

European Association of Remote Sensing Companies

Sentinels Benefits Study (SeBS)

A Case Study

Growing Potatoes in Belgium



The Home of Belgian Fries



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Setting the Scene

Antoine settled into his seat in Le Bistro Jourdan alongside his big brother Theo. It was their evening for Fritkot which their parents allowed them once per month. They would go out to one of the many Friteries around Brussels and enjoy the National staple food; Belgian fries with (usually) mayonnaise. Their parents preferred one of the more powerful sauces which were offered; his father liked Samurai but his mother liked the sweet and sour.

The frites came from Maison Antoine across the road. It was their favorite frieterie and Theo always joked that it was Antoine's second home! Maison Antoine has been a fixture in Place Jourdan, Brussels since 1948 for take-away snacks and meals. All the local cafes allow their clients to bring their frites into the café to eat with a beer or, in the childrens' case, a coke.

As they sat down, a man at the table next to them looked at Theo and said, *"So you are a spaceman?"* He had noticed the baseball cap that Theo was wearing marked ESA – a souvenir from his recent school visit to the Redu space centre. *"Did you know that satellites help deliver you those frites?"* Theo was astonished to hear that, *"No,"* he replied, *"how on Earth, or rather, how from space do they do that?"*

"Do you know about Copernicus," asked the stranger, *"the European satellite programme?"* Theo said that he did know about it and the Sentinel satellites. *"Then you are very well informed,"* said the stranger. *"So, the Sentinel 2 satellites,"* *"Those are the optical sensors,"* interjected Theo, and the stranger smiled at him, *"Yes, they are, and the images they take over Belgium are used in a system called Watch-it-Grow to provide your Belgian farmers with pictures of their fields where the potatoes are growing so that they know when to water them or when to apply fertilizer. But more importantly, they help the factories which process the potatoes into frites, to know when the crop will be ready and how good it will be."*

"Knowing about the potatoes before they are harvested, helps the factories plan their production which helps them work more efficiently. Further, by working more closely together, farmers in Wallonie and factories in Flanders can increase the potato crop; meaning more frites for you - and more exports for Belgium."

"Wow," said Theo, *"all that because of the satellites, and we get to eat more frites."* He looked at his father who smiled and nodded. The stranger got up to leave. As he did so, he placed his card on the table, *"You're a clever young man, if ever you want to know more, or later if you look for a job, drop me a mail,"* and he left the café. Theo's father picked up the card and read *"Josef Aschbacher, ESA Director"* before turning to his son and asked him, *"So, do you want to be a spaceman when you grow up?"*

This story is entirely imaginary, although realistic based on our knowledge gained through the case interviews. The places are real, as are the characters, although the conversation and the situation is entirely fictional.

Executive Summary

This case looks at the benefits to the Belgian economy coming from an important national sector; potatoes. The importance comes not just because of the farmers growing the crop but also due to the presence of a little-known, world-leading, potato-processing industry.

Sentinel 2 and shortly Sentinel 1 data is used through a service called WatchITgrow (WIG) which is offered to farmers throughout Belgium. It has been developed by VITO and supported by Belgapom and the potato processing industry. Today, WIG provides imagery from Sentinel 2 over Belgium. Farmers can identify their fields and can enter a number of data relative to the field such as planting time, potato variety, fertiliser and chemical applications etc. It allows farmers to build a picture of the field and assists them in their management practices. WIG also contains information on rainfall and supports crop irrigation.

The industry is very keen on WIG because it can help them understand the harvesting, yield and quality of the crop. As WIG matures, this information will become more precise and its value will grow. Benefits will increase due to this “technical maturity” and as more and more farmers use it. However, farmers are more cautious because they fear giving away information to the much more powerful processing industry. Safeguards are being built into the system.

But the information, based upon the satellite imagery and augmented by the other data, can help improve yields by up to 20% and improve the overall quality of potatoes, hence increasing revenues for the farmers and the industry and increase the performance of the Belgian potato sector. Farmers and agronomists can also save time through the availability of better, more recent and wider-area information. Overall benefits are analysed to be around €1m to €1.8m today and can potentially rise to €70m once the application is fully applied and mature.

In addition to the economic benefits, the use of farm management applications using satellite data generates environmental benefits. Improved knowledge of the fields performance (yield) allows better distribution of fertilizer and chemicals both before planting and during the season. This matches the crop need more precisely to the fertilizer application and reduces the excess fertilizer not taken up by the plants and hence reduces the excess nutrients which run-off into surface-water channels and into water supplies.

One further dimension of the case is the current initiative by the Belgian potato sector to create an organizational platform for all the actors to exchange and co-operate. This will an important step towards transparency and building trust between the players but especially between industry and farmers. Can this work? We hope so, and that satellites play a key role in enabling this to happen.

For each case, a value chain of benefits is constructed. The value chain benefits for the case of Growing Potatoes in Belgium is shown below.

GROWING POTATOES IN BELGIUM



The Satellite Data

Copernicus Sentinel-2 provides free-of-charge frequent wide-swath, high-resolution multispectral imagery with 13 spectral bands over Belgium. In the future, also Sentinel-1 will be used.



The Service Provider

VITO has drawn upon the Sentinel data in combination with other data sources to develop the platform WatchITgrow that provides a farm management system and decision-support service to farmers.



The Primary User

Thanks to better management of inputs, irrigation, field inspections and optimised harvest time, farmers have become more efficient and thus currently save time and costs. With full technical maturity and market uptake, benefits can reach between €60.33m and €85.33m in the future.

€1.195-1.595m pa



Other Direct Users

Agronomists, consultants and the industry make use of the information to get an overview of crop growth and yield forecasts to better adapt their strategy, planning and logistics, making their operations more efficient.

€150-180k pa



Secondary Beneficiary

Processors, distributors, exporters and logistics companies will benefit from an increased output by the farmers to produce more fries and export more on the world market.

€425-850k pa



Tertiary Beneficiary

Supermarkets and shops are not heavily affected economically by the increasing potato yields, though shortage and oversupply can lead to promotion actions.



End Use Beneficiary

The general public benefits from stable prices, "healthier potatoes", a more efficient use of water and more sustainable environment.

Total benefits: €1.78-2.6m pa

1 Introduction & Scope

1.1 The Context of this study

The analysis of the case study ‘*Growing Potatoes in Belgium*’ is carried out in the context of the ‘[The Sentinel Economic Benefits Study](#)’ (SeBS). This 4-year study is looking to develop cases showing how EO-derived products based on data generated by one or more Sentinel satellites deliver value to society and citizens. The [Sentinel](#) satellites form a crucial part of EU’s [Copernicus Programme](#), providing space-based observations on a full, free and open basis. Data coming from the Sentinels – together with other data collected by contributing missions and ground, sea or airborne instruments – is used to support key economic or societal areas such as agriculture, insurance, disaster management, climate change monitoring, etc. Sentinel data are thus a key component of the [Copernicus Services](#), and a crucial source used by companies to deliver products and services helping different users across the Globe.

1.2 What is the Case all about?

Potatoes are very important for Belgium! Pommes frites or more appropriately Belgian Fries are at the heart of a very important part of the Belgian industrial sector. As a key grower of potatoes, Belgium occupies an important position on the world stage (8th in rank worth around €180m). But as an exporter of processed potato products, Belgium stands at number 1 and in 2017, Belgian exports of potatoes products was worth over €2b to its economy¹.

Belgium has developed a full processing chain based upon the humble potato and it is this aspect which make the case so interesting. Both potato growers and industrial processors are well-represented, and the strength of the latter is of key importance. As a result, a new service has recently been introduced, developed by VITO and sponsored by Belgapom and Boerenbond (see chapter 4), called Watch-it-Grow (WIG). This service is aimed at farmers to the benefit of the whole industry, to improve yields and reduce costs.

The service Watch-it-Grow (WIG) takes data from Sentinel 2 to provide the farmers with information on the growth in their fields. But it also assimilates many other data which is what makes it particularly interesting for the potato processing industry. For sure, the inclusion of in-situ data is extremely important for the uptake of the application. WIG has now operated for 3 years and is evolving both in technical terms and in business terms as we shall see throughout the case.

Potatoes are one of the few crops not covered by the European Common Agricultural Policy (CAP). For this reason, as well as the fact that both growers and the industry are distributed throughout the country, policies linked to potatoes are largely managed at the federal level. So, the humble potato also plays a political role in this complex country.

¹ <http://www.worldstopexports.com/potatoes-exports-by-country/>

The case analysis is based on a number of assumptions which are visible and open to challenge by experts more knowledgeable in the industry than us. Calculating the benefits of the service is already quite hard. Extracting and calculating the value of the satellite data is even harder and assumptions are used quite widely. These are open for challenge and we encourage any reader to contact us at info@earsc.org if they think the assumptions are unreasonable for any reason.

1.3 How does this case relate to others?

This is the 1st case linked to potato growing and the third linked to agriculture; other farming cases are developed for cereal growing in Denmark and Poland. There are some similarities but many differences between cereal and potatoes as crops which will be discussed during this report. The growing seasons differ, the productive parts of the plant differ (over-ground and underground respectively) and the farming practices are different. Nevertheless, they both involve farmers seeking the best return from their agriculture land as well as the use of chemicals on the fields.

But one characteristic stands out, which is the relationship between the players in the value chain. Potatoes are a high value crop, but which is extremely sensitive to disease and to the condition at harvest. The processing industry which turns the potatoes into fries, potato crisps and many other products follows closely the farmer and maintain a close relationship with them. In this respect, the “potato value chain” is fully involved in the use of WIG and has much more to gain than the value-chain for cereals where we see the high value for the farmer, some for the community, but little value extending down the value chain to processors due to the very large market for cereal products.

1.4 More About the Study

Each case study analysed in SEBS, focuses on products and services which use data coming from Sentinel satellites, measuring the impact of that product or service throughout the value chain. The starting point is the primary user of the satellite data, followed by a step-by-step analysis whereby the operations of beneficiaries in each subsequent link of the value chain are analysed, all the way down to citizens and society.

In this process, the main aim is to understand and demonstrate the value which is generated using satellite-based Earth Observations (EO) and particularly the data coming from the Copernicus Sentinel satellites. Each case study thus underlines the causal relationship between the use of Copernicus Sentinel satellite data and benefits resulting from their use, including increased productivity, more efficient and environmentally friendly operations, economic gains and improved quality of life, among others. The evaluated and demonstrated benefits can be used by:

- **Decision makers:** Having access to a portfolio of concrete cases where the benefits from the operational use of Sentinel data in decision making are clearly articulated, helps

decision makers not only to justify future investments but also to direct them towards areas that most matter in their country or organisation.

- **Users:** Moving beyond a vague idea of how EO services can support more effective operations requires a concrete understanding of the benefits they can actually bring in similar cases. In this regard, it is both numbers and stories that can resonate with users and attract them to explore further or deeper uses of EO in their operational activities.
- **Service providers:** Solid argumentation around the economic and environmental benefits stemming from the use of EO, coupled with powerful storytelling, can become an effective marketing tool for service providers seeking to promote their solutions and for EARSC to promote the sector.

In the framework of this project, 20 case studies will be developed with reports to be published on each one. The study has started in March 2017 and will end in mid-2021.

1.5 Acknowledgements

We wish to thank the following persons for their time spent talking with us to develop the case. In particular, we are grateful to Jürgen Decloedt and Romain Cools who gave us much of the background and introduced us to a number of the experts we have consulted including many informal meetings which took place at the biennial Interpom – the largest trade fair dedicated to the potato in the world!

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- Nele Cattoor – Regulatory Affairs Manager, Belgapom
- Jean-Pierre Goffart – Head of Central services, CRA-W (Agriculture Research Centre – Wallonie), and Vice-president FIWAP.
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- Yannick Curnel – Scientific Associate, CRA-W (Agriculture Research Centre – Wallonie)
- Koen Vaneyck – Farmer & WatchITgrow user.
- Pierre Lebrun – Agronomist, FIWAP (Walloon Association for Potatoes)
- Daniel Ryckmans – Associate, FIWAP (Walloon Association for Potatoes)
- Maria van de Vin – Agronomist, Agristo
- Steven de Cuyper – Agro Director, Agristo

2 Potatoes and the Belgian Economy

2.1 The Potato's Importance to Belgium

Although often flying under the radar of the general public, the potato industry in Belgium with its associated sectors and elaborate value chain plays a significant role in the Belgian economy. The potato is the second largest cultivated crop after grain in Belgium and has experienced substantial growth over the last years. Many farmers are switching to growing potatoes, but the real story, lies with the processing industry and the links it has with the growers.

Globally, the sector is evolving significantly. The total world potato production is estimated at 388,191,000 tonnes in 2017 (Source: FAOSTAT, 2019). Until the early 1990s, most potatoes were grown and consumed in Europe, North America and countries of the former Soviet Union. Since then, there has been a dramatic increase in potato production and demand in Asia, Africa and Latin America, where output rose from less than 30 million tonnes in the early 1960s to more than 165 million tonnes in 2007. FAO data show that in 2005, for the first time, the developing world's potato production exceeded that of the developed world. China is now the biggest potato producer, and almost a third of all potatoes are harvested in China and India, see Figure 2-1.

Rank	Country	Potato Production in 2017 in tonnes
1	 China	99,205,600
2	 India	48,605,000
3	 Russian Federation	29,590,000
4	 Ukraine	22,208,200
5	 United States	20,017,400
6	 Germany	11,720,000
7	 Bangladesh	10,216,000
8	 Poland	9,171,730
9	 Netherlands	7,391,880
10	 France	7,342,200
11	 Belarus	6,414,760
12	 United Kingdom	6,218,000
13	 Iran	5,102,340
14	 Turkey	4,800,000
15	 Peru	4,776,290
16	 Algeria	4,606,400
17	 Belgium	4,416,660
18	 Canada	4,410,830
19	 Egypt	4,325,480
20	 Pakistan	4,142,400

Figure 2-1: Global Potato producers - top 20.

Potatoes are an important crop for Europe as well as for Belgium. Total EU production of 56mT in 2017 puts the region in 2nd place globally and in the so-called 'European potato belt' including the countries of France, United Kingdom, Germany, the Netherlands and Poland, Belgium stands out

due to its central location and thanks to its highly efficient potato cultivation and highly specialised processing companies at the heart of the belt.

The key to Belgium's leading position is the frozen potato processing industry. To supply the factories, on top of its own large-scale potato production, Belgium imports potatoes from its neighbours to supply these highly specialised processing companies, and, partly as a result, Europe stands second in the world production rankings for potatoes.

Belgium then exports most of the processed, frozen potatoes in the European and world market, profiting from the open borders within the EU Single Market and its central position therein. Thanks to the potato's, or fries', popularity, the potato has thus become a national symbol and also a clearly recognisable cultural object. Figure 2-2 shows Belgium's central position within the potato belt.



Figure 2-2: European potato belt with major processing companies

Economically, the potato sector ties the countries of potato belt closer together as the sector is operating transnationally and the potato business is cultivated on a large scale. In 2014, c. 550,000 ha of potatoes were cultivated in this region – out of that, about 92,000 ha of potato area were harvested in Belgium². The cultivation activities around the potato growing are thus highly concentrated in the region, bringing other key actors of the value chain including processors, traders, washing and peeling companies, packaging, equipment manufacturers, shed

² <https://www.potatopro.com/belgium/potato-statistics>

construction, storage facilities, large-scale ventilation systems and many others. This really shows that the potato business is big business in Belgium!

Belgium has a rich potato history and since the end of the 20th century has experienced spectacular growth. In 2012, Belgium ranked No. 23 among the world's potato producing countries, with an output of just over 2.9 million tons. Thanks to an average yield of 42 tons per hectare (2005), the potato is the country's main food crop, even though the cultivated area is less than 5 percent of total farmland. In 2018, the exports of processed potato products continued to grow and passed 5mT for the very first time as a result of strong investment in the sector. This success will bring a challenge to the sector in 2019 as the very dry summer of 2018, reduced the potato crop both in quantity and quality.

In 2017, Belgian potato growers rank 8th in Europe and 17th in the world with production exceeding 4.4mT for the first time (see Figure 2-3). This is already good for a country the size of Belgium but after processing, Belgium is ranked first for the export of processed potatoes (Figure 2-4) just ahead of the Netherlands; a position which is highly contested between the two countries!

