and both see business opportunities arising from the data. In this sense there is a 3-way tussle going on between them and the farmers over who owns the data being gathered about the fields and crops; the farmer as it is his land, the agro-chemicals because they are enabling the crops to be grown and the farm machinery suppliers which incorporate sensors and controls on the machines ie they activate the variable rate maps.

Other EO suppliers[28,29] are working with either or both of these players in order to support their activities with similar products as those provided by Fieldsense. There are business models where this information is provided free of charge to the farmer in order to enable the business models of the other players.

In this case in Denmark, the link to the crops and fields is directly with Fieldsense and the other value-chain players are not (yet) directly involved. Hence today, the benefits are being generated by the farmers and are all remaining with the farmers. This can be expected to change as the different players adapt and new businesses and business models emerge.

4.2.4 Livestock farms, Food Processors (tier 3)

Almost all of the cereal crops in Denmark are used for animal feed and are supplied to livestock farms. The aforementioned co-operatives Danish Agro and DLG are intermediaries buying from the cereal farms and bulk selling to livestock farmers.

Denmark is home to some of the world's leading food processing companies many with an international footprint. Leading dairy food producers are Arla and Thise. The former has a strong presence in Scandinavia. Danish Crown which is Europe's largest meat processing company, Tican, a leading pork processing company, DAT-Schaub, and DAKA (part of the German Saria group).

As leading customers, this tier benefits from the Fieldsense service through improved quality of the produce and more stable production. Nevertheless, the impact on this tier is rather small since their supply is driven by factors outside the control of Fieldsense.

Being a highly competitive and fairly transparent bulk market, the reduction in costs for the farmers may eventually feed through into lower costs along the value chain. This being said, in Denmark, many of the food processors are co-operatives and some are actually owned by the farmers themselves. Hence there will be less business pressures to share the benefit being generated by reduced farm costs. Nevertheless, competition with other commercial businesses and especially in the supermarkets can be expected to release some value along the value chain.

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[28] Spatial Business Integration is a German company offering a crop risk information service to farmers free of charge. SBI uses the information gathered from the farmers to sell services to agro-chemical and farm machinery businesses.

[29] Baywa is a German commodities company which has recently acquired a majority holding in Vista an EO services provider. Baywa sees an opportunity to develop a new business providing agriculture information to farmers and traders.

How much leverage this will have is very difficult to say. The average potential savings represent only a small fraction of the total sector sales (around 0.1%) and hence will not have a major impact on the market.

4.2.5 Supermarkets (tier 4)

Supermarkets are the power buyers in the value chain and in consequence have a strong role to play in forcing farmers to become more efficient to keep the food cost down. Supermarkets are both drivers and followers of public opinion and the trend towards lower use of chemicals is surely a result of customers opinion. Denmark has a large market for organic food.

As for tier 3, eventually, some of the savings from the farm production resulting from Fieldsense use could pass down the value-chain to the supermarkets but there would appear to be few factors which would create leverage and hence generate further benefits.

4.2.6 Water Supply Companies (tier 4)

Lower levels of chemicals in the water catchment area leads to reduced cost of water treatment. This would have an impact through the value-chain as clean water is a necessity for high quality food production and is held in high regard by the Danish population.

Water suppliers are unique to and controlled by the local authority where they operate. Whilst other European countries obtain much of their drinking water from the surfaces of lakes and rivers, in Denmark there are such large quantities of clean water underground that it covers the entire country's water needs including domestic consumption and use, agriculture and industry[30]. In this case, few chemicals reach the underground reservoirs and further water treatment is unusual.

4.2.7 General Public / Consumers (tier 5)

Ultimately, the output of the food processors, distributed by supermarkets and other outlets, end up on the plates of consumers, either in Denmark or abroad. Obviously, the effects of the availability of the Sentinel data will have been watered down significantly, also since, at present, the benefits generated in previous tiers are not likely to have been passed on. Obviously, this may change over time as the technology reaches a higher level of distribution, allowing market forces to their work, leading to lower consumer prices in the end.

The quality of the food for consumers is an important factor and the Danish public, with a strong market for organic foods, would appear to be no exception. The strongest benefit to consumers can come through reduced chemical use and this could even be used as a marketing message by producers.

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[30] Denmark Official website. http://denmark.dk/en/green-living/sustainable-projects/a-land-enriched-by-water

4.2.8 Other Stakeholders

Danish Ministry of Environment and Food

The Ministry of the Environment and Food is the home to both the Agriculture Agency and the Environmental Agency. The Ministry of Environment and Food of Denmark is responsible for administrative and research tasks in the areas of environmental protection, farming and food production. The Ministry consists of four agencies and local Centres across the country. The Ministry of Environment and Food was created in the summer of 2015 as a result of the fusion between The Ministry of the Environment and The Ministry of Food, Agriculture and Fisheries of Denmark.

Danish Agriculture Agency

The Ministry of Environment and Food is responsible for the legislation linked to the EU Common Agriculture Policy and the Agriculture Agency is responsible for its execution. Included within the organization of this agency is the Paying Agency (PA). The Paying Agencies, as they are known, exist in each EU Member State to implement this policy. The PA pays the farmers based on EU defined parameters and effects controls to ensure good behavior. Satellite data is widely used but this is generally high-resolution commercial data and not that coming from the Sentinels.

Today, neither Sentinel data nor the Fieldsense service are being used in connection with the CAP but in Denmark, as with many of the Paying Agencies around Europe, trials are running as research programmes to understand how they may help in the future.

As Copernicus has been developed as a European asset, it makes sense that it should be used as far as possible in all areas of EU policy planning and implementation. With respect to agriculture, the recent review of the CAP in preparation for a new multi-annual financial framework (MFF)[31], has been considering how Copernicus services can be used to improve monitoring and controls. Given the potential role, it makes sense that any changes to the CAP should be designed in the full knowledge that Copernicus exists as a control and validation instrument.

Hence the interest of the PA's to understand in what ways Copernicus can help them in their current and future tasks. In Denmark, research is going-on (and a tender for this has been released in 2017) to understand how the monitoring of crop succession (or rotation) can be improved using satellite services. Whilst farmers are free to invoke a rotation, the Ministry may make "recommendations" which will reduce overall chemical use.