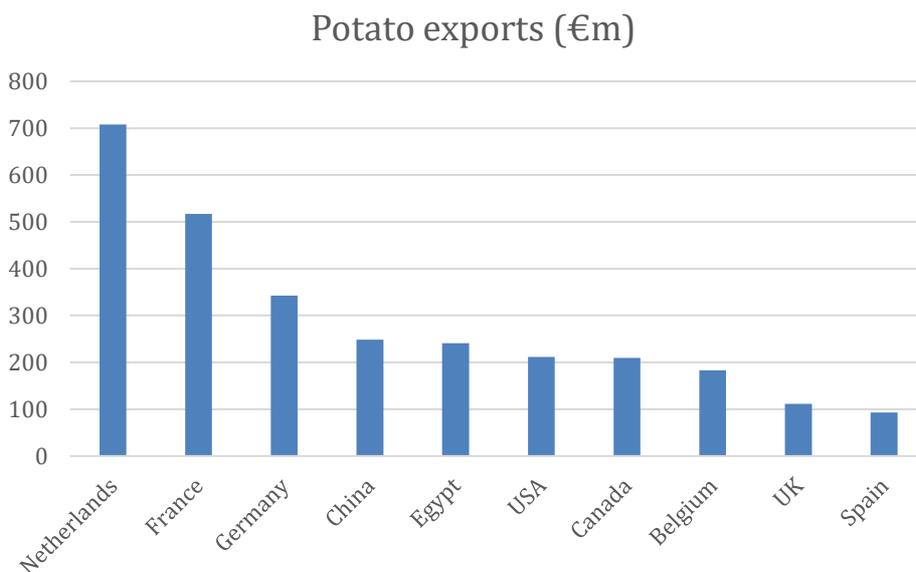


Figure 2-3: Potato exports in 2017 (€m)

The successful formula is made up of the rich soil and the mild climate which are ideal for growing potatoes. These circumstances, combined with professional skill, lead to an excellent quality potato. The perfect basis for a wide range of potato products such as the original Belgian fries, mashed potato, flakes, granules, crisps, etc. which are known far outside Belgium. In 2017, export outside Europe already represented a quarter of the total export of Belgian potato products.

According to Europatat³, potatoes belong to the most competitive segments of EU agriculture. In 2017, 62 million tonnes of potatoes were harvested in the EU, up by 12.4% compared to the

³ <https://europatat.eu/activities/the-eu-potato-sector/>

average of the 5 previous years, and 10.9% compared to 2016. Belgium contributed 8% to this total.

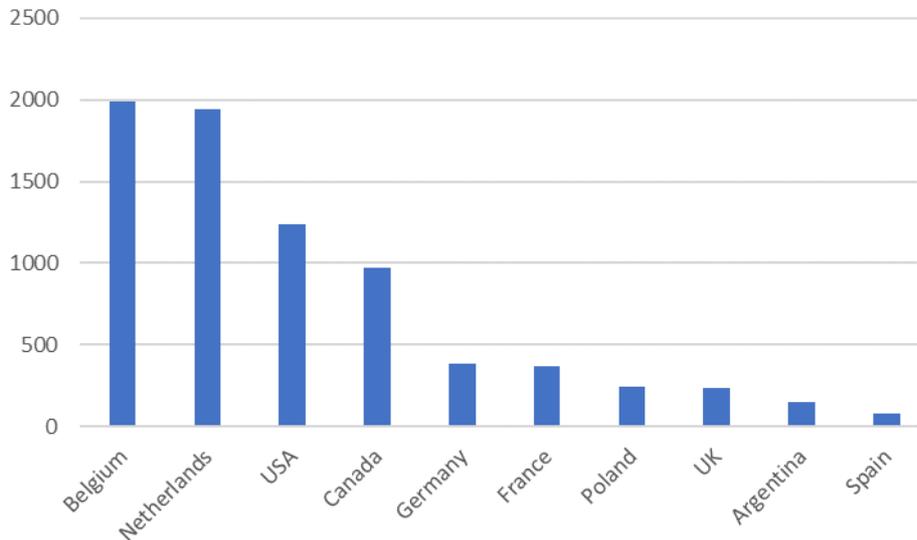


Figure 2-4: Exports of Processed Potato products (€m)

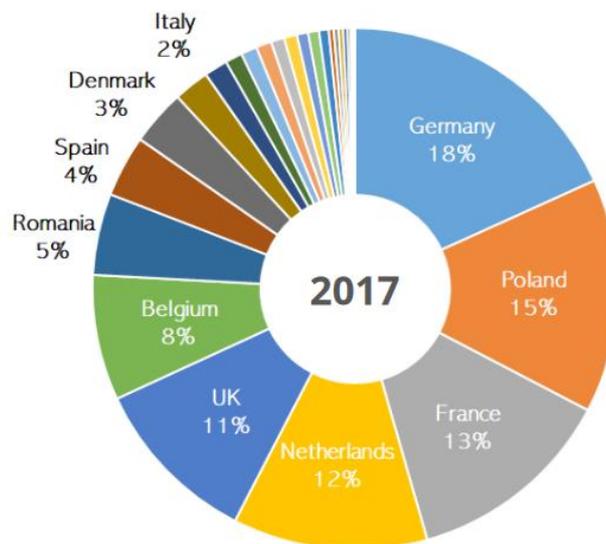


Figure 2-5 Share of Potato Production in the EU. © Europatat Annual Report 2017⁴

The growers and the processing industry are closely linked, creating a cluster in the country and indeed in the region. The synergy and the role that satellite data may play in stimulating growth lies at the heart of our story.

⁴ https://europatat.eu/wp-content/uploads/2018/05/Europatat_Annual_Report_2017-2018_web_.pdf

2.2 The Potato Sector in Belgium

Potatoes are grown both for the fresh market or for processing into refined products. Even if the former is also an important part of the overall picture, it is the latter which is of greater importance to this case since it generates most of the value-added and is crucial for the Belgian potato cluster.

Around 6-7% of Belgian potatoes are eaten fresh - about 86 percent are processed into crisps, frozen fries, starch and other products. It is important to note that fresh potato market has a very distinct value chain separate from the processing market whereby very specialised farmers work with highly specialised packers and retailers⁵. In 2006, the country exported more than one million tonnes of processed potatoes and 21 000 tonnes of seed potatoes. It also imported more than 1.2 million tonnes of fresh potatoes and 140 000 tonnes of potato products, mainly from France, Germany and the Netherlands. (Source: International Year of the Potato)⁶.

Given the importance of the Belgian potato sector and its long history, the sector has developed a rich institutional and highly organised structure with many research centres and extension services for farmers, interest groups, trade associations and policy-making organisations. An important aspect that is reflected in the organisation of the potato sector is the federal structure of Belgium.

Belgium is a country with three main regions (Flanders, Wallonia and Brussels) and three recognised languages (flemish, french and german). This gives rise to multiple levels and often overlapping governments and administration. The importance of the two major regions, Flanders and Wallonia, means that most types of organisations active in the value chain can be found in both regions along with research and institutional actors. The administrative reform of 2001 had a profound impact and led to the division of many organisations including in the potato sector⁷. As the reform advanced the federalisation of the Belgian state and transferred more competences (including over agriculture and fisheries) from the federal authority to the Communities and Regions, this resulted in the split-up of some federal organisations into a Flemish and Walloon entity.

The potato sector does not "stop" with the potato growers in Belgium. The sector comprises a diverse range of actors that are key to the potato industry and the value chain as we shall describe in chapter 4. Belgian companies are highly specialised, international leaders and highly competitive. The sub-sectors include the processing industry with companies such as Lutosa and McCain, machinery and equipment industry, storage facilities and ventilation systems, potato washing, peeling and cutting as well as packaging.

It is a sector that finds itself at the crossroads between tradition and modernity which seems to be a balancing act. The sector is currently undergoing an evolution towards more specialised farms with more and larger fields. Overall, employment is increasing but the number of workers

⁵ <https://www.dhnet.be/regions/mons/borinage/frameries-le-ministre-di-antonio-sort-du-silence-sur-le-projet-clarebout-5c9e1694d8ad58747730f51c>

⁶ <https://belgapom.be/en/blog/>

⁷ The Potato in Belgium, the Land of Fries (published by *Belgapom*)

per farm is reducing. It is a sector that is turning increasingly towards professionalisation and mechanisation using tools such as GPS equipment, self-driving tractors, digital tools as well as bigger better equipped machines - a development that is sometimes overwhelming for (often older) less technology savvy farmers. While for instance digital applications or computer-assisted and GPS-controlled machines are used more commonly for higher efficiency and quality levels enabling a more targeted and location specific operations, these new innovations bring new diverse challenges such as digital skills competences on the side of the farmer or heavier machinery risking soil compaction and sealing.

This degree of common interest between the various players in the value-chain as well as those in the coming under different, regional administrations, is leading to an effort to establish a “branch”. This will be an organisation platform bringing together all the interests in the sector. By opening a sustained dialogue, it is hoped that the branch will be able to overcome tensions in the value-chain and allow decisions to be taken which will maximise the production in Belgium, allow more investment in the sector and generate higher exports sales for the country. The branch is in the process of being formed as this report is written.

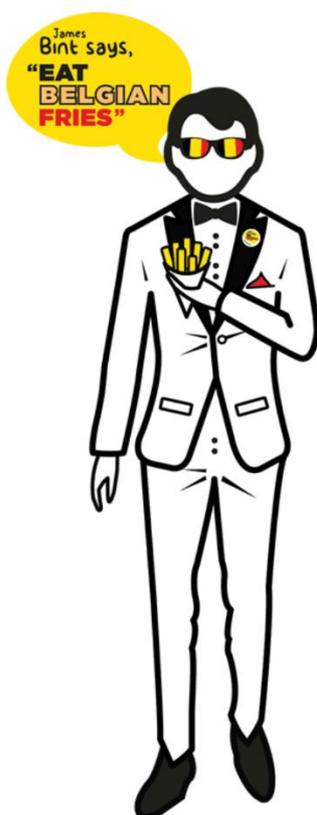


Figure 2-6: James Bint

2.3 The Potato Processing Industry

During the past few years, the Belgian potato industry has developed into one of the fastest growing sectors in the Belgian food industry.

While the number of processing plants has remained stable from 2016 to 2018 with one currently under construction⁸, the number of workers and employees has steadily increased over the last three years from 3,257 to 3,701 and 858 to 1,061, respectively as shown in Figure 2-7. On top of that, investments have been increasing greatly and hit a record-breaking level of almost €311m⁶ in 2018. This has led to yet another record-breaking year in 2018 when over 5mT were processed.

Trade plays an important part in the potato sector. As local supply cannot satisfy local demand coming from the industry, Belgium imported about 1.587 million tonnes of consumption potatoes in 2013, representing an increase by 61% over 10 years. These large, and constantly increasing, imports function as gap fillers to the Belgian supply for Belgian processing companies which need increasingly

large quantities of raw materials to produce chips, crisps, etc.

At EU-level, potatoes are traded mainly on the EU internal market; however, the sector shows also a competitive advantage internationally, especially in the sub-sectors of seed potatoes and processed products. Furthermore, the EU is a net exporter of

⁸ https://www.belgium.be/en/about_belgium/country/history/belgium_from_1830/formation_federal_state/fifth_reform_of_state

potatoes: in 2017, it exported 1.2 million tons worth around EUR 500 million. These were mainly seed potatoes (70% in value and 55% in volume) and some crop potatoes (30% in value and 45% in volume). The EU is also a net exporter of processed potatoes⁴.

Belgapom⁹ is the recognised association for the Belgian potato trade and processing industry and a major promoter of the sector. In 2015, James Bint “Licensed to Fry” was introduced as the International ambassador of Belgian Fries¹⁰.

As would be expected given the impact of factors such as weather and climate conditions, exports by the Belgian potato sector fluctuate. In 2017, the volume was 838,000 tons compared to a peak in 2004 of about 900,000 tons. Thanks to its central location in the western European cultivation area, Belgian potato trade is a driving force in the European market. Figure 2-8 shows the global potato trade and the internal EU potato trade highlighting the interconnectedness inside Europe. It also shows the major export markets in South America as well as Southeast Asia.

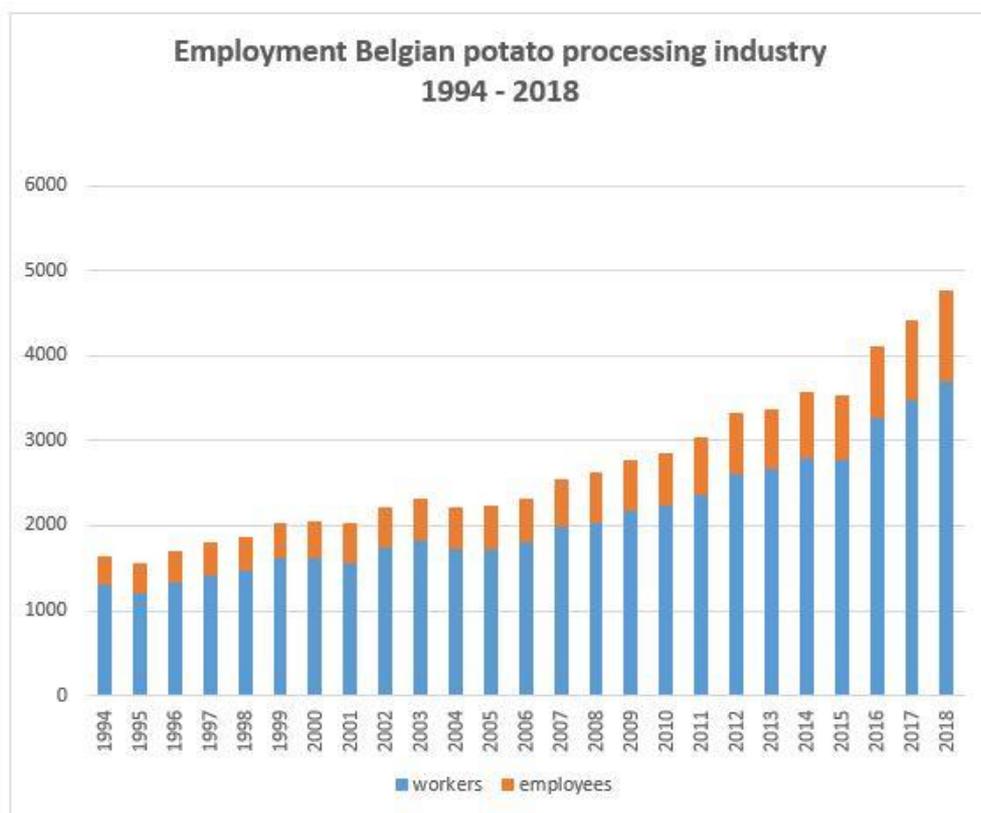


Figure 2-7: Employment growth in the Belgian potato processing industry

⁹ <https://belgapom.be/en/home/>

¹⁰ <https://jamesbint.be/>

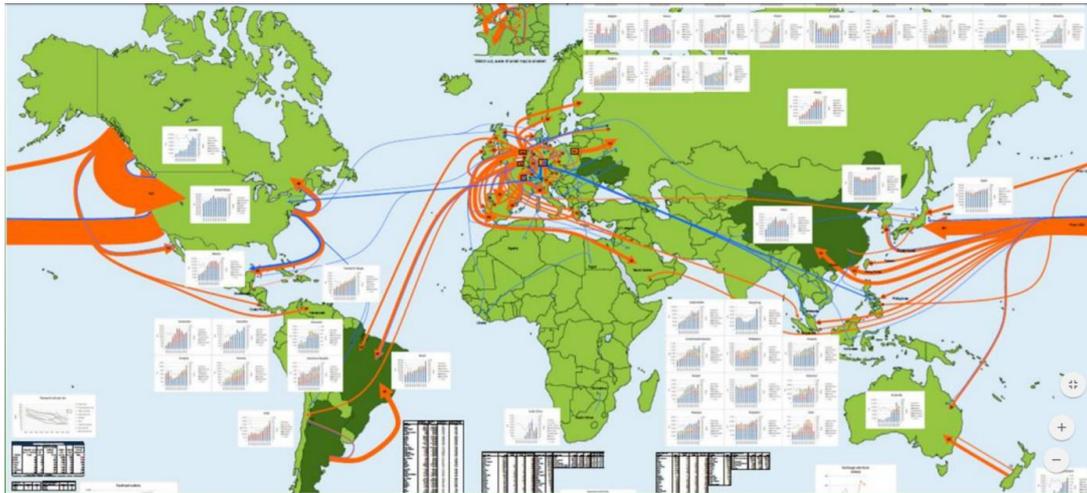


Figure 2-8 World potato trade of processed potatoes¹¹

2.4 The Potato Growers

Belgium is both in the vanguard of the European potato belt countries as well as the global leader in yield per hectare (ha). In 2014, Belgium potato growers achieved a remarkable yield of over 56 tonnes per ha for all varieties combined and a total of slightly more than 4m tonnes. Whilst the Bintje variety, one of the most common in Belgium, obtained c. 55 tonnes per ha, other very typical varieties such as Fontane, Innovator and Challenger achieved over 60 tonnes per ha. These record levels were underpinned by an increase in the agricultural potato area to about 90,000 ha in 2014 which is considered the maximum by some interviewees for sustainable potato cultivation in Belgium. After two weaker years in 2015 and 2016 due to mainly very wet springs that are detrimental for potato cultivation, 2017 was a record-breaking year with a total of 4.4 million tonnes in Belgium thanks to good climatic conditions, the expansion of the agricultural area (see Figure 2-9) and the high yields per ha.