The approach appears to be similar to the situation in Sweden[32], where "freedom with responsibility" lies at the heart of the forest management policy. In Denmark, farmers are free to follow the crop rotation which they plan for but if the PA can know and watch this, they can

[31] The MFF is the primary budgeting instrument for the EU. A perspective (or budget) lasts 7 years and presents the EU financial planning for the period in question.
[32] Forest Management in Sweden, Copernicus Economic Value Study, December 2016.

“remind” farmers if there is a better rotation which can be more sustainable and give longer term higher yields.

Danish Environmental Protection Agency

The Danish EPA[33] is responsible for the development and execution of policies linked to the protection of the environment. Since 2009 a National action plan – “the Green Growth Agreement” - in Denmark has been introduced which is a concerted Action Plan incorporating Danish nature, environmental and climate initiatives.

Part of the Green Growth Agreement relates to plant protection products and thus to initiatives aimed at significantly reducing the harmful effects of plant protection products on humans, animals and nature. These include the future introduction of a new tax and indicator on plant protection products.

The EPA is also responsible for ensuring high quality drinking water in Danish homes. All of the water is extracted from underground sources which means that the quality is one of the highest in the world. The impact of pesticides and fertilizer use in Denmark is primarily on other wildlife and the ecosystem.

[33] http://eng.mst.dk/

5 Assessment of the Economic Benefits

Now that we know which effects the Fieldsense service is causing in the subsequent tiers of the value chain, we can establish the economic benefits that are sparked thereby: which financial value can we attribute to the availability of the service? It is the question we address in this chapter.

In our study – as we did in previous ones and will do in future ones - we are concentrating on the positive economic effects brought about by the availability and subsequent usage of the Sentinel data in the value chain. That being said, one needs to realize: where there are winners, there must also be some losers. Put differently, innovation and subsequent economic benefits will partly come at expense of some of the existing beneficiaries, especially in the short-term. However, recent studies demonstrate that 'on balance' and at the macro level, once the change is adapted to, there is a distinct positive effect. Annex 3 holds some further observations hereon.

5.1 The Service Provider (Tier 1)

It is fair to say that Fieldsense, the company, probably would not exist without the free and open Sentinel data. Today, it is giving employment to 12 persons. Encouraged by ESA (hackathons), the Copernicus Masters and follow-on schemes their skills have been directed into developing a business around Sentinel data.

It is worth noting also that the original EO Service Provider – Geocledian - has benefited by having Fieldsense as a reference customer and this has led to business of a similar nature in Italy and in Germany. Geocledian is introducing an agri-information service and is in the process of expanding from 3 persons to 5 and potentially 6 within the next 12 months an increase which can arguably be ascribed to the initial participation to the Fieldsense service.

Both Fieldsense and Geocledian also benefit from the knowledge acquired from their customer ie user feedback, which has allowed them to come up with new product ideas and product improvements. In a developing market it is extremely important to be active and reactive to new ideas.

The cost of Fieldsense is €335p.a. to subscribe to the service. This gives the rights to cover 125ha whilst each additional hectare will cost €0.95. For commercial reasons, Fieldsense will not reveal how many paying customers they have nor what their annual revenues are. In any case, these revenues are cancelled out as costs to the farmers and we can ignore them for the purposes of our analysis.

According to the EARSC industry survey[34], the average revenue generated by each person in a micro enterprise is €75k. If we ascribe all the jobs in Fieldsense and 2 of the new ones in Geocledian to the use of Sentinel data, 14 new positions have been created giving a benefit of around €1m.

[34] The State and Health of the European EO Services Industry; EARSC 2017.

5.2 Farmers, Agronomists & Consultants (Tier2)

5.2.1 Generic Parameters

At present, the farmers and their consultants supporting them are the main beneficiaries of the availability of Fieldsense. There are 4 ways in which the benefits are seen to accrue:

a) Cost reduction through reduced use of chemicals.
b) Improved efficiency through time saving for the farmers and consultants.
c) Increased yield through earlier intervention.
d) Improvement in farm management through greater digital awareness.

Currently, these benefits are relatively small but will increase as the service achieves (1) greater technical maturity as well as (2) increased market adoption. We will address this potential – which is core to the case (and possible follow-up thereon) - in the analysis.

Meanwhile, the table below shows the generic parameters (largely based on statistical sources and the interviews undertaken), which we have relied on to calculate the benefits in each of the 4 categories identified.

Input elements	Amount and unit	source
Amount of farmland in Denmark (DK)	2.6 Million hectares	Statistical Year book 2017
% of cereals planted	57% of which - 43% wheat - 44% barley - 17% oil-seed rape	Statistical Year book 2017
relevant number of hectares (ha)	1.482.000 ha	Statistical Year book 2017
Number of farms in DK	37.000 farms	Statistical Year book 2017
Big farmers (> 100 hectares)[35]	21% of 37.000 = 7.770 farms	Statistical Year book 2017
Hectares being managed using Fieldsense	50,000 hectares	CEPTU
Costs chemicals	1000 DKK / 130 euro per annum per hectare	interviewees
Costs fertilizer	2200 DKK / 280 euro per annum per hectare	Interviewees
Costs seeds	400 DKK / 52 euro per annum per hectare	Interviewees
Total costs	3600 DKK / 47 euro per annum per hectare (DKK / €)	interviewees

Table 5-1: Generic parameters used in calculating the benefits.

[35] All stakeholders have confirmed that only farmers holding more than 100 hectares of land are considered to be relevant, meaning a potential user of Fieldsense services.

5.2.2 Technical Capability

To start with, lets explain further what we mean by the technical capability level as we shall address this in the relevant benefit categories.

In the interviews, we were told that whilst the value of Fieldsense to the farmer is significant, it will increase as the service becomes more accurate and contains more information. This is intuitive considering that the service is using machine learning which will improve as more data is analysed and more feedback on the real cause of a detected anomaly is gathered.