¹¹ <http://media.repro-mayr.de/15/573215.pdf>

Development of Total Potato Area Harvested in ha in Belgium

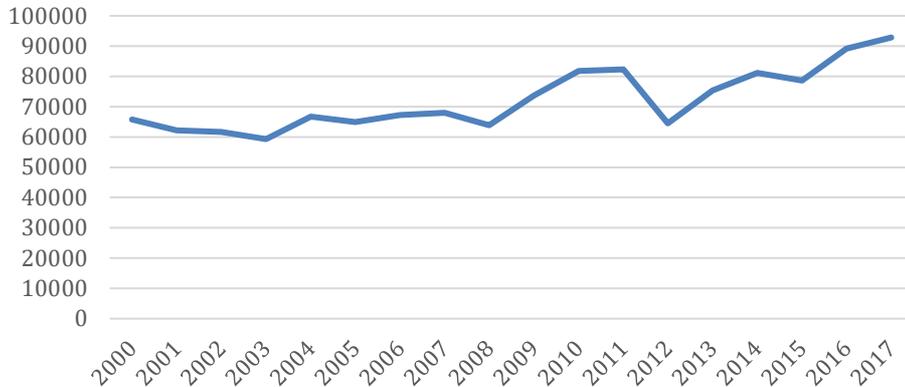


Figure 2-9: Evolution of the potato growing land in Belgium

A factor that considerably benefits the productivity and efficiency of the Belgian potato cultivation is the natural preconditions in Belgium. The temperate maritime climate is ideal since it shields the plants from extreme temperatures and ensures that potatoes find themselves in a long growing season where they are provided with enough rainfall and hence good yields. Moreover, the Belgian soil is ideal for potato plants such as loamy or sandy-loamy¹².

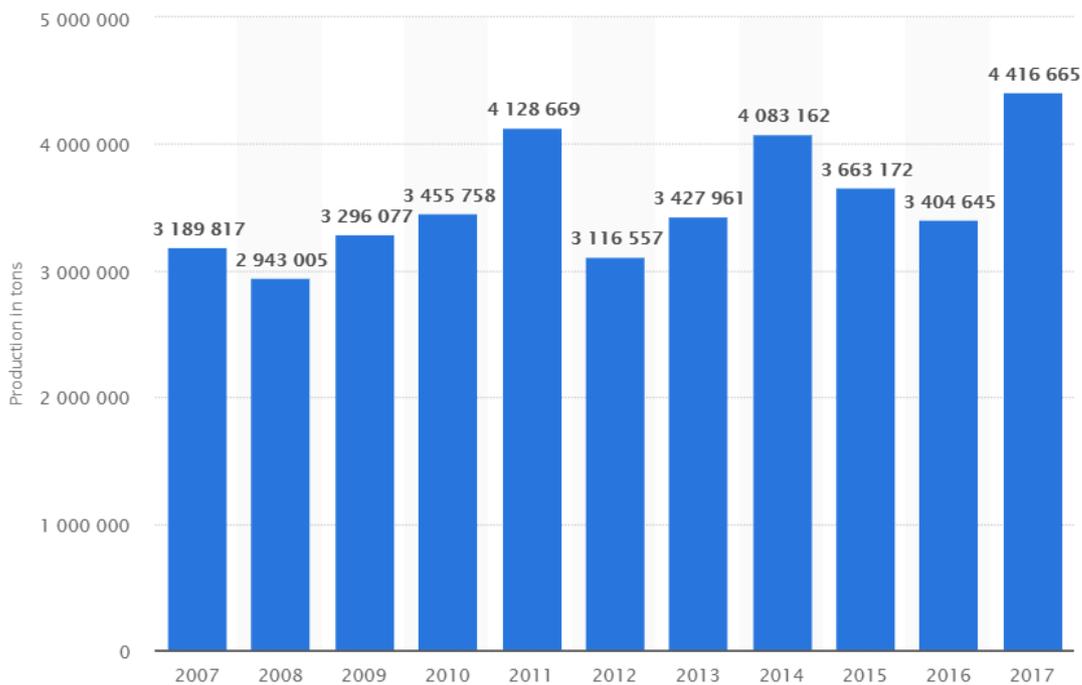


Figure 2-10: Production of potatoes in Belgium from 2007 to 2017 (in tons). © Statista 2019

¹² <https://www.potatopro.com/belgium/potato-statistics>.

It must be noted that potato farmers do not fall under the Common Agricultural Policy (CAP)¹³ and hence do not profit from CAP funds. The sector has only very little regulation and follows the principles of a very free commercial market which means that lots of pressure is diverted up the value chain and on to the potato farmers themselves. Since they are being subject to high fluctuations and seasonal changes due to changing weather conditions, high pressure is on the potato farmers to deliver good products.

Given the domination of the Belgian processing companies, within the potato sector and the decline in fresh consumption and exports, potato farmers are under immense pressure to deliver their product at a low price. There is a constant tension between the upstream and downstream parts of this value-chain. Belgian growers cannot meet all the needs of the processing companies which, consequently, import supplies mainly from France, but also from the Netherlands and Germany.

As a result, supplier competition from the potato belt (BE/FR/GER/NL/UK) puts further pressure on Belgian farmers to provide good yields at attractive prices. The Belgian potato sector is also special in the sense that the sector operates through very high numbers of intermediaries and traders who purchase the potatoes from the farmers and then sell them to one of the key actors mentioned above such as processors, packaging companies etc. However, direct sales between farmers and for instance processors – as is already common practice in the rest of Europe – is gaining traction.

Like the fluctuating potato production, the price of the potato in Europe has been fluctuating quite a bit over the last years and is highly variable from year to year both on farmers and consumers markets. The sales price of potatoes not only fluctuates significantly over time, but also across countries and types of potatoes as can be seen in Figure 2-11. Whilst the highest price for potatoes was paid in Greece, Belgian farmers received 4.8 times less than their Greek counterparts.

The Belgian potato season can be divided into two parts. The early season lasts approximately from the end of June to the end of August. The cultivation of early potatoes takes place in sandy soils mainly in Flanders where farmers can choose between a number of early varieties suitable for chips with a shorter growing season. Potatoes that can be kept an entire season if stored professionally are harvested from August to October and then stored from November to the end of June/beginning of July¹⁴. Some of the processors indeed own storage facilities – the biggest capacities can be up to c. 10,000 tonnes of storage per processor such as the ones from Clarebout. The impact of storage capacities on the negotiations between farmers and processors is probably quite low given that for instance Clarebout processes a total of c. 1,5m tonnes of potatoes per year.

¹⁴ <https://belgapom.be/en/belgapom-quotation/>.

	Main crop potatoes			Early potatoes			Seed potatoes		
	2013	2014	2015	2013	2014	2015	2013	2014	2015
Belgium	14.8	2.7	10.0	27.3	5.1	12.9	.	.	.
Bulgaria	23.9	20.4	19.8	.	.	.	.	.	.
Czech Republic	22.4	17.7	16.6	31.7	21.4	25.3	25.4	28.8	23.9
Denmark	23.0	24.1	25.6	.	.	.	28.2	28.2	23.0
Germany	24.7	15.4	12.8	52.0	18.0	.	.	.	.
Estonia	.	.	.	.	.	.	.	.	.
Ireland	.	.	.	.	.	.	.	.	.
Greece	53.8	44.8	47.9	57.9	46.5	49.2	29.0	26.4	24.1
Spain	33.9	11.2	19.8	60.4	27.3	35.4	.	.	.
France	67.1	36.7	43.7	141.0	.	139.6	43.1	47.3	38.3
Croatia	22.4	15.5	14.4	42.4	22.6	30.4	64.1	59.6	62.7
Italy	47.3	37.1	35.9	.	.	.	.	.	.
Cyprus	28.8	25.7	.	.	.	.	67.7	64.5	.
Latvia	15.8	15.9	13.6	20.2	27.7	23.8	26.2	29.2	26.6
Lithuania	17.2	15.4	11.5	21.4	21.0	23.5	.	.	.
Luxembourg	38.1	20.8	31.2	.	.	.	17.8	13.1	13.1
Hungary	27.1	19.3	21.6	34.2	23.0	29.9	88.6	.	.
Malta	36.5	28.3	32.7	.	.	.	.	.	.
Netherlands	19.6	10.2	11.5	.	21.1	38.7	27.6	27.9	24.6
Austria	25.6	12.3	18.9	30.6	15.7	22.8	.	.	.
Poland	15.4	12.4	12.2	12.8	10.8	11.8	22.8	25.5	23.0
Portugal	32.8	15.2	18.6	54.0	26.4	28.1	.	.	.
Romania	40.1	34.4	27.0	33.9	25.2	25.0	.	.	.
Slovenia	32.7	16.5	13.1	53.8	28.8	31.6	46.7	.	.
Slovakia	26.1	26.8	24.7	36.9	29.8	32.1	.	.	.
Finland	23.8	14.6	17.7	36.3	45.9	46.2	.	.	.
Sweden	32.5	26.6	27.2	41.4	33.5	35.6	.	.	.
United Kingdom	25.0	17.8	19.6	45.2	38.7	63.6	.	.	.

(.) data not available

Figure 2-11: Annual agricultural selling prices for potatoes (in EUR/100kg). © Eurostat 2019

Potato growers, dealers and processors can sell their potatoes both during the early and the storage season in several ways. There are two main ways to market the potatoes. In production contracts which make up about 70% of production, farmers engage in forward selling meaning they sell a certain amount of the expected potato harvest to the buyer ahead of the start of the growing season. The second option is the more conventional way of the free market (the remaining 30%) where contracts can be concluded with immediate or later delivery (within days or months later, respectively).

The practice to sell forward their crops helps the farmers with cash flow and financing investments, but it also creates risk when conditions and harvests are poor. If their final crop is not sufficient to cover their supply contract, they must go onto the open market and buy in stock to meet their obligations. This encourages potato traders to enter the market and as a result there is quite an open market for potatoes in Belgium which raises strong interest in the price.

For reasons of transparency, several quotations (e.g. from [PCA-FIWAP¹⁵](#) or [Belgapom⁹](#)) exist in Belgium to inform market players about the latest developments on the free market price of the potatoes. As regards the Belgapom quotation for instance, once a week, a committee of dealers and processors who buy and sell potatoes every day quote the most used price on the day before the quotation for the Bintje variety - as it is the most important variety on the free market. The quotation also offers insights into the general market mood and is a tool for both buyers and sellers to better understand the dynamics of the free potato market. Recently, a quotation is given for the most relevant freely traded fries varieties Fontane and Challenger. The quotations

¹⁵ <https://www.pcainfo.be/fr-fr/Aardappelprijs/PCAFiwap-notering>

are important to create transparency as virtually all market players including growers, dealers and processors are following the market using both contract and free market sales¹⁶.

2.5 Future Growth and Development

Growth in the potato sector in the future will not derive from an extension of the agricultural area for potato cultivation. In the European potato belt, potato cultivation has enlarged to such an extent over the last decades that any further switch from any crop to the potato crop is very likely to result in soil degradation and soil depletion. Thus, a higher output and growth can be achieved through making better and more effective use of the current utilised agricultural areas for potatoes. Currently, Belgian potato fields have an output of between 45-55 tonnes/ha. We have heard in interviews that the estimated maximum output is about 100 tonnes/ha. This higher supply can only result from better, more sustainable and more effective farm management practises.

Furthermore, in the long-term, growth and the demand for products will not be stimulated by the local industry given changing food trends and habits in Belgium, but internationally by a growing Asian market demand with a 'big appetite' for processed potatoes. This means that the international potato trade is likely to intensify over the next decade. It also seems likely that imports of potatoes as well as exports of processed potatoes will increase given increasing global demand. Locally i.e. in Belgium, growth will be driven by even higher market concentration and economies of scale as the sector is witnessing a trend whereby smaller farms are bought up by bigger farming corporations leading overall to less farms with larger fields. Highly specialised companies in the value chain will continue to grow and be the job engine of the potato sector¹⁷.

The sector is already showing a high degree of maturity and saturation. Further growth may stem from continued professionalisation, specialisation and digitalisation of farms. As we heard during our interviews, extensive cooperative thinking among farmers is not yet visible on a large scale and remains the exception. Sharing expertise and lessons learnt could trigger the dissemination of best practices and stimulate further growth. Furthermore, it has been mentioned that more farmers need to join organisations to stay informed about the latest technological progress and innovations.

2.6 Climate and Environmental Considerations

The weather has always been a major factor for farmers driving many daily decisions and strongly affecting the overall farm performance. Changes in the weather and especially long-term changes associated with the climate are possibly already being felt in the potato sector.

¹⁶ <https://belgapom.be/en/belgapom-quotation/>.

Potatoes are a crop which is very sensitive to abrupt changes in environmental and weather conditions. Potatoes are a very hungry crop and also a thirsty one. But paradoxically, because they lie in the ground, they are equally sensitive to too much water as to too little. For instance, a crop which is flooded will be completely lost if the potatoes lie under water for more than 24 hours. Hence extreme events by way of storms are damaging to the potato crop.

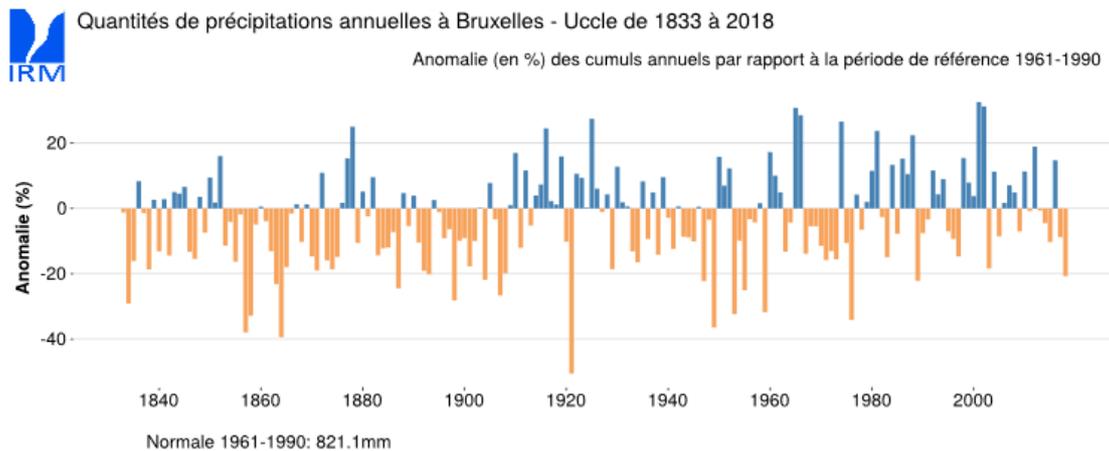


Figure 2-12: Annual rainfall compared to the average reference period 1960-1990¹⁸.

Figure 2-12 shows the annual average rainfall and the 2 last years with below average. What the average does not show is that the drier periods occurred during the summer when the growing potato most needs water.

Similarly, rising temperatures exacerbate the situation as evaporation is higher and water retention in the soil is poorer. The average temperature for Belgium, shown in Figure 2-13, indicates the rise apparent right across northern Europe.

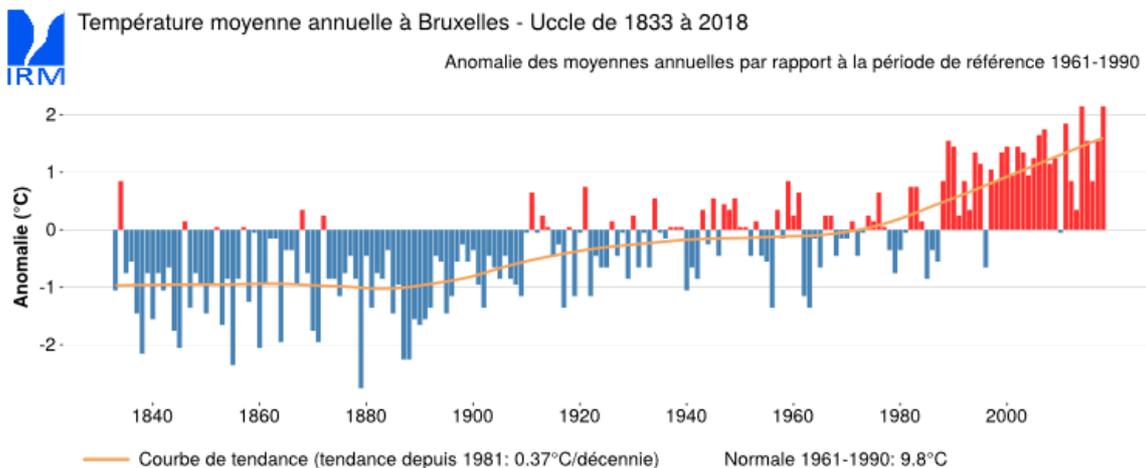


Figure 2-13: Average annual temperature in Belgium 1833 to 2018¹⁸.

Climate instabilities impact on the yield also in another way. Long and wet periods followed by drought or vice versa induce slowed growth followed by renewed growth: this leads to secondary

¹⁸ <https://www.meteo.be/fr/climat/tendances-climatiques-observees/en-belgique>

tubers growing alongside the main one i.e. it results in 2 small tubers rather than 1 larger one thus reducing the size of the potatoes if not the total mass. This is a major problem for the sector and any help to increase the awareness of the conditions and the likelihood that secondary growths will occur is regarded as extremely beneficial.