The result will be greater accuracy and reliability such that the farmer can rely on it to a higher degree. All the experts agree that the full potential can be realized once there is a better identification of the cause of the stress and a better delineation of the area to be treated which can be input directly into the farm machines. (Note that even in the time taken to prepare this case, the performance of Fieldsense has been noted to have been improved!).

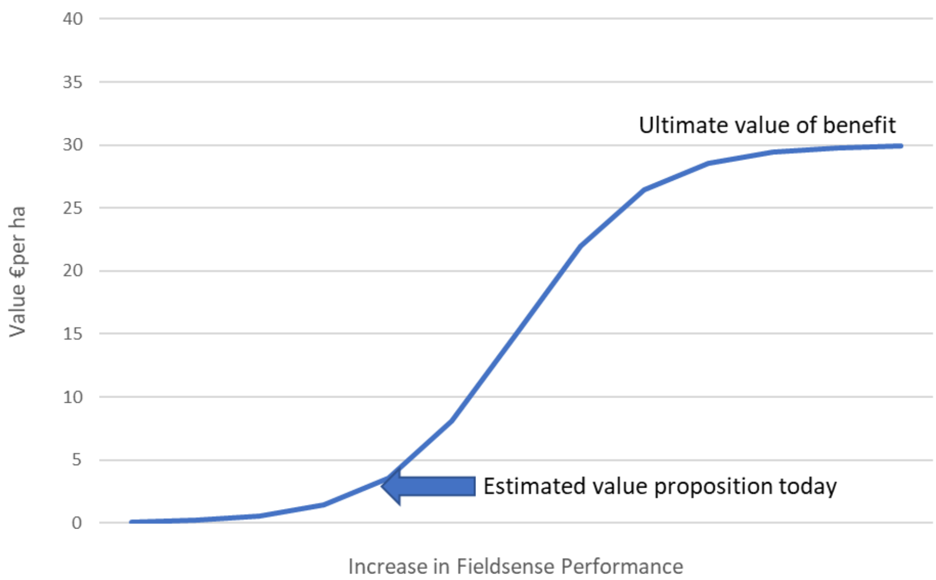

Figure 5-1: Characteristic increase in value with performance for Fieldsense.

This will result in a form of curve where the value starts low and increases as the accuracy improves. Figure 5-1 illustrates this where the ultimate value of the benefit is calculated to be €30 per hectare whilst the value of that benefit today is around €2.5 per hectare. As the accuracy improves, the value today will move up the curve to ultimately reach the final value.

5.2.3 Benefits for the Farmers

a) Reduction in the use of chemicals.

Each year, farmers spend an estimated €130 and €150 per hectare on chemicals which are spread onto the fields taking into account all the available information from scouting. Once more accurate information about the status of the crops is available from Fieldsense, this can be done in a more targeted way which experts advise can lead to a reduction of between 10 and 20% of the amounts used.

Based on the assessments of the farmers and agronomists interviewed we end up with a low and high estimate, being: 10% x 130 euro per hectare = 13 euro per hectare and 20% x 150 euro = 30 euro per hectare. Accordingly, this gives an annual benefit in the range of 13 euro to 30 euro (and an average of 21,50 euro per hectare).

Building on that, if we assume the improvement in the performance will follow an "S" curve whereby the early and later gains are hard won whilst the greatest rate of improvement occurs as the technology is maturing, we can draw up a graph illustrated in Figure 5-1. Taking this maximum value of 30 euro per hectare, as a starting point, and based on the input from the interviews, we assess that at present around 20% of the technological potential is being cashed-in, giving it a current value of 6 euro per hectare. Obviously, as the technical maturity will increase - the identification of the anomalies becomes more certain and the accuracy improves – gradually the value will reach 100% of the full potential, being 30 euro per hectare.

b) Saving in time

Secondly, as a result of receiving the alerts through the Fieldsense service, farmers are saving time on crop scouting. Rather they are better able to use their time to investigate where there are problems identified. Our discussions led us to understand that 1 – 1.5 hours per week - where the farmer normally spends 3 hours per week - during the growing season (taken as 26 weeks on average) could be saved once the full potential of Fieldsense has been reached, thus giving us a range between 26 and 39 hours per growing season. Against an hourly rate of 120 euro (for a senior farmer), this yields a benefit in the range of 3,120 – 4,680 euro per year per farm being equivalent to 6 - 9.4 euro per hectare calculated for a farm of 500ha.

Again, cashing in on this potential will require technology to mature and the (machine) learning curve to be established. Based on further exchanges with our interviewees, the farmers and their consultants in particular, we estimate the savings to be at 10% of the full potential, leading up to current savings of between 0,6 – 1,5 euro per hectare.

c) Increase in yield from early warning

It seems intuitive that if the farmer knows about a problem earlier, the remedial measures can be taken earlier so saving more of the crop. In this case we should expect a benefit through increased yield.

However, trials carried out by SEGES do not substantiate this. Field trials show great variations in the yield in both a positive and a negative direction. It would appear that other variables are having more impact on the yield than that arising from early warnings. Experts told us that the impact is zero!

This would in any case be expected to be very small. Firstly, we would assume that up to a week saving in time would result from the Fieldsense alert. Not all the growth would be lost and hence the yield impact will be a small fraction of the total. Secondly, it is only a part of the field which is affected and usually not all the crop would be lost.

Hence, we have made a conservative assumption that currently the value is 0 but, after maturing technology, there could be a 0.1% increase in yield due to Fieldsense alerts, leading up to a potential benefit of 1 euro per hectare (as an average crop value is around 1000 euro per hectare).

d) Increased digital awareness.

Finally, one would expect that the usage of Fieldsense will also result in more digital awareness, sparking further potential benefits. However, this was quite strongly disputed between researchers and farmers; the latter who consider that they know the farm quite well already! Again, intuitively, there should be some benefit through a better digital image of the farm. This is indeed re-enforced by the actions of the Danish Ministry to monitor crop rotation with a view to advising farmers if they are not following best practice. However, given the contention together with the difficulty to assess this value we have not made any allowance in the system. It can also be argued how much this is additional value coming from the use of Sentinel and how much is due to more general IT technology being applied.