Harvesting before a heavy wet period can increase the storage capability of the crop. Extreme weather events place a stress on the potatoes which can seriously impact their resistance to disease during storage. In 2018, the crop was reduced by 30% due to drought. This is leading to investigation into irrigation and the development of necessary infrastructure.

The use of satellite data is anticipated to lead to reduced application of fertiliser by providing more accurate data on the intra-field growth. Fertiliser is applied before the crop is planted at a rate of around 200kg per ha. The experience of the farmer coupled with soil samples will help adjust the rate of application, but which is generally uniform through the fields. Historic data on the field yield can be used to adjust the rate of application. A second application is usually made in June as the leaf growth accelerates and satellite data can help assess how much nutrient to apply and where.

Potatoes are also very sensitive to disease and especially potato blight which can wipe out the crop within a few days of infection. For this reason, much of the research and support has developed for the sector in Belgium to help mitigate against the extreme climatic impacts especially through a better identification of appropriate timing of harvesting. As the impact is so damaging, spraying against blight is made automatically up to 14 times in a single season. Better digital awareness and satellite information can potentially reduce the spraying to a limited degree.

More regular satellite observations will be needed to have a stronger impact on the spraying decisions. One advantage is the ability to observe a wider area and hence to “see” whether blight is affecting crops in the neighbourhood.

At harvest, chemicals are sprayed onto the crops a few days before harvesting begins. This kills the leaves and reduces the volume of the crop making it easier to separate out the potatoes. The current chemical used is to be banned after 2019. Researchers are looking at other means to achieve the same effect, but it remains to be seen whether satellite-derived data can help in this process.

In the next few years, chemical used to prolong storage is likely to be banned and hence the knowledge of the state of the harvest will become even more important as an aid to decision-making.

3 The Use of Sentinel Data

3.1 General Introduction

Sentinel imagery is used by farmers and the industry in Belgium as part of a new service called WatchITgrow. WatchITgrow (WIG) is a geo-information platform that has been developed for the Belgian potato sector with the objective of estimating and increasing potato yields in a sustainable way. Through the platform, Belgian potato farmers, agronomists, traders and processors have access to data and information on the growth of different potato varieties comprising Fontane, Bintje and Nicola – the most common potato varieties in Belgium.

The platform centralises several types of data. It combines data coming from the Copernicus Sentinels and other satellites, drones, weather and soil measurements as well as integrates external models to generate yield prediction models. Thanks to the platform, the user can gather information about one or multiple potato fields and is able to:

- Access information on the state of the crop
- Monitor the potato crop in function of growth, health status and development
- Map spatial variability within the field
- Improve yields
- Estimate the harvest date and yields during the season
- Reduce production and quality losses

The platform is the product of the 3-year research project iPot¹⁹, a collaboration between researchers from Flanders and Wallonia (the Flemish Institute for Technological Research (VITO), the Walloon Agricultural Research Centre (CRA-W) and the University of Liège (ULg)) together with the Belgian potato trade and processing industry association Belgapom²⁰. Rebranded as *WatchITgrow* since its operational use, it allows farmers and agronomists to both detect changes in the fields pointing to the conditions of the crop and centralises and compares current data with historical data.

Satellite imagery from the Copernicus Sentinel-2 satellites is used to map the vegetation and especially its change over time. Each time the satellites pass over Belgium, fresh imagery is provided and processed in an automated fashion using machine-learning algorithms to generate up-to-date assimilated vegetation maps which are at the core of the management platform. Other data is being fed into the application such as temperature and rainfall data collected at weather stations and processed by the Belgian Royal Meteorological Institute, in-field data and observations such as location, planting data, planting density etc. with the support of farmers as well as AquaCrop²¹, a crop growth model developed by the Food and Agriculture Organisation of the United Nations (FAO).

¹⁹ For more information on the iPot research project, see here:

<http://www.belspo.be/belspo/Fedra/proj.asp?l=en&COD=SR%2F00%2F312>.

²⁰ Here you can trial the application and find more information: <https://watchitgrow.be/en>.

²¹ More information on AquaCrop can be retrieved here: <http://www.fao.org/aquacrop>.

Currently, the application is used by about 600 active users comprising farmers, agronomists and the industry. While the current strategy is to build up reference customers first, the application will soon scale-up its geographical coverage and expand into neighbouring countries the Netherlands and Germany.

3.2 How do satellites help potato farmers?

Satellites are benefitting agriculture in several ways, initially as a way of estimating crop yields, but increasingly we can see more and more decision support tools for precision agriculture coming on the market that are based on satellite imagery. Optical sensors such as on the Sentinel-2 satellites provide data that enable a precise overview of the cultivated fields, while also being able to distinguish between crop types and determining the health and maturity of the crops. This information does not only help the farmer to make the right decisions in his operations, but also to inform other market players such as agronomists and the industry to provide expected yields or early warning of crop failures so that they can adjust their planning and logistics. Policymakers can use the data to generally improve agricultural policymaking.

As a decision support system, satellite-based applications can be used as an information or management tool that supports and guides the farmer's business or organizational decision-making activities through the practice of precision agriculture. Satellite imagery is used to describe farmer's fields in detail, often combined with geographical information systems (GIS), to allow more intensive and efficient cultivation practices.

Furthermore, farmers are profiting from a satellite (r)evolution that has taken place over the last few years.²² Satellites have become both more numerous and smaller, and at the same time have increased spatial and temporal resolution providing both more details and more frequent images, respectively. This development has resulted in a trend of satellite images from being previously very expensive to ever cheaper data provision. Moreover, the free and open data policy of the Copernicus programme has made possible the development of many of the EO applications for agriculture such as WatchITgrow and – more importantly – affordable for farmers in the first place.

Satellite imagery provides wide area, synoptic pictures of the potato fields. While the scale of the fields is relatively large, moderate resolutions are working well down to around 10m in scale. Having added commercial imagery from DMC's Deimos-1 satellite with a resolution of 22m previously to increase temporal resolution, WatchITgrow has completely changed to and fully relied on the free imagery from Sentinel-2 since the launch of the Sentinel-2B in 2017. With fresh imagery about every 3-5 days coming from the Sentinel-2 constellation, Sentinel 2-B has helped to mitigate the problem of cloud cover in Belgium. This is clearly a constant disadvantage that the use of multispectral satellites such as Sentinel-2 A and B entails as their optical sensors cannot "look through" the clouds and thus do not provide any useful data at times. On the other hand,

²² See https://watchitgrow.be/sites/watchitgrow.be/files/documents/02_watchitgrow_launch_vito.pdf.

the Sentinels' spatial resolution has proven to be working very well for potato monitoring and figure XXX displays the higher resolution of Sentinel 2 compared to Deimos-1.

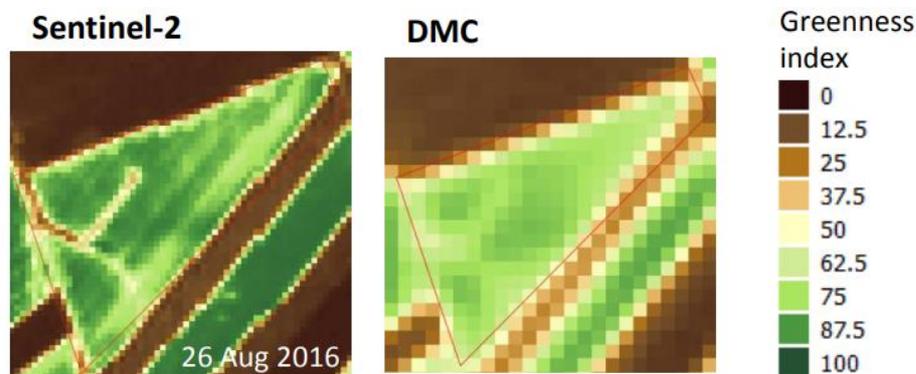


Figure 3-1 Comparison of Sentinel-2 and DMC resolution, processed by WatchITgrow

For the potato farmers, the data coming from satellite imagery is significant and, through WIG, allows them to more efficiently operate their farms as the derived information guide them towards more effective decision-making. The more traditional multispectral, optical imagery from Sentinel-2 provides the farmers with information about the biophysical properties of their potatoes such as health and productivity. In the near future, radar imagery from Sentinel-1 will also provide information on the structural properties of the farmers' potatoes such as canopy development. As Sentinel-1 radar can look through clouds, it will complement the optical imagery and close the gaps resulting from frequent cloud cover in Belgium and enable continuous crop monitoring and hence better decision-making on the part of the farmers (see 3.6 for more information on the future evolution).

Applications based on Earth observation such as WatchITgrow benefit from the free and open data policy of the Copernicus program that provides for imagery at no cost and has made possible applications like WatchITgrow in the first place. Free imagery means that marginal costs are 0 in case of automated solutions unlike cases where imagery has to be purchased from commercial providers. It also means that the application is easily extendable and scalable. The cost, or non-cost, of the imagery is very decisive for the development of geo-information platforms like WatchITgrow and their business model heavily rests on the free availability of high-quality satellite imagery from the Sentinel satellites. Moreover, the sentinel data are an important improvement compared to Landsat 8 with insufficient supply of data for an operational service and too expensive commercial data providers.

Compared to other data sources coming from drones or ground-based sources, satellite data is able to provide for a much higher and faster (and cheaper) coverage of a whole area, and the data collection can be more effective than in-situ measurements. Constant monitoring is crucial to identify risks such as diseases in time and take preventive measures.

3.3 The Service - WatchITgrow

3.3.1 Dashboard

The WatchITgrow service has a handy dashboard menu from where farmers can access the various functions of the application. From left to right, farmers can get an overview over the status of their fields, consult the latest yield predictions, temperature and rainfall forecasts as well as receive the latest greenness indices for their acreages.

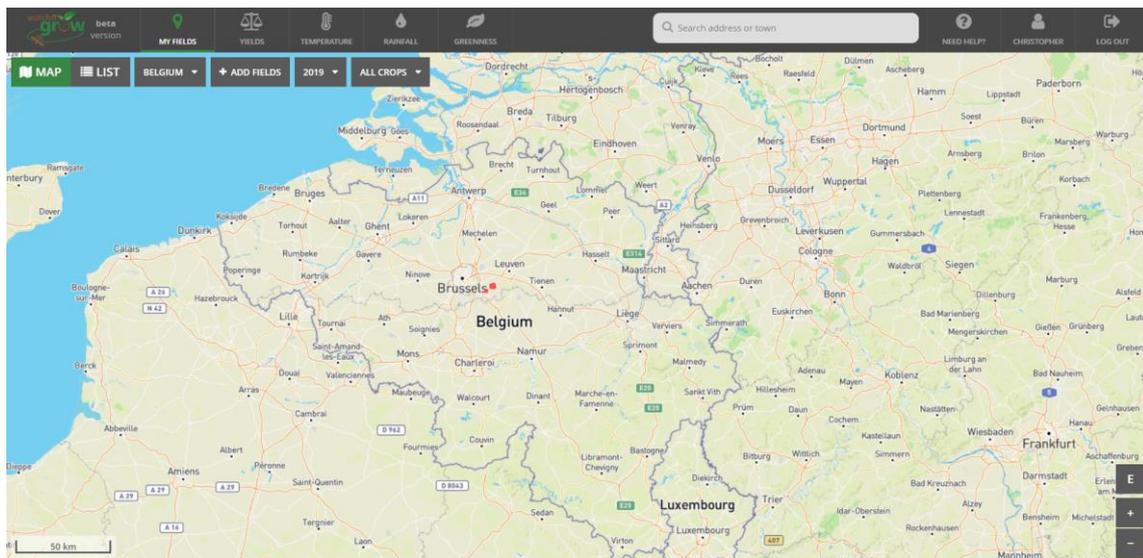


Figure 3-2: Dashboard view of WatchITgrow

3.3.2 Fields Overview

WatchITgrow²³ allows the farmer to easily enter field data into the system. The farmer can enter data for several fields at the same time, import field boundaries and information via shape or kml files and choose from a predefined selection list of legally permitted plant protection products. Farmers are able to compare their fields quickly based on growth curves and can examine also a specific field's history. This is especially important for farmers who lease parcels and have no experience with the field's specificities. Thanks to archived Sentinel data and other data sources, WIG can provide information about the specificities of the parcel which helps the farmers in more targeted farming decisions. In addition to potatoes, farmers can also monitor other crops²⁴ via WatchITgrow such as sugar beet, corn and various vegetables²⁵.

²³ You can trial the platform at <https://app.watchitgrow.be/#/login>

²⁴ The full list of monitored crops includes alfalfa, barley, beans, broccoli, cabbage, cardoon, carrots, consumption potatoes, fiber hemp, flax, grassland, leeks, maize, onions, peas, rapeseed, barley, sorghum, soybeans, spinach, starch potatoes, sugar beets, sunflowers and wheat.

²⁵ <https://vito.be/en/news/are-you-ready-growing-season-watchitgrow>

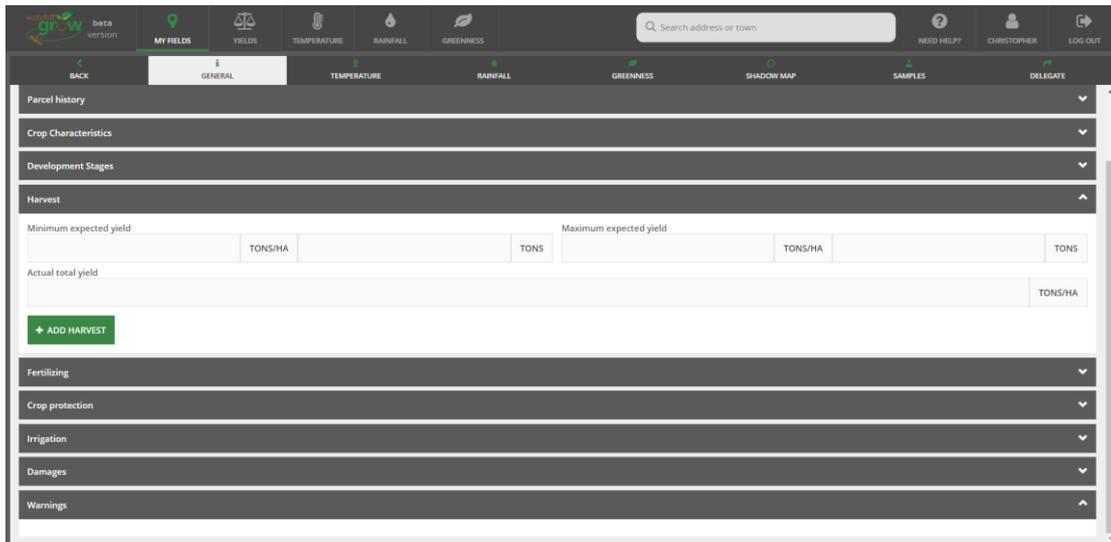


Figure 3-3 Specific field overview including expandable parameters

The platform also allows farmers to store the field data including general information such as the variety, planting date, development stage of the crop, harvest date and more specific information on treatments such as the application of fertilisers (incl. date, used machine, type, etc.), crop protection (incl. used machine, type, product, etc.) as well as irrigation (incl. data, source and type of water source, etc.), observed damages (pest, disease, drought, waterlogging, flooding and contamination) and warnings. Potato farmers using the app are also encouraged to take regular yield samples for their potatoes to enable more precise results and improve the algorithms. These samples can be stored and managed in the platform which then visualises expected yields in graphs as per selected parcel. Naturally, the more data the farmers provide for each parameter, the more accurate the models and recommendations of WIG will be to the farmers.

Moreover, farmers can retrieve information regarding the actual specific temperatures over the last three months as well as the historic average temperatures for specific parcels, allowing for insights into current temperature deviations which might result into better treatments and irrigation. The same applies for the field-specific rainfall tab which also indicates the aggregate rainfall sum over the last three months.

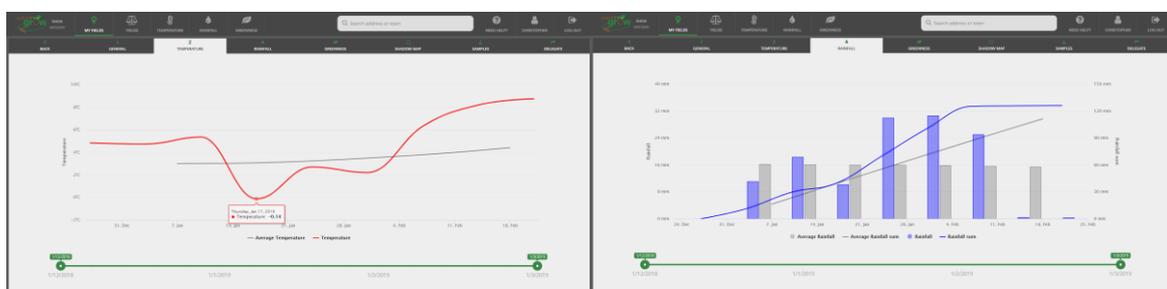


Figure 3-4 Field-specific temperature and rainfall tabs

The greenness index gives the field-specific crop growth and health and lets farmers compare it with regional greenness (more information on the greenness index in the sub-chapter 3.3.5).

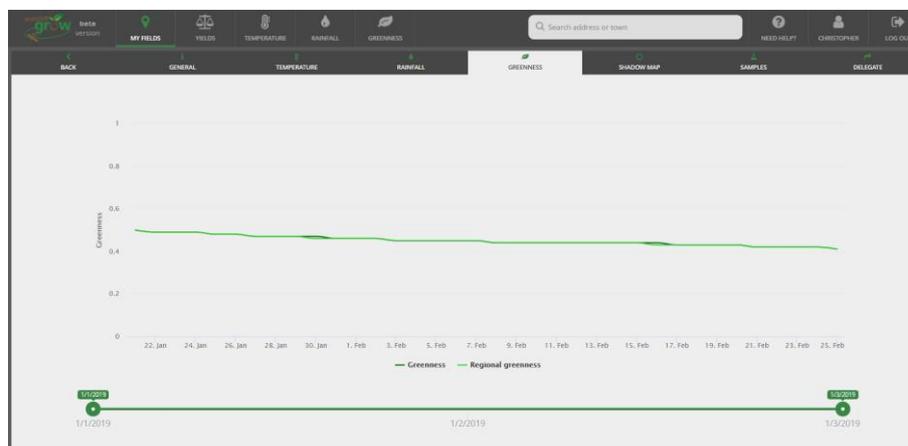


Figure 3-5 Comparison of field-specific and regional greenness index

Since 2018, WatchITgrow features the shadow map that indicates the sunny and shadowed parts of the fields to the potato farmers²⁶. This element of the application allows for variable rate planting and adapting planting densities. Through planting less in the shadowed sections, plants absorb more sunlight and receive more water and nutrients as opposed to normal planting density leading to higher yields. As a consequence, farmers profit from both cost savings by planting less seeds and from higher yield results in the shadowed parts of the field. The shadow maps function also as an instrument for generating green zones in the shaded field borders within the frame of the greening obligations^{27, 28}.

3.3.3 Yield

Besides field-level observations, the platform lets its users also compare yield forecasts for the regional, municipality and province level as can be seen in Figure 3-6.

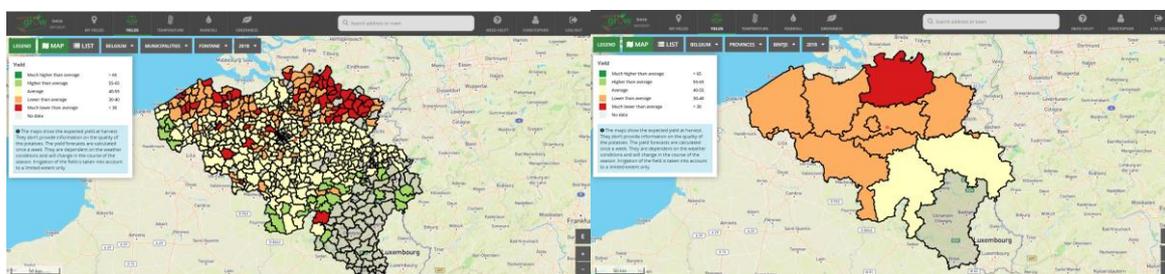


Figure 3-6 Yield forecast for Fontane (municipality level) and Bintje (province level) varieties for 2018 for Belgium

²⁶ <https://vito.be/en/news/are-you-ready-growing-season-watchitgrow>

²⁷ See CRA-W activity report 2016-2017-2018: <http://www.cra.wallonie.be/en/2016/1/activity-report>

²⁸ https://ec.europa.eu/agriculture/direct-support/greening_en

The maps show the expected yield at harvest – they do not provide information on the quality of the potatoes. The yield forecasts are calculated once a week and depend on the weather conditions. Hence, they will change in the course of the season. For yield forecasts, the app takes into account irrigation of the field only to a limited extent.

3.3.4 Temperature & Rainfall Tabs

The temperature and rainfall maps which can be selected at the top of the dashboard display the deviation of the actual temperature or rainfall with the average historical temperature or rainfall. They are updated on a weekly basis. The 5 classes in the legend in the top left are defined by analysing the historical meteorological archive from the Belgian Royal Meteorological Institute. For the temperature and rainfall indication, WatchITgrow has divided Belgium into several small grid cells of 5x5km in size for which figures are calculated. The temperature and rainfall data are collected from over 200 weather stations all over Belgium. For temperatures, a simple average is calculated based on the surrounding weather station measurements with a correction for the altitude difference between the station and grid cell centre, whilst rainfall data are gathered directly from the nearest station.

For the potato farmers, information about rainfall and temperature deviations from the average are crucial for more effective decision-making and enable farmers to take appropriate measures in order to maximise yields. Farmers can zoom into “their” grid cells and assess the effects of temperature and rainfall deviations. The legend on the top left tells them how much the deviations are. For instance, if a grid cell is classified as “much warmer/colder than usual” or “much wetter/drier than usual”, it means that the temperature or rainfall in that grid cell belongs to the 20% warmest/coldest or wettest/driest observations in the history of that grid cell. For the other classes the deviations are smaller²⁹.

By monitoring the weather data, potato farmers can better assess the risk for production or quality losses at their fields. Figure 3-7 shows the current temperature difference respective to average temperatures at this time of the year. The red colour indicates that current temperatures deviate from average historical rainfall data in most of Belgium whilst the south enjoys normal “average” temperatures (see the white colour). On the bottom, farmers can the temperature differences over the last weeks.

²⁹ For more information see <https://watchitgrow.be/en/faq>.

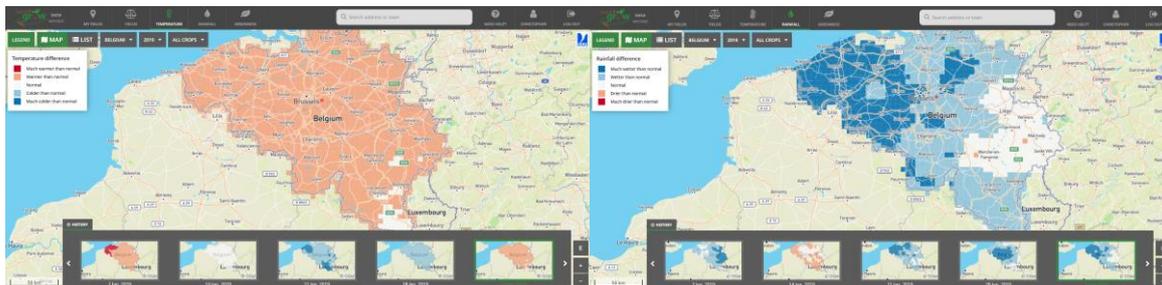


Figure 3-7 Temperature and rainfall difference in Belgium on 4th February 2019

Figure 3-7 shows the rainfall differences with regards to average historical rainfall data. Farmers in the north-west and centre of Belgium can currently expect to have much more rainfall than usual at this time of the year (in the top 20% rainiest observations). While the more central and southern parts of Belgium relatively wetter weather than usual as well, eastern Belgium has average rainfall. The data on the bottom also show that this has been the case throughout the last weeks with the exception of the 14th January.

3.3.5 Greenness index

The underlying indicator of the WatchITgrow application to measure crop growth is the greenness index (i.e. pixel colour) called **FAPAR** (Fraction of absorbed Photosynthetic Active Radiation). The index represents the fraction of the sunlight that is used for photosynthesis. FAPAR is thus a measure of the crop's primary productivity and is often used as an indicator for the state and evolution of crop cover. The index is also one of the main factors of the application for the development of yield models. As can be seen in Figure 3-9 on the right, low greenness index values (brown colour) mean that there is no crop growing on the field yet (bare soil). On the other hand, when the crop is growing, the greenness index will increase (green colour) until the crop has reached maturity. Then the index will decrease again until harvest.

The greenness graph showing the development of the greenness index enables farmers to closely monitor crop growth during the season. It allows farmers to monitor the development and the current development stage of the potatoes. The green curve in Figure 3-8 depicts the greenness index while the pictures in Figure 3-9 demonstrate what is actually the situation on the field at the same time. The yellow curve shows the progressive development of the tubers. With respect to blight, the greenness index is an imperfect measure due to the rapid rate at which the disease spreads. More frequent observations would help. But it can be useful to monitor conditions over a wider area to detect if neighbouring fields are stricken by blight. In general, the farmers do not take any risk and spray as a preventative measure.

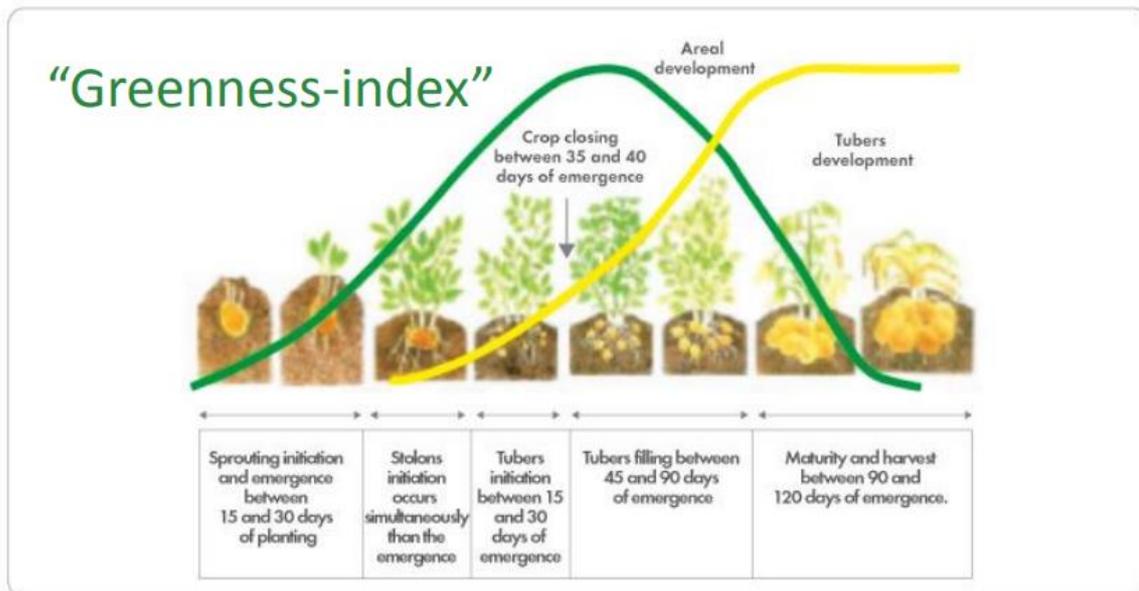


Figure 3-8 Development of the Greenness Index. © VITO 2019

The greenness map allows users to easily identify variability between (benchmarking) and within (precision agriculture) fields. Differences in greenness within a field show that crop growth may be variable within the field and can also point to anomalies. The reasons for this can be diverse and can include (natural) soil heterogeneity, climate induced problems such as drought or water logging and local damages due to pests or diseases, emergence problems, among others.

Figure 3-9 shows variability between fields whereby early varieties are indicated in blue and late varieties are indicated in red. This information is especially important for the processing industry and enables agronomists, traders and industrialists to improve their planning and logistics as they can estimate when and how much the yield will be in the following harvest.

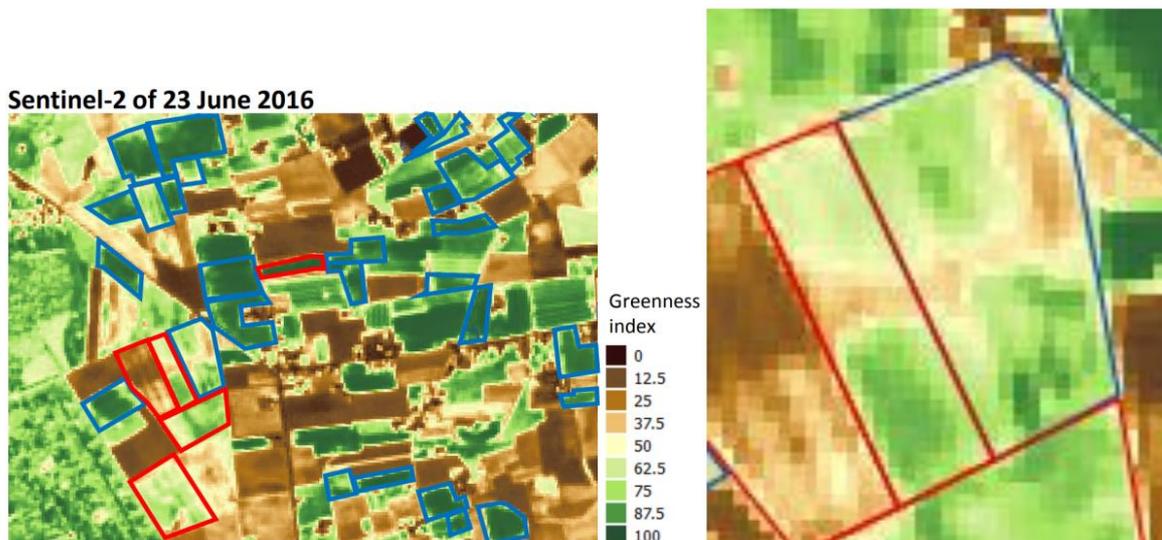


Figure 3-9 Variability between and within fields

Figure 3-9 shows the variability within fields. This kind of information allows farmers to manage their fields more effectively and apply variable rate application (fertilisers, irrigation etc.). For farmers, this is crucial in order to make cost savings in inputs, increase yields, produce higher-value potatoes and use their fields in a more sustainable way. Since leasing fields is common practice in the potato sector and in agriculture in general, farmers might not be familiar with the specificities of a certain leased field at the beginning. Through the app and the archived data and historical satellite imagery, farmers can become acquainted more easily with the field and its specificities.

3.4 Future Evolution of WatchITGrow

3.4.1 New Features

WatchITgrow is constantly developing and incorporating new features to improve the application and support the farmers in their daily decisions and operations. Currently, farmers are developing a larger collaborative approach between the various key stakeholders of the Belgian potato sector with the objective to share increasingly more volumes and more accurate data with the platform. As more data will be integrated into the web platform, developers expect the application to become more and more precise. This will also increase other features of the application and for instance result in more accurate yield estimations. Combining several crop growth simulation models including meteorological data, soil map data and crop data will further increase accuracy in yield estimations. Furthermore, the supply of potato samples and quality assessments regarding tuber dry content and size is crucial for the industry and the developers to improve the algorithms of WatchITgrow.

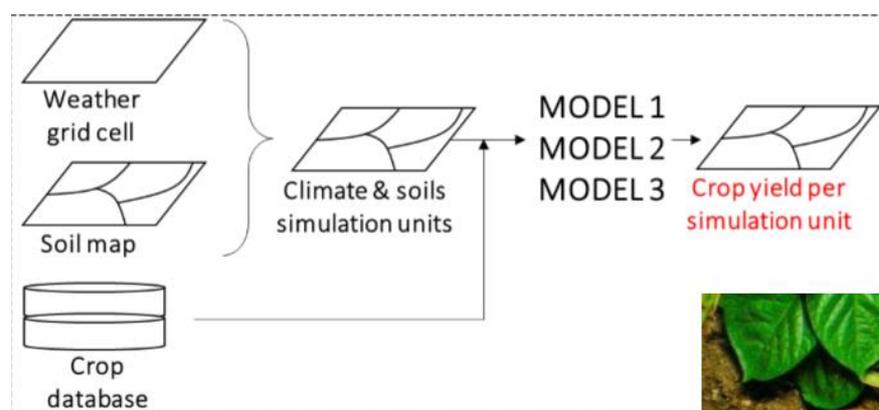


Figure 3-10 The Future of WatchITgrow: combining crop growth simulation models

WatchITgrow is currently the basic piece of a larger puzzle for potato crop monitoring in Belgium. Further pieces are developed in other research projects or web platforms, are interlinked with

WatchITgrow and will be integrated in the application soon. These research projects focus, among others, on

- nitrogen fertilisation recommendations,
- a warning system for major potato diseases such as late blight,
- a warning system for irrigation scheduling and
- links with official databases on cropping practices such as Phyto Products or VEGAPLAN.

In general, WatchITgrow will link further external data sources to the WatchITgrow application and continue to develop the deep learning algorithms that the application is based upon. This will lead to yield improvement advice.

Moreover, VITO is actively looking for international partnerships and cooperation (for instance at the World Potato Congress in Peru) to further improve and develop the application³⁰. As potato cultivation is practised on a global scale, international exchange and cooperation in order to exchange of best practises and innovative techniques can lead to a further improvement of the application.

VITO is currently working on a separate project with the Soil Service of Belgium³¹ in Louvain, an independent research and advisory institute for agriculture, horticulture and the environment, regarding the improvement of soil sampling and irrigation advice. The research results will soon be integrated into the WIG as well.