5.2.4 Market adoption potential

As indicated above, next to the 'technical maturity' upsell described above, there is second potential multiplier: the increased market adoption, as more farmers start using the Fieldsense product (and/or other similar services entering the market). This effect applies universally to all 4 benefits identified.

At present 50.000 hectare of the Danish farming land is being served with Fieldsense. Adding up the *current* benefits identified above - so the reduced costs for chemicals (with a value of 2.6-5.2 euro per hectare) and the time savings (with a value of 0.6-1.5 euro per hectare) leads to a *current* benefit of 3.2 – 6.7 euro per hectare, which leads up to a *current* total value resulting from the use of Fieldense of €160k – €335k.

However, being still in a fairly infancy state, having only captured the innovators and early adopters (equivalent to 3.4% of the relevant farmland hectares), we would expect that more users will come in quite rapidly, also given the modest pricing and the low risks associated. Accordingly, we would expect the penetration level to increase quite rapidly to a significant level. It could reach 100% but since some farms may not be suitable for Fieldsense type monitoring and some farmers will resist new technology to the death (!), we have assumed that the ultimate uptake could be 80% of all relevant farmers and farmed land.[36] Applying this 80% to the relevant area of farmed land, being 1.480.000 hectares), gives us a 'total potential market of farmland' of 1.184.000 hectares. Applying the *current* benefits per hectare (€3.2 – €6.7) to this *market* potential yields a value of €3,8m – €7,9m and applying it to full *technical maturity* potential delivers a stunning amount of €23.7m – €54.5m.

5.2.5 Total Benefits to Farmers (actual and potential)

Accordingly, adding everything up, the overall benefit for the farmers is:

Element	Actual today (Euro/ha)	Factor technical capability	Full potential (Euro/ha)
Reduced chemicals	2.6-5.2	20%	13-30
Time savings	0.6-1.5	10%	6-15
Yield Increase	0	0	1
Farm practices	0	0	0
Total	3.2-6.7		20-46
Total Benefits:			
Based on 50,000ha	€160k – €335k		€1m – €2.3m
Based on 1,184,000ha being 80% of the maximum adoption level assumed (1,480,000 ha)	€3,8m – €7,9m		€23.7m – €54.5m

Table 5-2: Benefits coming from Tier 2.

5.2.6 Other Tier 2 Factors

In Tier 2 we also include the co-operatives which are supplying or supporting farmers. We specifically mention SEGES, Danish Agro and DLG. These may yield some additional benefits in the future if they incorporate Fieldsense as a farm management service in their offering. We have not tried to calculate the impact of this as it will depend very much on the business model which is used.

[36] In this context, it should be kept in mind that we have only taken on board those farms running more than 100 hectares of land, leaving out the smaller (and possibly less professional) farms.

5.3 Farm Machinery, Agro-chemical businesses (Tier 2 & 3)

These are potential players in the value-chain but are not present as far as we have found in the case in Denmark. The interest in using services like Fieldsense is twofold:

- as a marketing tool: In some countries a service is offered free by the agro-chemical companies to gain a competitive advantage over their rivals.
- As a paid for service alongside other farm management services already offered by the companies.

The farm machinery sector is also seeking to offer services to their customers although here the motivation is different. The information helps them to design better machines and to an extent help the sale of higher value machinery.

In both instances, case there is a leveraged value which arises from the use of the satellite data. However, since there is no direct involvement in this case, we have assumed a benefit of 0.

5.4 Livestock Farms, Food Processors (tier 3)

The Fieldsense service can benefit also the farms which are consumers of the cereals. Lower chemical residues can lead to improved meat or dairy quality and possibly higher value sales. Nevertheless, the effect is very small and we have not included this in our calculation.

5.5 Supermarkets (tier 4)

Food producers will benefit from the very marginal improved production and possibly from lower prices as the lower cost to farmers gets shared through market forces. However, we do not see any significant leverage which would yield additional benefits.

Similarly, if the use of chemicals can be reduced then it is possible that a higher quality product can result.

5.6 Water Supply Companies (tier 4)

Given that the drinking water in Denmark is coming from deep underground reservoirs, the impact of reduced chemical use is insignificant with regard to drinking water. Hence the impact of the Fieldsense service on this part of the value-chain has been taken as zero.

5.7 General Public / Consumers (Tier 5)

As the agriculture value chain is very efficient in Denmark we see no possibility for leveraged benefits to consumers. They may have a small benefit from lower prices working their way down the value chain. The main benefit will arise due to environmental factors through reduced chemicals use in the fields.

The reduction of pesticides, fungicides and herbicides is of clear public benefit. The run-off of excess chemicals into water catchment areas is of concern to consumers everywhere even if the pollution levels in Denmark are among the lowest in Europe. Services such as Fieldsense are likely to become extended through the addition of additional data on the fields and the crops being grown. This applies to all chemicals although it is especially relevant when considering fertilizer use which was not part of this case.

- Criteria defining the sensitivity of each hectare for excess chemicals to enter the water catchment area.
- The cropping potential of each hectare which can be used to determine the efficacy of using chemicals to deal with problems ie less effective on low potential areas.
- The regulatory limits which are being tightened all the time and hence where it is most effective to use chemicals.
- The crop being grown and its reaction to different chemical types.
- Irrigation and ground water levels will affect all the above parameters.

Hence, the decision-making process by farmers becomes more complex driven by consumer concerns and wishes for high-quality produce.

5.8 Other Stakeholders

5.8.1 Danish Agriculture Agency

The Danish Agriculture Agency is responsible to the Ministry of Environment and Food. The Agency drafts the majority of the laws and regulations that govern the agricultural sector and provides grants for agricultural production. They oversee the inspections of Denmark´s agriculture sector that are closely linked to the EU subsidies which are disbursed to the farmers.

The Agency is also interested in the data coming from Sentinel satellites. Research is being carried out into the use for CAP control, for grassland monitoring and for control of fertilizer use. The Fieldsense service could be used in the future to enable the Ministry to gather a synoptic view of the agriculture practices in Denmark and to use the knowledge to advise or influence farmers. For instance, a tender was recently issued to perform after-season crop monitoring so to look at replanting patterns and the extent of grasslands.