One impact which will be explored further is the potential for WIG to help create a level playing field in Belgium. There is a strong imbalance of power between farmer and the processing industry which restricts the information flow. By bringing the different players together onto the same platform, WIG can offset this imbalance and create conditions which can optimise the overall production of potatoes and potato products in the country.

3.4.2 CropSAR

A major limitation regarding the use of Sentinel-2 data within WIG is related to Belgium's cloudiness. CropSAR is a new technology, developed by VITO, in order to overcome this problem³². VITO has found a solution using the Sentinel 1 radar which can "see" through clouds. A unique algorithm combines radar and optical satellite data from Sentinel-1 and -2, respectively and makes possible measurements also on cloudy days. Based on this new algorithm, VITO has already received crop data during cloudy conditions. CropSAR is expected to considerably improve crop monitoring and forecasting, thus advancing the application considerably and enhancing the benefits for potato farmers and the potato industry as a whole. The technology will be integrated into WatchITgrow by the growth season of 2019.

³⁰ <http://www.gfiaeuropa.com/wp-content/uploads/2017/07/JURGEN-DECLOEDT-Vito.pdf>

³¹ <https://www.bdb.be/>

³² Ibid.

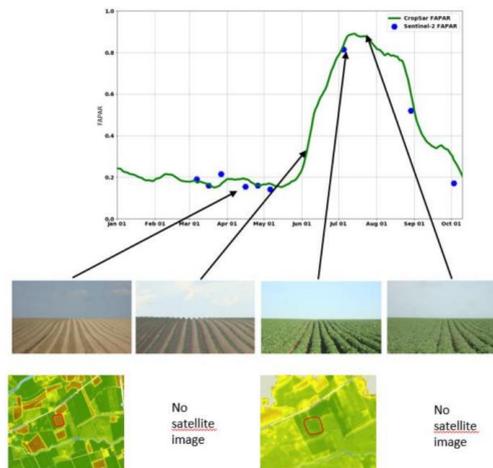


Figure 3-11 Comparison of original FAPAR and CropSar FAPAR

CropSAR will stop the application's dependency on clouds and will always provide data. Many EO-based applications were unsuccessful due to severe problems with cloud cover and associated limits of the applications. The new technology will provide for a continuous view on all fields and supply farmers with constantly available data on their potatoes' health parameters. It will facilitate more reliable information on crop status as well as input for disease warning systems.

The next stages in the development will see the upscaling from field to plant zone level. Moreover, the data from Sentinel-1 and -2 will be combined with other optical data sources such as Sentinel-3 and on very high-resolution data from commercial suppliers such as Planet, Airbus etc. Following further adjustments to the methodology, CropSAR will be integrated into WatchITgrow as an operational solution in the coming months³³.

3.4.3 Financial Incentive Programme

In 2019, VITO reached an agreement with Belgapom and the Belgian farmers' union (Boerenbond Belge) whereby the potato processors have committed to investing 859,000 Euros into a financial incentive scheme. The funds will be used as a stimulus for potato farmers to register and start using the WatchITgrow application. A farmer willing to become an active user including to provide data on field management practices will receive between 250 and 750 Euros. The scheme is designed to support the market uptake and widespread use of WatchITgrow in Belgium. The amount of 859,000 Euros shows the confidence of the potato processing sector in the application and its expected promising impact on the potato industry as a whole. For the potato processing industry, the app is promising as the use by potato farmers can result in higher yields, higher quality potatoes (and thus higher prices) and a positive brand image as stakeholders in the value chain can claim to contribute to more sustainable farming, thus gaining a competitive edge over rivals in the sector³⁴.

³³ <https://vito.be/en/news/monitoring-potatoes-growth-and-health-through-all-weather-circumstances>

³⁴ <https://vito.be/en/news/boerenbond-belgapom-and-vito-together-towards-digital-agriculture>

In a recent agreement among the WIG stakeholders, it was decided that farmers will not pay for WIG in the upcoming two years while Belgapom and the Belgian Farmers' Union have agreed to pay VITO to further improve the application and integrate new features. In the course of 2019, Belgapom and the Belgian Farmers' Union have pledged to support farmers in getting acquainted with the platform and help them in collecting all crop-related data. The platform is hosted by VITO guaranteeing data-privacy, data-security and data access.

Furthermore, it is planned to create an overarching umbrella organisation for the potato sector in which all relevant stakeholders from the value chain as well as public bodies and research institutes shall be represented to allow for a faster exchange between the market players and address the imbalance of power by better integrating the farmers' views. For this reason, the Belgian Farmers' Union has been cooperating more closely with the WIG stakeholders to address the concerns of farmers regarding the sharing of data entered into the platform.

3.4.4 Extension of the Service

Satellite data is also used to monitor the potato crop in the Netherlands and can be used throughout the potato growing belt. Belgapom is active promoting the capabilities of the Belgian potato industry around the world in S. America and in Asia. Sentinel data is inherently global, and the service can be applied in those regions.

A Horizon2020 project named DataBio³⁵ also enables VITO to extend the service to the Netherlands and Italy and enlarge the potential customer base. Through the project, both new crops are being incorporated and new features will be tested to be integrated into the platform later on and provide a better service to users.

³⁵ <https://cordis.europa.eu/project/rcn/206584/factsheet/en>

4 Understanding the Value Chain

4.1 Description of the Value-Chain

Having covered the service and the macro environment in which it is embedded, we will now look into its impact on the value chain it functions in: what parties are concerned and what subsequent effects does the availability of satellite-derived information 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.

Central to our methodology – in this case and in past and future ones – is the value chain originating from the use of satellite data. It is the basis for the analysis of the value generated by the availability of the Sentinel data. The value chain displays 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 Sentinel data³⁶.

Figure 4-1 shows the value chain analysed in this case. It starts with tier 1, the service provider VITO which supplies potato farmers with crop growth and variable rate maps through WIG. Besides the farmers, the potato processing industry, their agronomists as well as independent consultants directly use the application to receive up-to-date information and market intelligence about expected yields (forming tier 3). The farmers’ produce is then sold to tier 4 where mainly potato processors, but also other highly specialized value-adding key players such as packagers, washing and peeling companies, storage facility and ventilation manufacturers benefit from higher yields and consequently a higher demand for their services and products. The resulting potato products are then sold to supermarkets and shops in Belgium and globally through distributors and finally reach the end beneficiaries, being the citizens and consumers.

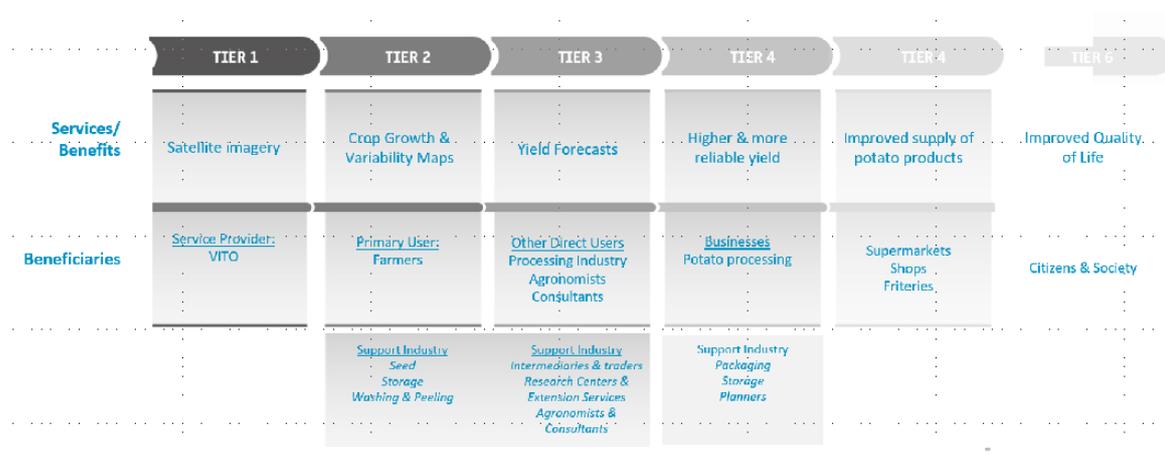


Figure 4-1 Value chain of the Belgian potato sector

³⁶ Annex 2 contains further details on the concept of the value chain and our methodology.

We deliberated on whether to place the processing industry at the primary user of the service. In many ways they are the drivers and are certainly the reason that there is a wider dimension than is the case for other farming cases. The processing industry are investing in WIG and encouraging the farmers to use it. This should lead to significant country-wide benefits.

However, we felt that the picture is more understandable if we follow the classical value-chain from farmer to processor and hence the value chain is drawn and will be analysed in that way.

4.2 The Actors

Beginning with the service provider VITO, we have conceptualised this value chain mainly around the primary user, i.e. the farmer, and the main beneficiary of the use of Sentinel data by the farmers, i.e. the processing industry. However, as will be seen below, the potato sector in Belgium is a well-organised and highly concentrated sector that comprises numerous (research) organisations and highly specialised companies that supply and support both the farmers and the industry. In a way, they (will) benefit from the use of WIG and certainly need to be mentioned here as well in order to give a comprehensive picture of the way the potato takes from field to fork.

4.2.1 Tier 1: Service Provider – VITO

WatchITgrow has been developed within a joint collaborative research project called iPot³⁷ financed by the Belgian Science Policy Office (BELSPO) between several partners including the Flemish Institute for Technological Research (VITO), the Walloon Agricultural Research Centre (CRA-W) and the University of Liège (ULG) as well as Belgapom representing the Belgian processing industry. Whilst research continues and more features will be added in the future, VITO is now responsible for operations, maintenance, customer service and market uptake of the platform.

Placed under the policy domain of the Department of Economy, Science and Innovation (EWI) of the Flemish Government, VITO is a Flemish research organisation in the area of cleantech and development. Having sustainability as their guiding principle, VITO is involved in a number of research fields including health, energy, chemistry, materials and agriculture in which remote sensing plays a major role. In each of the fields, VITO provides scientific advice and technological innovations that support the transition to a sustainable world and counter major societal challenges such as climate change, food security, raw materials scarcity, sustainable energy supply and an ageing population. By doing so, VITO promotes both the future vision of Flanders³⁸ and the United Nations Sustainable Development Goals³⁹. VITO cooperates with companies, either directly or in partnership with industry networks such as the spearhead clusters and business

³⁷ For more information see here: <http://www.belspo.be/belspo/Fedra/proj.asp?l=en&COD=SR%2F00%2F312>

³⁸ <http://financeflanders.be/sustainability>

³⁹ <https://www.un.org/sustainabledevelopment/sustainable-development-goals/>

organisation. In Flanders and by extension internationally. VITO also works closely with European scientific communities and international institutions.

As a public-owned company, VITO's revenues of 172 million Euros (2017) were coming from both own resources (contract research and patents) and grants from the Flemish government. Around 75 out of a total of 842 employees are working in the remote sensing team. The remote sensing team works on several remote sensing-related services and products. Besides WatchITgrow, VITO remote sensing specialists work on services towards more intelligent fruit cultivation⁴⁰, Terrascope⁴¹ (the Belgian national access point to the Copernicus, PROBA-V and SPOT VEGETATION satellite data) and MapEO⁴², a drone-based crop growth optimisation service.

This shows that VITO is well experienced in the processing of satellite data and skilled to develop and derive services from satellite imagery data. The WatchITgrow platform has been enabled with the availability of the Copernicus Sentinel data and especially Sentinel-2. Before the launch of Sentinel-2B, Deimos images were acquired in the gaps between Sentinel-2A images to provide better update frequency and supplement the Sentinel-2A acquisition cycle over Belgium.

4.2.2 Tier 2: Primary User – Farmers

The primary users and beneficiaries of the WatchITgrow (WIG) platform are the potato farmers who use it directly to inform and help them with farm management. They may also share it with their consultants and agronomists and the processing industry is trying to encourage data to be shared further. This is one goal of the “branch” organisation that is being established.

The availability of data and information provided by WIG has been a game changer for the operations of farms. Whilst much of the data is coming from the farmers or other sources, the satellite data is the key to making WIG stand out as a farm management tool for the whole sector. The use of farm management applications has changed the role of the farmers from a more traditional one to a technological savvy and thus has impacted heavily on the way the farmers operate their potato fields. Naturally, these developments take time whereby some farmers are at the vanguard of technology adoption (‘innovators’ and ‘early adopters’) while others are very slow or even reluctant to adopt any digital, modern decision support systems.

Moreover, whilst the number of farms is decreasing, the average size of farms has been increasing over the last decades. On top of that, farmers have increasingly less employees and workers available to them who are often unskilled or inexperienced in potato cultivation and more specific plant problems. WIG can help the farmers by targeting scouting as they know where and when problems occur.

WIG supports farmers in getting a general overview over the state of their fields, and direct viewing and scouting of the fields on a daily basis is not needed anymore. WIG can also help the

⁴⁰ <https://vito.be/en/remote-sensing/intelligent-fruit-cultivation>

⁴¹ <https://terrascope.be/en>

⁴² <https://mapeo.vito.be/>

workers in giving guidance and thereby add great value to the farm. Satellites can provide imagery on a sufficiently regular basis that anomalies can be detected, without having to be in the field. Currently, fresh imagery is provided every 3-5 days depending on cloud cover. With the add-on CropSAR⁴³, WIG will be able to provide data and information in between these days and will allow to monitor potato growth and health even more closely. In the far future, it is likely that different data sources will be merged giving a comprehensive picture of the state of the fields with data coming from in-situ self-driving tractors, drones and satellites.

Farmer often do not own the fields which they farm for potatoes; they are leased or swapped with other farms specialising in other crops. This allows farmers to specialise in specific crops and to reach further to find additional fields which they can then cultivate. A four-year crop rotation is now mandatory for farms in Belgium, so one of the most important features for the farmer is the field history which is contained within WIG. As the tool becomes used over longer periods and builds up a history of cropping, so the value will grow.

4.2.3 Tier 3: Other Direct Users

Farmers are supported through a wide range of actors who are benefiting from the use of WIG by the farmers.

a) Processing Industry

The processing industry appear twice in the value chain both as direct users of the WIG system and as beneficiaries of the results it brings to the primary users; the farmers. The processing industry is made up of over 40 companies in Belgium; some are family-owned, and others owned by major international brands ie McCain owns the Lutosa factories and markets under its own name as well as the Lutosa and Igloo brands. The processors turn the raw potatoes into mostly frozen but also some chilled products (fresh potato for fries). Other major players are Agristo, Clarebout and Farm Frites.

The sector has grown significantly in recent years, driven by a number of family-owned businesses. Recently, some consolidation has concentrated the sector to 18 main processing plants with some in the hands of multi-national owners. The growth in employment over the last 25 years is shown in Figure 2-7 and some statistics coming from the sector are shown in Table 4-1.

The table also shows the volumes of some of the key products and the remarkable growth to over 5mT of potatoes processing in 2018. Many different products are made including hash browns, formed products like potato croquettes, dehydrated potato products like flakes, granules, potato wedges (with or without rosemary) and sliced potato crisps. The sector is very innovative, and it is quite extraordinary what can be done with the humble potato!

The processing industry and their (independent) agronomists can benefit from direct use of the WIG platform in two ways.

⁴³ For more information see subchapter 3.6.2.

- First of all, the industry has a great interest in having as much knowledge and up-to-date information about the current state of the potato crops as possible. Information entered into WIG allows the factories to understand the provenance and quality of the potatoes that they will receive. Presently, information on the crop type and origins, planting, spraying, and harvesting is collected by each processor. Farms with contracts are obliged to provide this information which is quite similar to that required by the regional and federal authorities. Hence WIG provide a common database of crop information and saves time and reduces entry errors. Farmers are wary of this as we shall discuss in chapter 5.
- Based on knowing expected yield forecasts provided by WIG, processors can adjust and improve their planning and logistics for the non-harvesting season when potato supply will go down. Some processors possess special storage facilities where they keep the potatoes throughout the year to have a constant supply for their processing machines. Thus, they can afford to buy the potatoes when potato quotations go down. Planning the production is of critical importance. Different potato types are better suited to different end-products. Agronomists are visiting their contracted and other potential suppliers on a regular basis during the growing season to assess the crop.

The Belgian potato processing industry in 2016 – 2018			
	2016	2017	2018
Number of processing plants	18	18	18
Number of workers :	3.257	3.467	3.701
Number of employees:	858	943	1.061
Investments:	€ 309.775.177	€ 305.513.247	€ 310.923.634
Raw material :			
Potatoes :	4.414.390 t.	4.571.297 t.	5.101.522 t.
Flakes :	6.300 t	6.039 t.	5.630 t.
Finished product :			
Frozen fries :	1.681.332 t.	1.770.298 t.	2.073.747 t.
Refrigerated fries :	234.694 t.	226.796 t.	231.734 t.
Mashed potato products, croquettes, chips, ...			
Flakes and others	468.513 t.	690.159 t.	695.321 t.