Fertilizer use is an especially hot topic at the moment. The Ministry is working with SEGES to understand the impact of policy changes to control its use. Currently, the use is capped ie each farm may use a certain amount per hectare each year. The limit set is tighter than that applied by the EU generally. Reduced fertilizer use will be possible once variable rate technology becomes more widely-used. This will be further linked to yield potential for each field and ultimately to water-catchment maps showing how the fertilizer can enter the draining water either for drinking or for run-off into rivers, lakes and ultimately the sea where it pollutes. Matching the applied fertilizer more closely to the plant need is the goal.

In terms of regulation and controls, Sentinel offers a lot of potential. Amongst all the actors we have spoken to (not just those in Denmark), there is no use of Sentinel data linked to CAP measures. This is likely to change in the future as the CAP is modified and the results of research projects matures.

5.8.2 Danish Environmental Protection Agency

The Danish Environmental Protection Agency (EPA) is also reporting to the Ministry for Environment and Food. They are responsible for Danish environmental legislation. Reduced use of both pesticides and fertilizers is good news even if the impact in Denmark is quite limited. The table below shows the trend of pesticide sales over the last few years. These peaked in 2012 at 5kg/ha and have fallen significantly since showing the success of the pesticide strategy as reported in the 2016 annual statistical report from the EPA (p10)[37].

	2010	2011	2012	2013	2014	2015	2016
Pesticide statistics based on Sales	3.39	3.02	5.0	3.55	1.47	1.95	1.40

Table 5-3: Annual EPA Pesticide statistics sales kg/ha.

A further 10% reduction in the use of pesticides, whilst beneficial would be small compared to the overall trend of pesticide use driven by Danish regulatory actions especially given the limited penetration into the drinking-water chain.

[37] Pesticide statistics in Agriculture; http://eng.mst.dk/chemicals/pesticides/pesticides-statistics/agriculture-etc/

6 Conclusions

6.1 Summary of Findings : Benefits to Denmark

The use of Sentinel data for agriculture is growing strongly although most of the instances are research focused and not yet part of a business. The case in Denmark was one of the first that we came across which is indeed operational with traceable decisions coming from the use of the data. It has proven interesting for several reasons:

- It shows how even moderate resolution data coming from the Sentinels can provide added value services to farmers.
- It shows a value-chain where the benefit generated is quite compressed; there are few leverage effects which drive value down the value-chain.
- The value-chain is quite dynamic and we have seen changes to the business models of the actors even as the case has developed. Many more changes are possible if not likely during the coming years.

Overall, it is a case which can be readily scaled to other countries and can also lead to a number of complementary cases concerning other parts of the farming sector.

The case has focused on the value to the farmer of having a decision support service which can improve the management of farms covering 100ha and above. It considers the use of satellite data to trigger an early warning of threats to crops from pests, diseases and invasive plants so enabling reduced and more effective use of chemicals. It specifically does not cover fertilizer use which is a significant and growing application as this was not part of the use-case when we started the analysis.

The technology is just being introduced and, as it matures over the next few years, it will become more performant. Hence, we consider not just the situation today, but also how it may improve in the future. Improvements will arise from the use of machine learning and artificial intelligence to automate the designation of the problem and so to provide specific alerts which are reliable.

Furthermore, today, the service is being used by less than 5% of Danish farmers. Our analysis shows the value to each farmer of using the service is significant and it’s use should be expected to grow quite rapidly. This will be encouraged by the presence in the value chain of the farmers union and other co-operatives which can “spread the word”.

The socio-economic benefits to Denmark come mainly through four mechanisms:

- Improved efficiency and cost savings by farmers.
- Increased employment by the service provider
- Economic benefits through the rest of the value-chain
- Reduction in chemical residues in the crops and run-off into water catchment

1. **Improved Efficiency and Cost savings for farmers**.

   Benefits to farmers arise primarily through increased efficiency and the savings arising from reduced use of chemicals and reduced time spent in the fields scouting.

   a. Today the saving is in the range €160k to €335k
   b. Extended throughout Denmark to 80% of the potential market, this can become €3.8m to €7.9m.
   c. In the future, as the technology becomes fully automated and more performant, this can become €23.7m to €54.5m

2. **Economic Benefit along the rest of the value-chain**

   For the rest of the value chain, extended or leveraged economic gains have been considered as zero for the present study. Additional benefits may arise in the future that are not existing today. For example, increased food quality could potentially generate a high pricing position while in theory reduced amounts of chemicals in the water could lead to lower treatment costs. We consider however that these should be economically very small especially for the Danish case.

3. **Increased employment by the EO Service Providers**
   a. Today, 12 jobs have been created in Fieldsense by the availability of Sentinel data for this case. In the EARSC industry survey, each job in a micro company delivers €75k revenue on average. Hence these jobs are worth around €1m to the Danish economy. Depending on the success of Fieldsense, this could become much higher.

4. **Environmental benefit through the reduced use of chemicals on the fields**.

   Any reduction in chemical use is desirable leading to less chemical residues in food and drinking water as well as reducing adverse effects on the environment (biodiversity).

These benefits are shown graphically in Figure 6-1. Where the actual benefit is that being realized today with the limited uptake of Fieldsense, and the potential benefit is either through increased market adoption (vertical axis) or improving technical capability (horizontal axis).

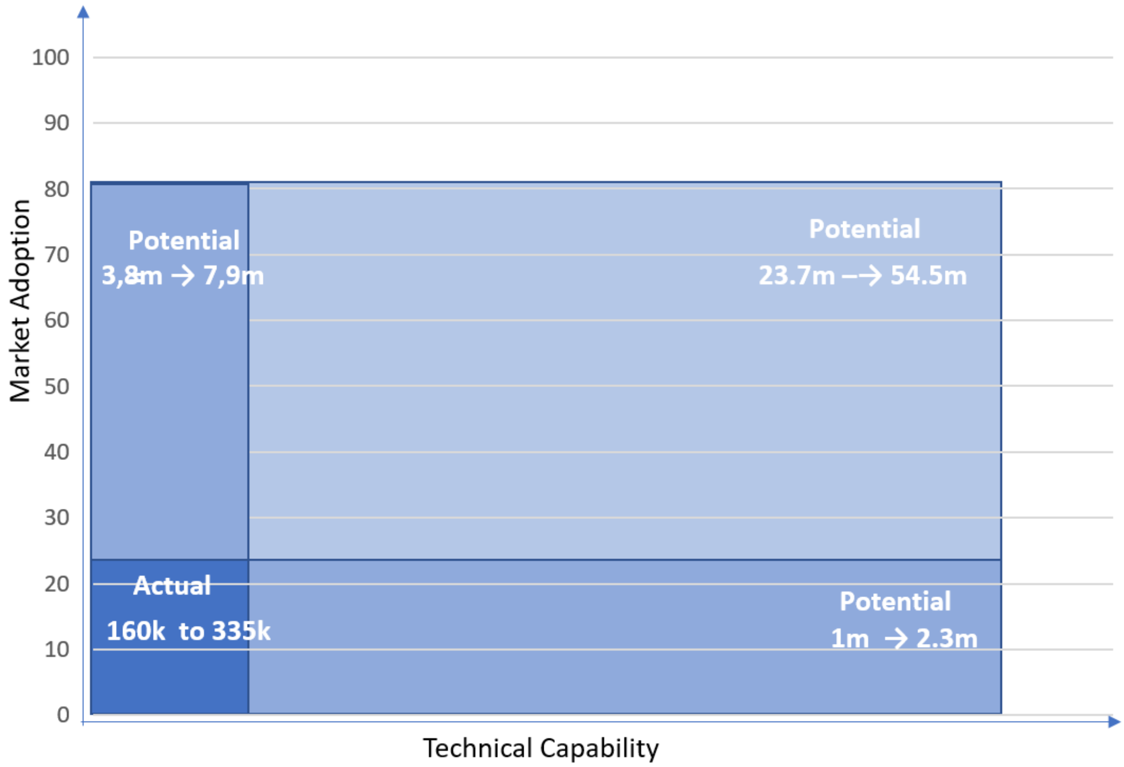

Figure 6-1: Actual and potential economic benefits

If we look along the value-chain, the economic benefits are being generated almost entirely in the first two tiers; by Fieldsense employment and by the farmers and the use of Fieldsense on the farms. This is unusual as we have seen in other cases that benefits in one tier are leading to further benefits in subsequent tiers.

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Value generated at each Tier[38]	€900k	€3.8m - €7.9m	€0	€0	€0

Table 6-1: Value generated at each Tier in the Value Chain

Table 6-1 shows the individual contributions to value from each tier whilst Figure 6-2 shows how this accumulates. The dark blue values are taken from Table 6-1 whilst the light blue narrower columns are the cumulative value of the previous tiers. For the last three tiers the individual benefits are taken as 0.

[38] Assumes current technological status and 80% farms over 100ha use the service.

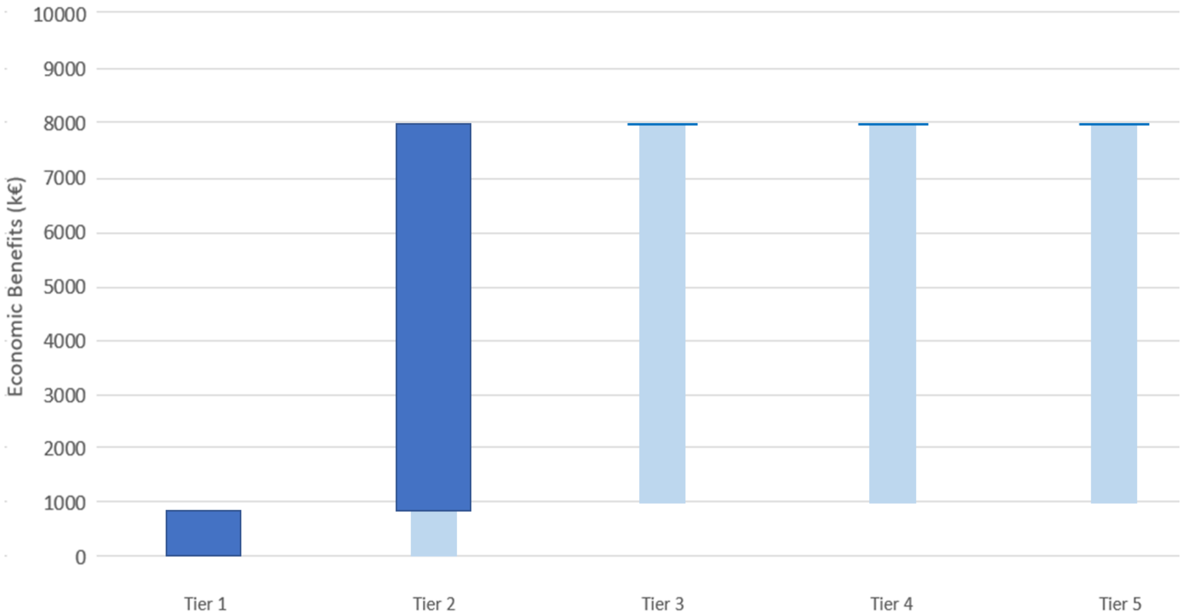

Figure 6-2: Cumulative Benefits coming from the use of the Fieldsense service

It would seem that there is significant potential to improve farm management through the use of digital mapping and especially the improved applications of fertilizers, but we shall leave this for another case as, at the time we started, this was not a feature of the Fieldsense service (whilst it has not been introduced).

6.2 The Impact of Sentinel Data

Sentinel data is a key driver for this case. The free and open data from Sentinel 2 allows a specific business model to be developed and a service to be offered at a low cost. Fieldsense is but one example, and possibly the most developed, out of many information services targeting the agriculture market.

The Fieldsense service is evolving very rapidly. The company has already in-sourced the processing linked to the satellite imagery and has the goal to extend the service using machine learning and artificial intelligence. We have found it very important to include these developments in our analysis.