Table 4-1: Some statistics of the potato processing industry

b) Intermediaries and traders

In Belgium – unlike in most other European countries – farmers sell part of their produce and potato stocks to so-called traders which can be subdivided into three categories. **Packers** take care of the washing, drying and packing processes. With packing stations all over the country they are a valuable and increasingly important part of the value chain. **Exporters** are the second category of traders and are responsible for shopping and selling fresh and processed potatoes abroad in Southern Europe and increasingly distant regions in Africa and Asia. Thirdly, there are **intermediaries** whose main business is to buy from many small-scale farmers. They function as a bridge between the farmers and the processing industry locally or abroad. In most European countries, this intermediate stage has disappeared, and farmers directly sell their produce to processors or local consumers as fresh potatoes. However recently, there has been a trend towards a direct selling model in Belgium too as it has been widely recognized that intermediaries and traders add limited value to the final product and can easily be skipped⁴⁴.

c) Research centres and extension services

The Belgian farmers benefit from a rich research landscape and numerous extension services who can support the farmers in their farm management and in particular in the use of WatchITgrow. Their task is to provide for a rapid and efficient flow and dissemination of information as well as to facilitate technology adoption in the potato cultivation sector. This structure of the Belgian potato sector makes for a more dynamic and integrated sector and is certainly one of the reasons for the competitive advantage of the sector. Research centres are in close contact with the farmers and help them extract the most benefits out of the application.

In Flanders, the PCA⁴⁵, the Interprovincial Testing Centre for Potato Cultivation, as well as Inagro⁴⁶, an independent agency of the province of West Flanders, work on practical research, provision of advice and information dissemination for farmers. They also advise potato farmers on crop protection and the latest developments in the sector. In Wallonia, this support is provided by CARAH⁴⁷, the Centre for Agronomy and Agro-industry of the Province of Hainaut, as well as FIWAP⁴⁸, the Walloon potato chain. Further crucial actors in the sector are ILVO⁴⁹, a research institute for agriculture, fisheries and food, that used to be one entity together with CRA-W, the Walloon Agricultural Research Centre before the 2001 reform. On top of this, several universities engage in research at the intersection of remote sensing and agriculture/potato cultivation such as the University of Liège and Ghent.

Currently, there are two key research projects in Belgium dedicated to the potato sector. The first is WatchITgrow and the second is called RESKIA which is looking at the issue raised by the use of Chlorpropham (CIPC) as a growth inhibitor – extremely important to the storage life of potatoes. CIPC has been recognised as a possible health risk⁵⁰ and may be banned by the European Union.

⁴⁴ Belgapom (2018). *The potato in Belgium, the land of fries*,

⁴⁵ <https://www.pcainfo.be/Over-PCA>

⁴⁶ <https://leden.inagro.be/>

⁴⁷ <http://www.carah.be/>

⁴⁸ <http://www.fiwap.be/>

⁴⁹ <https://www.ilvo.vlaanderen.be/language/en-US/EN/Home.aspx>

⁵⁰ <http://www.cipccompliant.co.uk/regulation/>

Potato storage is essential to enable processing to be planned all-year-round and to keep seed potatoes fresh to the point of use. RESKIA is a collaborative effort amongst many of the research institutes to find alternative storage methods.

d) Agronomists and consultants

Farmers are not experts in all aspects of crop management and can either turn to organisations mentioned above, or to professional independent agronomists and consultants. Their advice can comprise various aspects of farming and include for instance technical assistance regarding the farm machinery to use and especially new technologies being incorporated into it such as variable rate planting, shadow maps, digital rate maps, positioning and automatic controls, or it may concern planting and harvesting date for potato cultivation, crop problems and possible treatments and simply the interpretation of information provided by WIG. Sometimes, processors make available their own agronomists in support of farmers.

e) Other actors

Other key actors are the *Boerenbond*⁵¹ (Farmers' Union) and the *Algemeen Boerensyndicaat*⁵² (General Farmers' Syndicate) who both represent the interests of the farmers vis-à-vis policymakers and other institutions. Belgapom, that is also part of the WIG project, is the body that represents the processing industry⁵³. Belgapom plays a very active marketing role to promote the Belgian industry around the world. Recent agreements have been made in Latin America and in Asia to help grow the export business. Further, many European associations exist to promote the potato growers and processors and to defend their interests.

4.2.4 Tier 4: Potato Processing Industry

In tier 4, we consider the secondary economic benefits from the use of the WIG platform, i.e. the businesses which are better served and can operate more effectively⁵⁴. We consider this only for businesses located in Belgium although there will be some benefits for businesses overall in the European potato belt. The main beneficiaries here are the potato processors which we have already discussed as part of tier 3. Other secondary beneficiaries come from the support industry who, as a result of a higher yield, have more processed potatoes to "store", "package", "distribute", "transport" etc.

As well as the direct benefit derived from using WIG, the processors also benefit through an increased yield as the platform should enable potato farmers to take better decisions that will eventually result in a higher produce. WIG has the potential to provide a system to underpin the

⁵¹ <https://www.boerenbond.be/>

⁵² <http://www.absvzw.be/>

⁵³ For a comprehensive overview of key actors on regional, national, European and global level, consult *The potato in Belgium, the land of fries*, pp. 180-81.

⁵⁴

https://www.food.be/companies?search_api_fulltext=&field_company_filter%5B432%5D=432&field_company_filter_1%5B432%5D=432&field_company_filter_2%5B432%5D=432&field_main_category=All&field_sub_category=All&field_product_category=All&field_company_countries=All

formation of a national “branch” organisation in Belgium. By enabling transparency, confidence and exchange between all the players in the value chain, the “branch” can increase the overall yield from the farms so providing the factories with more raw material. This has a direct benefit on the Belgian economy by increasing the size of the sector and generating increased exports.

In 2014, the Belgian industry recorded a volume of 3.8 million tonnes of processed potatoes, mainly to frozen chips. A large portion of this is exported globally, making Belgium the largest exporter of frozen potato products. This record volume comprised almost 1.4 million tonnes of frozen chips and 455,000 tonnes of other products (puree, croquettes, flakes and crisps among others). Overall, the figures showed an increase of 6.9% compared to the previous year⁵⁵. The potato processing industry is a major driver of the Belgian industrial agri-food sector and employs about 3,600 employees on a permanent basis as well as support numerous indirect jobs (tertiary suppliers). The industry concentrates increasingly on exports and on expanding into remote regions such as Asia. It is a sector that is relatively resistant to economic downturns and experiences increasing employment rates and investments⁵⁶.

4.2.5 Tier 5: Supermarkets, Shops and Friteries

Supermarkets and shops are the main retailers that sell processed potatoes. Naturally, they are interested in a reliable and stable supply of potatoes and potato products that, if possible, are produced in more environmentally friendly ways. A major beneficiary of processed potatoes is the food service industry made up of the hospitality, catering and convenience sector who comprise thousands of restaurants that overwhelmingly serve fries. Moreover, tier 5 also features the famous Belgian culture of fritkot/frituur/friteries (chips shops) which need a reliable supply of their main offer: processed potatoes i.e. chips. The economic factor may not play such a big role overall in Belgium. However, there are 5,000 local friteries (one for every 2,500 Belgians) and they certainly play their part in the socio-cultural landscape in Belgium and benefit from a stable supply of processed potatoes.

4.2.6 Tier 6: Citizens and Society

Belgian citizens have for long been one of the biggest consumers of fresh and processed potatoes per capita in the world. As you can see in Figure 4-2, the average Belgian consumed around 95 kg of fresh and processed potatoes in 2013. Looking at the long-term trend however, the average consumption has been in steady decline since 2000 with some temporary ups and downs. This long-term trend can be ascribed to new food trends and dietary patterns, for instance due to the spread of less potato-heavy foods from Asia or other regions in the world⁵⁷. Moreover, major strategies against food loss and waste over the last years have helped to fight food loss and waste effectively resulting in an apparent consumption decrease while in fact consumers buy and eat

⁵⁵ <https://www.thebulletin.be/belgium-largest-exporter-frozen-potatoes>

⁵⁶ Belgapom (2015). *The potato in Belgium, the land of fries*, p. 98.

⁵⁷ <https://www.helgilibrary.com/indicators/potato-consumption-per-capita/belgium/>

what they really need. The European Platform on Food Losses and food waste⁵⁸ describes many measures being taken and more under consideration. The EU and the EU countries are committed to meeting [Sustainable Development Goal \(SDG\)](#) 12.3, adopted in September 2015, which targets to halve per capita food waste at the retail and consumer level by 2030, and reduce food losses along the food production and supply chains.

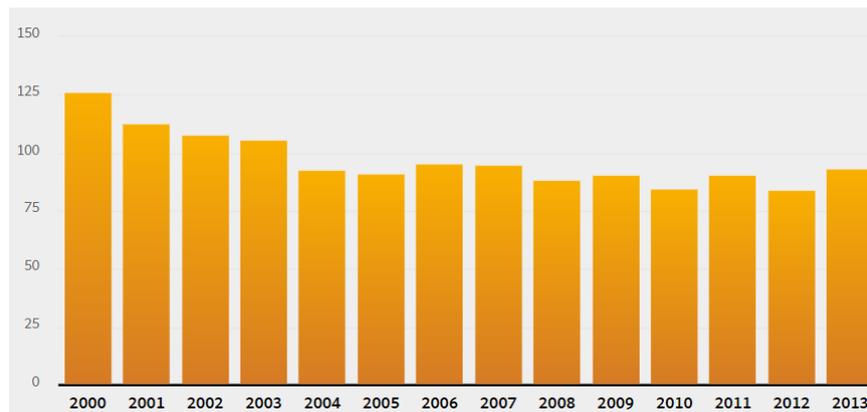


Figure 4-2 Belgian Potato Consumption (kg/capita). © FAO Statistics

Nevertheless, Belgians still rank among the biggest potato consumers in Europe and the potato is set to remain a major staple food for Belgians for the future. Thus, a more reliable supply of fresh and processed potatoes along with more sustainable farming practises thanks to the use of WIG is certainly in the interest of Belgian citizens. Moreover, whilst fresh and home consumption is under pressure, processed and out of home consumption is gradually increasing which is why job growth mainly occurs in the processing industry⁵⁹.

4.2.7 Other Beneficiaries

We noted earlier the complex nature of the administration in Belgium with 3 regions, 3 language regions and a federal level. The interest in potatoes acts to unify the country at Federal level.

Satellite data makes no distinction for political boundaries and indeed, due to its neutral, wide-scale view has the ability to promote co-operation. It is one of the major factors linked to the ambition to form a national level platform (referred to as the branch) where a synoptic view available by the use of satellite data. The platform will be a critical factor to promoting transparency and developing trust between the various actors in the value chain.

⁵⁸ https://ec.europa.eu/food/safety/food_waste/eu_actions/eu-platform_en

⁵⁹ https://watchitgrow.be/sites/watchitgrow.be/files/documents/01_watchitgrow_launch_belgapom.pdf

5 Assessing the Benefits.

5.1 Overview

The benefits of the use of Sentinel data are felt in several tiers of the value chain and can provide an overall support to a more effective production of potatoes and especially potato products in Belgium. As we have found for other agriculture services, the full potential is far from being realized for 2 reasons;

- The service is only used by a limited number of farmers and hence the market penetration is low at present.
- The quality of the service will improve with time and there is a build-up of data regarding the fields. This will take many years as crop rotation means a field will only be used once every 4 years and the variation in meteorological conditions means that several growth years are required before a true picture is built up.

Hence, the approach - which has been used in other agriculture cases – whereby the value of the benefits will be assessed for the system as used today and then extrapolated for the future according to a greater market uptake and a more mature technology. The analysis is based on a number of assumptions which are visible and open to challenge by experts more knowledgeable in the industry than us.

In addition, the role of the satellite data varies between crops and some contrasts will be developed in the discussion in this chapter. Calculating the benefits of the service is already quite hard. Extracting and calculating the value of the satellite data is even harder and assumptions are used quite widely. These are open for challenge and we encourage any reader to contact us if they think the assumptions are unreasonable for any reason.

The overall benefits of Earth observation-based products and services can generally be summarised as the following, either directly as a result of using the service by farmers or indirectly by stakeholders in the value chain profiting from the effects of the farmers' use of the service that are passed down the value chain:

- Efficiency and productivity gains
- Increase in quality of the potatoes
- Better resource management and monitoring
- Integrated impact assessment
- Improved planning and strategy building
- Improved transparency⁶⁰
- More sustainable cropping

As we shall see, benefits can accrue in both qualitative and quantitative forms. Qualitative benefits are for instance a better knowledge of the market or also social organisation which might lead to better cooperation between farmers and faster knowledge diffusion. Clearly, they are

⁶⁰ GeoBuiz 2018 Report

positive but hard to measure. Quantitative benefits are relatively easy to measure and can result for instance if farmers' save one round of chemicals spraying per season.

Finally, 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. In most cases, there are both winners and losers. For example, cost savings are usually associated with loss of employment. In general economic theory, this is overall a good thing as labour becomes devoted to more effective use so driving greater value for society.

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.

However, for this particular case, there are no real losers as it would seem that the hours saved by the use of WatchITgrow can be deployed more effectively in the sector leading to overall productivity and yield volume gains.

5.2 Benefits along the Value-Chain

5.2.1 Tier 1: Service Provider – VITO

VITO, the service provider of the application, does not benefit economically from the development of WatchITgrow as at this stage WIG is not a commercial product. The study at the origin of WIG was largely financed through public funding, though also the partners involved invested money in the IPot project. With the creation of WIG, Belgapom and Boerenbond are financing – together with VITO - the integration of new features into the application and all stakeholders involved have agreed to offer WIG for free on the market for the next two years to support a faster market uptake.

The members of Belgapom (processors & traders) agreed to pay a premium to farmers that register their contracted crop on the WIG website, including all information (field registration and yield). The program schedules that farmers will have to pay a contribution by ha after 2 years. By then new features will also be added to the application.

VITO are seeking to make WIG available in other countries and their role as operator is still not determined. Hence the main benefits to VITO come from increased R&D activities which we shall not include as benefits from the application of the WIG service.

5.2.2 Tier 2: Primary User – Farmers

There are currently 600 active users of the application of which the majority are farmers. Other users are agronomists, consultants and the industry. Our primary focus in this section shall lie on

the benefits generated by the farmers’ decisions based on the application. As explained above, benefits can be created through qualitative and quantitative ways. The next paragraph will focus on the quantitative benefits followed by a discussion of the qualitative benefits to the farmers.

Quantitative Benefits:

(a) *Saving time on scouting:* In the case linked to Farming in Denmark⁶¹, one of the main benefits to the farmers came from reducing the time they need to spend each week in the growing season for scouting their fields for signs of stress. This was for cereal crops; is this also applicable for potatoes?

In fact, the management of potatoes differs significantly from cereals. Potatoes are a high-value crop with a strong risk of blight causing a complete or very serious loss of the crop. When blight strikes its effects are rapid and consequently, farmers spray potatoes as a preventative measure throughout the growing season. We discussed whether the WIG surveillance of fields could help reduce the number of sprayings?

Farmers spray up to 15 times i.e. every 7 to 10 days during a season against potato blight and other pests. It is binary: if blight enters a field, then the whole crop is lost very quickly so farmers take a precaution and spray so frequently to be on the safe side. Moreover, the farmers receive advice from the PCA (Interprovincial Testing Centre for Potato Cultivation) on the likelihood of blight. This could however change in the future when the WIG application improves, gains a higher level of technical maturity and farmers gain trust in its capabilities so that sprayings are less frequent and thus farmers spend less time on field inspections.

(b) *Savings on chemicals:* WatchITgrow and the satellite data may help extend the interval between sprays if conditions look good. Diseases which are detected early in the season can be managed whilst late in the season the impact can be managed (ie by early harvesting). It is when the disease strikes during the main growing season that the problem is greatest. Consultation led to the view that 1 to 2 sprayings could potentially be saved during a season once there is confidence in the system. But this would not apply to the whole area planted so this should be discounted for the part-area of the farm.

The cost of chemicals is around €20/ha and €15/ha for labour cost for each spray. The average potato area per farm is 17ha (<https://europatat.eu/activities/the-eu-potato-sector/>) giving an average spray cost of €340 for chemicals and €255 for labour. We shall assume that 50% of the fields will be able to sustain the reduced number of sprays. In calculating the total potential saving for the whole of Belgium, we shall assume that 20% of the farms will not adopt WIG due to size or simple technology resistance. We shall later reduce further the benefits assigned to the use of satellite data recognising that whilst it is a key component of WIG it is not the only data being used.

		Potential Savings
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Sprays saved per season		1	2
Average potential saving / per pray	€595	€595	€1190
Number of farm users of WIG	420		
Percentage of fields sustaining the reduced spray	50%		
Potential savings for farms using WIG		€125,000	€250,000
Total Number of farms in Belgium	5000		
Less percentage which will not adopt WIG	20%		
Potential saving for 50% farms in Belgium		€1,190,000	€2,380,000

Table 5-1: Potential savings due to reduced spraying enabled by WIG.