Today, the farmer is presented with the information linked to crop stress. He provides the interpretation to identify the cause and the possible remedy before taking a decision on treatment. The goal is to automate this operation to a large extent so that the processing system will be able to say with a good degree of accuracy what is the cause and what to do about it. This automatic process to identify the cause of a stress and to provide direct remedies is not yet possible; but will be in 1 or 2 years' time.

Commercial satellite imagery can replace or complement that from Sentinel 2. It can provide higher spatial resolution and hence ground discrimination as well as more frequent revisit times. Higher resolution can distinguish smaller areas of unwell plants and further optimize the application of both fertilizer and chemicals. However, this is still limited by the capability of the machinery and notably the spray head or distributor spacing. There is no advantage to having detailed crop information at 1m spacing on the ground if the spray heads on the machines are spaced at 3m! In this case, increased ground/spatial resolution only offers diminishing returns.

However, unlike Sentinel 2 data, commercial data comes at a price. Fieldsense is based almost completely on the free and open data from Sentinel 2 (complemented by some data from Landsat which is also free and open).

Both higher spatial resolution and more frequent measurements can be taken by drones. However, the operating cost is not negligible, and the advantage may not outweigh commercial satellite imagery let alone that coming from free sources and open such as the Sentinels.

6.3 Widening the Perspective

We have shown that there is value in the case in Denmark and potentially there is much more. Not just in Denmark but in many countries, services are being developed to offer decision support to farmers. Indeed, the strategic pressures on farmers leading to larger farms to manage create a ready environment in which to introduce these services. For many reasons, agriculture looks to be a very fertile area in which to find future cases for analysis.

In the case, we already consider the extension to cover up to 80% of the cropping land in Denmark and the impact of developments of the technology. Beyond this, it should be possible to scale / extend in several dimensions:

- the service can be extended to be used to control fertilizer application. This is happening with Fieldsense but was too late to be included in our analysis. The main impact will be to reduce costs to the farmers but reducing fertilizer use also will reduce pollution and improve water quality.
- The same information also has the potential to be used by the Paying Agencies to monitor farmers actions and in particular related to crop rotations and grasslands to achieve best practice (not dissimilar to the freedom with responsibility we saw in the case Forestry in Sweden).

Both of these apply to the use of Fieldsense in Denmark so there is strong potential to see a large upside on benefits in Denmark. But the services can also be applied elsewhere in Europe, globally, and to other crops. Hence there are a further three dimensions in which the service is scaleable; technical application, type of agriculture and geographical market.

- Firstly, to simply scale the Fieldsense service to the rest of Europe (EU-28). In Europe, there are around 180m hectares of cultivated cropland compared to 1.48m in Denmark. In

Denmark, 65% of the total farmland is dedicated to cereals. However, Denmark has an average farm size much higher than most of the rest of Europe[39], and so using 40% as a factor leads to an estimate of 70m hectare of cultivated cereal land on farms of more than 100ha. This leads us to estimate a market which is around 50 times that of Denmark alone. Hence the potential for services such as Fieldsense across Europe, based on this case alone is some €1.2b to €2.7b[40].

- Elsewhere in Europe, services are being developed in almost every country. Research activities are looking at similar services for vineyards, for grasslands (an example in the Netherlands where damage to grassland by geese is being monitored and in Estonia where grassland monitoring is being linked to the CAP) for high value cops such as potatoes (in Belgium a service is offered by VITO and in UK a new venture has started).
- Another factor is that the value chain may evolve. In this case already we see a form of vertical integration within Fieldsense. The interests of farm machinery and agro-chemical manufacturers may lead to further consolidation as well as convergence with other technologies such as drones and in-situ measurements.
- The above examples are all aimed at the farmer and for improving their farm management through better data. The second main market linked to agriculture is that for governments implementing the CAP or other national agriculture policies.
- Hence, expansion in the geographical market adoption also depends on the local regulatory environment. Across Europe this is quite similar driven by the CAP. The vast majority of farms cultivate a relatively small area which are not well suited to satellite applications but there are a small number of farms which cultivate much larger areas. The majority of precision agriculture and agri-information services offered are so far targeted at large-scale farming operations[41]. Indeed, the adoption of precision agriculture services across Europe has been observed to occur in "hot spots", such as, for example, in eastern Germany (where large communist-era state farms have been divided into privately-owned lots of 1000-2000 ha. Field size on these farms (often >50 ha) is frequently larger than whole farms elsewhere in Europe.
- The free and open Sentinel data has the potential to offer less precise services but at a much cheaper cost than those using commercial data. Hence the market adoption will be possible for many of the less-large farms and smaller fields size.
- One further factor is the local ecosystem. In this case, Fieldsense is based alongside the technical university in Aarhus where the founders studied. Aarhus is a centre for agriculture research and so the ecosystem has been a great enabler for the development of the service.

[39] Eurostat Farm Structure Statistics: http://ec.europa.eu/eurostat/statistics-explained/index.php/Farm_structure_statistics

[40] EU area is 50 times that in Denmark. 50 times €18.95m to €40m yields €0.95b to €2b in total.

[41] Precision agriculture – An opportunity for EU farmers - Potential support with the CAP 2014-2020, IP/B/AGRI/IC/2013_153, European Parliament, 2014

Hence other cases linked to farming should be considered so as to flesh out this picture over Europe, with different technical capability and different farming practices (including crop types).

6.4 Final Thoughts

This case has been a very good one to start looking into the EO services serving the agriculture sector. These are many and varied and are developing rapidly driven by new commercial data together with the increasing availability and ease of access to the free and open Sentinel data. From our background research we expect many new services to come on stream over the next 12 to 24 months and consequently many more cases which could be investigated and analysed.

This, the first one selected, shows some very interesting characteristics. Agriculture is one of the fastest growing application areas being driven by Sentinel data. Both for chemicals and fertilizers (not studied here) the use of variable rate maps will develop a better match between the amount that is applied and what is necessary for the plants to deliver their potential yield.

Warnings of threats to crops enable the farmers to save time and money. This is significant when considered against the overall farm profitability and the business case seems rather compelling.

Further advances in digital information for farmers will further improve the efficacy of using satellite data. Artificial intelligence and machine learning are expected to improve the technical capability of Fieldsense over the next few years.

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Annex 2: General Approach and Methodology

This is the first case of a new set to be analysed following the 1st 3 cases published in 2015/16. It follows the same basic methodology[42] based on establishing a value chain for the use of a single EO service and analyzing the benefits at each step (tier) in the value-chain. Additionally, improved attention is made of the socio-environmental impacts and on possible extrapolation of results with a wider perspective.

For each new case, a comparison of the methodology which has been used will update our perspective on the overall methodology to be used for future cases. What have we learned from this case?

In this case 4 points stand out:

- The value chain is fully described but the large majority of the economic value is created in one tier, through cost savings by the farmers. Leverage of these savings into other tiers further down the value chain is very limited and, in the analysis, has been considered as being zero.
- The value-chain is changing quickly. Firstly, the EO Service provider has integrated the processing chain under his own control. Fieldsense also adds other data in order to provide a crop information service. Further changes to the value-chain are likely as the market matures. This may involve integration with other service providers (horizontal integration) or with others further along the chain ie farm machinery or agro-chemical companies or farm supply companies. These changes will not be unique to Denmark and may involve international players. Further, the integration may differ according to local market conditions.
- After many years of promise, the use of satellite data to support agriculture is finally becoming a reality. Driven by more commercial data becoming available and by the free and open Sentinel data, many applications are starting to be used to provide services supporting crop management.
- We can identify many similar services around Europe, at various stages of maturity. Different business models are being adopted and future cases should examine these aspects in more detail. Not all are using Sentinel data as some are offering higher resolution products based on commercial, satellite data. This needs to be contrasted with the free data coming from Copernicus which we hope will be possible in the future.

[42] SeBS Methodology; June 2017.

Annex 3: Winners… and losers?

The creation and subsequent usage of Sentinel data down the value chain has a significant economic impact. Quite prominently, product and process innovation based on the availability and subsequent application of the data, lead to positive effects where new products and services emerge and existing processes can be run more effectively and efficiently. Conversely of course, there are also consequences on some of the previous beneficiaries. For instance, revenues might be shifted and jobs displaced and sometimes even destroyed, creating technological unemployment. In the current study, for example, some workforce might have been lost in reducing the site inspections while savings from farmers certainly translates into loss of revenues for the agro-chemical industry.

> As we have shown in our study 'Winter navigation in the Baltics' as the captains on the icebreakers in the Baltics could suddenly rely on Sentinel based ice charts providing a fully synoptic picture of the ice, the helicopter pilots they traditionally relied upon, became abundant.[43] Similarly, in our study 'Forest Management in Sweden' the Swedish Forest Agency could reduce the number of forest inspectors, as Sentinel data allowed for a reduction of in situ inspections.[44]

How technological progress and innovation are related to employment has been an area of fierce debate for centuries. From fairly recent studies appear that product innovation spark new economic activities, creating new sectors, more jobs, whereas process innovation[45] is more job destroying, although market mechanisms can sometimes largely compensate for the direct job losses, mitigating the ultimate impact on demand for labour. Such price and income compensations can derive from a decrease in wages, leading to an increase in demand for labour or the effects of new investments (enabled by accumulated savings) creating new jobs elsewhere. Obviously, the speed and impact of such effects are highly dependent on the flexibility of markets, the level of competition, demand elasticity, the extent of substitutability between capital and labour and, of course, possible institutional rigidity.[46]

> A German study on the co-evolution of R&D expenditures, patents, and employment in four manufacturing sectors concluded that patents and employment are positively and significantly correlated in two high-tech sectors (medical and optical equipment and electrics and electronics) but not in the other two more traditional sectors (chemicals and transport equipment).[47] Similarly,

[43] Sawyer, G. and De Vries, M. "Winter navigation in the Baltics." Copernicus Sentinels' Products Economic Value: A Case Study (2015)

[44] Sawyer, G. and De Vries, M. "Forest Management in Sweden." Copernicus Sentinels' Products Economic Value: A Case Study (2016)

[45] As process innovation is defined as producing the same amount of output with less labour (and sometimes other) inputs, logically the direct impact of process innovation is job destruction when output is fixed.

[46] Vivarelli, M. "Innovation and employment: Technological unemployment is not inevitable—some innovation creates jobs, and some job destruction can be avoided." IZA World of Labor 2015: 154

[47] Buerger, M., T. Broekel, and A. Coad. "Regional dynamics of innovation: Investigating the coevolution of patents, research and development (R&D), and employment." Regional Studies 46:5 (2012): 565–582.

a study using a panel database covering 677 European manufacturing and service firms over 19 years (1990–2008) detected a positive and significant employment impact of R&D expenditures only in services and high-tech manufacturing but not in the more traditional manufacturing sectors.[48] Another study found a small but significant positive link between a firm's gross investment in innovation and its employment based on longitudinal data set of 575 Italian manufacturing firms over 1992–1997.[49]

Clearly, this tells us that the ultimate 'net' impact of innovation – both at product and process level - brought about by the availability of new technology, such as Sentinel data, will be closely related to the market and institutional settings in which they become effective. However, on the whole the conclusion seems justified that the 'negative' effects, in the form of possible loss of employment, is largely outweighed by the positive economic effects throughout the value chain.

Accordingly, in this study – and likewise for the past and future ones - we will concentrate on the positive effects brought about by the availability of the Sentinel data throughout the value chain. That there are also (temporary) 'negative' impacts is a given, but the net effect at macro level will always be positive.

[48] Bogliacino, F., M. Piva, and M. Vivarelli. "R&D and employment: An application of the LSDVC estimator using European data." Economics Letters 116:1 (2012): 56–59.

[49] Vivarelli, M. "Innovation, employment, and skills in advanced and developing countries: A survey of the economic literature." Journal of Economic Issues 48:1 (2014): 123–154 as well as "Technology, employment, and skills: An interpretative framework." Eurasian Business Review 3:1 (2013): 66–89.

Annex 4: About the Authors

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