(c) *Increased yield:* It is considered that, through a more efficient use of inputs, potato fields in Belgium will have a greater yield; it is one of the major goals of the project. At the moment, it is too early and the mechanism to develop the shared approach is missing. As a result, there is no noticeable increase in the yields due to WIG. As more data is added, the WIG partners estimate that a 3% increase in yield is possible with the system as it is today. if more (or almost all) potato farmers make a comprehensive use of the platform. Once the technical maturity becomes higher and more years of data have been gathered, then a potential 15-20% increase is considered possible. However, to remain conservative a gain of 10%-15% has been used in these analyses.

	Min	Max
Total potato yield in Belgium	3,000,000tonnes	4,400,000tonnes
Increase by 3%	90,000tonnes	132,000tonnes
Average price per tonne (2009-2017)	€90	€90
Value of 3% increase in production yield	€8.1m	€11.9m
Crop increase by 10%	300,000tonnes	440,000tonnes
Value of 10% increase in production yield	€27m	€39.6m
Value of 15% increase in production yield	€40.5m	€59.4m

Table 5-2: Value of yield increase by using WIG

Note this is the value of the yield increase as a result of using a mature WIG. The value of the Sentinel data as a component of WIG is still to be factored in and will be significantly less.

(d) *Optimum harvesting*: WIG gives recommendations to farmers about the optimal time of harvesting in order to get the biggest output from the fields. Potatoes have to be harvested before senescence kicks in and total output starts to decrease again. WIG supports farmers in choosing the best date of harvesting. This benefit certainly could come with the improvement in other factors and we have taken a figure of 1% as representing the increased yield due to better timing of the harvest.

	Min	Max
Value of total crop	€270m	€395m
Increase of 1% in yield on total crop	€2.7m	€3.95m
Today, 420 farmers / 10% of crop	€270k	€395k

Table 5-3: Benefit of improved timing of harvesting

Qualitative Benefits

(e) *Quality of Potatoes*: Better knowledge of the cropping conditions will lead to increases in the quality of potatoes making them of higher value to the processing industry. We have discussed the issue of splitting of potatoes due to irregular irrigation and a loss of size of potatoes reducing their suitability to produce fries. This has been reported by many of those with whom we have spoken. Whilst there will be a clear economic benefit, we have not been able to place any specific value on this aspect although it is clearly there.

(f) *Water*: For many of the farms, one field is surveyed at the start of the growing season and the results act as a reference for the others. The water level and soil wetness differ considerably from the one field to the others, but the farmer needs to understand the relationship between the reference field and the others they are cropping.

The Interprovincial Testing Centre for Potato takes soil samples, looks at leaves, the local climate and many other factors. This information is used by the farmers to compare with other fields and to decide whether irrigation is needed. WIG can improve this service by providing more precise conditions for the fields and hence improve the extrapolation and reduce water use.

Today, water for irrigation is coming largely from nearby rivers and streams. These sources do not provide enough water in dry years and, with increasing areas of land devoted to potatoes, we understand that the irrigation policy is being examined in Belgium following the two last dry seasons. Whilst WIG will help monitor the impacts of the policy, and there should be benefits from this in the future through reduced water use, there are no benefits today and this element has not been included in the WIG benefit calculations.

(g) *Environmental gains:* Many concerns are felt today by policy makers and citizens alike regarding the increased application of chemicals on farmland and the possible impact on health through their presence in crops and in drinking water. This is leading to new legislation controlling the application of pesticides, fungicides and fertilisers.

As discussed in chapter 2.6, fertilisers are usually applied once before planting (at nominal 200kg/ha) and a second time around early June as the leaves form. Currently, farmers treat the fields as homogeneous entities although fields are usually highly heterogeneous with diverse needs for chemicals in different locations of the field. Knowledge of the field performance over previous years together with the measurements taken from the satellite images, will allow variable rate maps to be produced. This will reduce the amount of fertiliser applied which will be more matched to the plants needs. More precise application leads to a much better take-up and heavily reduced excess in the soils. Consequently, the amount of fertiliser leaching into the environment and surface-water sources is strongly reduced.

The same holds true for irrigation requirements. More efficient water use on the field i.e. only where it is really needed can lead to reduced use of water or of pesticides. At the moment, this benefit is likely to be only marginal since farmers pre-emptively spray the fields against potato blight to avoid risk, but, as a greater understanding is developed of the relationship between satellite measurements and disease, then earlier and more accurate application of chemicals should result. Earlier application means less chemical is needed so reducing the amount which leaches into the environment.

These benefits are not quantified.

(h) *Farm awareness:* WatchITgrow will certainly give an unprecedented overview of a farmer's fields and operations and raise awareness to the farmers for their farm characteristics which may lead to improved decisions in the long-run⁶¹. This factor was also found in the Denmark case. Having a digital picture of their entire farm encourages the farmers to think more holistically about their management practices. This can lead to overall greater efficiency.

Moreover, the stakeholders from WIG have emphasised the social factor of WIG during the interviews have aimed at bringing the farmers closer together who have so far operated mainly in isolation from each other so as to advance a more cooperative attitude in the potato sector to foster knowledge exchange and the sharing of experience. This notion of learning from other farmers has been backed by data from WIG.

Neither of these benefits are quantified.

⁶¹ See also the SEBS case 'Farm management in Denmark' regarding farm awareness: <http://ears.org/Sebs/all-cases/>

- (i) *Digital awareness/digitalisation*: WIG has the potential to stimulate an awareness of digital tools available to farmers and generally support digitalisation in the farming sector, thus functioning as a catalyst for the uptake of digital tools. Digital tools and instruments are estimated by many organisations to bring huge economic benefits to farmers and the farming sector in general⁶². Thus, getting acquainted with WIG may also make farmers more open towards other digital tools that hold a lot of potential to farmers.

There will be an added value of WIG as this becomes linked to automated precision agriculture tools e.g. on harvesters. Online images of harvested potatoes, linked to the WIG registration and information, could help the operators in the value chain to decide on the usage of the crop (directly processed or storable for a longer time). As such food waste can be prevented. This shows some of the potential growth in benefits for WIG as a result of technological developments.

- (j) *Accidents/emergencies*: WIG provides warnings to farmers in case of abnormal events in the fields such as storms, burst pipes, etc. The application can detect such emergencies so that farmers can take actions or even preventive actions before such occurrences in order to mitigate negative effects on the yields and minimise field damages. This can save money and time and is also helpful for insurance and damage claims.

- (k) *Supervising distant fields remotely*: As farm sizes grow and farmers rent rather than own the fields they are farming, so the distances travelled to operate and manage those fields becomes greater. In consequence, farmers risk to spend more time traveling to fields whether it is for scouting, spraying or other field operations. Mainly farmers with an aggregate size of 400-600ha have very scattered fields. The remaining farmers usually have their fields relatively concentrated around their home base.

Further, many of the tasks, such a spraying, planting and harvesting, are sub-contracted leading to less direct engagement with the fields leading to an increased need to scout but less opportunity to do so. Sub-contracted labour has much less knowledge of local conditions nor the history of the fields making it necessary for the farmers to visit and help them make more focused visits. WIG can reduce some of this time spent by the farmer to travel to fields.

An optimised field registration and communication of the field registration field in the value chain can support farmers in this regard and provide continuously the opportunity for farmers to check and monitor the status of the fields from their desk. The field registration file can be linked to other schemes such as the food and plant & IPM scheme

⁶² <https://www.biooekonomie-bw.de/en/articles/dossiers/digitisation-in-agriculture-from-precision-farming-to-farming-40/>

Vegaplan. A digitalized file can be easily shared to third parties in the value chain (buyers) and controlled for distribution.

- (I) *Knowing the history of a field:* Many farmers benefit from the archived satellite data that WIG provides. They do not know the potential of some of their fields for potato cultivation as they have to stick to regulations regarding crop rotation. Furthermore, some farmers lease the fields and do not know the specific characteristics of the field. In this case, WIG can provide them with information and data about fields' performance in recent years so that the farmer can take better decisions and actions on his fields. This in turn should lead to a better output and higher produce.

Generally, one must note that at this stage WIG does not directly benefit the quality of the potatoes. It does so indirectly since for instance disease outbreaks can be detected faster and thus controlled more effectively. The greatest benefit currently derives from an increased yield as well as other factors described above.

5.2.3 Tier 3: Other Direct Users

Farmers are not the only direct users registered at the WIG platform. Agronomists, consultants and the industry make use of the information provided by WIG as well in order to get an overview of crop growth and yield forecasts. However, it has to be noted that, they do not have access to the individual data the farmers entered. They do have access to more general aggregated information. Nevertheless, this information is crucial for the industry as the more information they possess the better they can adapt their strategy, planning and logistics, making their operations more efficient.

Agristo has 6 agronomists working in Belgium, the Netherlands and northern France whilst other Belgian companies such as Ecofrost, Lutosa, Mydibel and Clarebout have fewer agronomists employed. In total, the potato processing industry has around of 40-50 agronomists working for it.

These agronomists visit the farms and assess the state of the crop and check how the farmers' potatoes are doing so having better information on how much the yield will be and when the crop will be ready to bring to the factory. Their expertise is important for planning the cycle of operations in the factories.

An average agronomist drives about 90,000 km per year. By using WIG we estimated (in discussions with agronomists) that they can save about 30% of their journeys, saving fuel costs, time and saving the environment. The time set free by this is not saved labour cost but can be used for more productive purposes. According to the Moniteur Automobile in Belgium⁶³, the cost of running a moderate sized car comes out at around 18c per km using the figure in the table

⁶³ <https://www.moniteurautomobile.be/conseils-financiers/prix-de-revient-au-km-par-mois.html>

below. This includes the fixed overheads and we shall take the marginal cost to be 12c (9c for fuel and 3c for wear and tear to the car).

Fuel cost (€/l):	1.30
Fuel use (l/100km):	7
Annual Distance (km):	90,000
Cost per km	18c
Marginal running cost per km	12c
Total annual cost for each agronomist	10,800
Saving of 30% by using WIG	3,600
Annual savings for 40 agronomists	144,000
Annual savings for 50 agronomists	180,000

Table 5-4: Driving costs saving by agronomists

If agronomists can save up to 30% of their journeys, this means the average agronomist can save around 3,600Euros each year. For the 40-50 agronomists working for the industry, a total economic benefit emerges of **€ 144,000 pa** to **€ 180,000 pa**. The time set free may result in further economic benefits as time previously spent on the car can be utilised in more productive ways.

We do not assign any value to time being saved or reducing numbers of agronomists. Whilst field inspections will be reduced, engagement with farmers will need to increase. Hence, we consider an overall efficiency gain as agronomists spend less time driving between widely spread fields and more with the farmer addressing measures related to yield and quality of the crop.

Sometimes a specific role is played by middlemen or traders which could increase with the trend towards more contract policies between farmers and processors. This is where a farmer contracts, early in the season, to supply a certain quantity of potatoes (see section 2.4) which can lead more and more towards a one on one relationship between (larger) farmers and their buyers. Consequently, more involvement of agronomists making use of the satellite data can be expected in the upcoming years. The project to start up a Belgian branch organization for the potato sector could strengthen the relationship in the Belgian potato value chain and result into more professionalism – including more agronomists – in the future.

5.2.4 Tier 4: Potato Processing Industry

Global demand in potatoes and potato products is increasing. New investments in factories will lead to an increased demand for potatoes. Processors, distributors, exporters and logistics companies will also benefit from an increased output by the farmers. They can use the greater

produce to produce more processed chips, export more on the world market and/or transport more produce into other countries. This results in a better commercial position and possible higher revenues for those companies. If with the current technical maturity an increase of 3% is possible and farmers make full use of the application, then processors should be able to increase their output by 3% as well.

As mentioned above, it has been announced recently that processors are ready to invest in a faster market uptake by farmers. Paying € 250-750 per farmer for using WIG and covering about 20% of potato farmers, the industry is investing together about € 850k. One can reasonably assume that the industry is prepared to do so since they expect that through the use of WIG by farmers the return of investment to them will be a minimum of € 850k over the next (at least) two years. It is difficult to estimate the time period when the industry expects to have fully recovered the investment.

A small economic benefit derives also from the fact that through WIG the industry knows what quantity and quality to expect from a certain farmer and field, improving efficiency and productivity. In the case of homogeneous fields and consequently potatoes both costly sorting and machinery settings adjustments are next to zero before processing. In contrast, more heterogeneous potatoes need laborious sorting and a change of the processors' machineries' settings which makes productions more expensive.

A disturbing factor for this evolution could be the fact that producers have often contracts with several buyers in trade and processing industry. Setting up a scheme as WIG demands investments, also from the buyers. Some are willing to do so, whilst others might just wait and profit. This will be a driver to strengthen one on one relationships between farmers and their buyers. Starting a project like WIG seems easier in Northern America, where big processors have already installed a one on one relationship with farmers in the neighbourhood of their processing facilities. The more diffuse network in Belgium and Europe doesn't make things easier.

Assessing the value to the processors would be a hard analysis to make. Fortunately, we have a good first indication from the investment of 850k which is being made by the processors into the use of WIG by the farmers. It is anticipated that this will be taken up by 20% of the farmers in Belgium so more or less the current user base of WIG. In general, as a first approximation benefits are shared so 850k investment would lead to 1.7m of benefits; both figures over 2 years.

If this were to become adopted across the whole industry, probably through adoption of regulations or market-based rules driven by the "branch" platform, the benefits would be 5x i.e. 4.25m up to 8.5m.

But the processors will also benefit from an overall increase in yields by Belgian growers. We saw earlier that between 15% and 20% of gain is anticipated once WIG has been fully developed and adopted. The market value of the processed potatoes is 2.2b. But, whilst this increase can help drive the processors business, only a fraction of this will be a benefit since potatoes could be sourced from elsewhere. We shall take a net benefit of 5% for the processors which leads us to

the results shown in xxx which we assign to an overall better control of the production ie improved process management.

	Today		Full Adoption	
Investment by processing industry	425k		4.25m	
Benefits deriving from investment	425k – 850k		4.25m -8.5m	
Yield increase			15% - 20%	
Revenue increase based on 2.2b			330m – 440m	
Share of benefits from increased production	5%			
	Today	Full Market	Full Technology	Full Market & Technology
Value of benefit	425k - 850k	4.25m -8.5m	1.6m – 2.2m	16.5m – 22m

Table 5-5: Benefits for the processing industry

5.2.5 Tier 5: Supermarkets, Shops – and Friteries

Supermarkets and shops are not heavily affected economically by the increasing potato yields, though shortage and oversupply can lead to promotion actions, especially by retailers. Since food patterns and new trends emerge as a result of globalization, the consumption of processed potatoes and chips in Belgium is estimated to either stay stable or experience slight decline over the next years. Supermarkets are thus interested in having a stable supply, satisfy the demand that is there and profit from a positive image through the decreasing use of chemicals on the part of the farmers. Furthermore, the 5,000 chip shops that are satisfying the Belgian need for chips can be sure of a stable supply of their main offering. On the other hand, the potato crop remains strongly linked to nature and the weather conditions. Contracts are being made before potatoes have been harvested. When “accidents occur” due to exceptional drought and heat – as in the 2019 crop – processors are confronted with higher raw material prices, which cannot be translated to the retail trade. WIG could contribute to better understanding of both historic trends and future predictions and offer at least a partial solution for this blindness.

5.2.6 Tier 6: Citizens and Society

The general public benefits in several ways from the services offered by WIG. As just mentioned, the societal food patterns have changed and so the demand for processed potatoes such as chips is slowly decreasing. Thus, a higher output of processed potatoes may benefit citizens if it means prices stay stable in view of climate change-induced extreme weather events or even decrease thanks to economies of scale. More interesting for the general public is most likely the decreasing use of chemicals in the fields that can enter the soil and ground water. Moreover, a more efficient

use of water generates savings. The general public thus benefits from more healthy potatoes and a more sustainable environment rather than financially.

5.2.7 Other Beneficiaries

The project to establish a cross-sector, and cross-administration platform known as a “branch” has been mentioned earlier in chapter 2. If successful, the platform will allow a more optimum sharing of benefits along the value chain and especially between the farmers and the processing industry. In time, this will allow the full benefit of Sentinel use to develop the Belgian potato industry both from the farmers perspective to maximise the homegrown crop and from the industry to increase their supply chain. This potential has been considered in looking at the overall benefits of the use of WIG.

5.3 Summary of Benefits

The summary of the quantitative benefits calculated is shown in Table 5-6 below. As indicated earlier, the benefits today are only a fraction of the potential benefits coming across the country as a result of using WatchITgrow. The benefits may seem high, but this must be considered in the context of the whole potato sector in Belgium to which WIG will contribute significantly.

Each benefit is shown against the tier in the value chain to which it applies. Hence the value of WIG today along the whole value chain (tiers 1,2,3,4) is assessed to be between €1.87m and €2.2m distributed according to the different impacts.

Today, WIG is addressing around 10% of the market in Belgium. It is being used by around 420 farmers out of a total of 5000. But there are always likely to be some farms which do not adopt the new technology and we have assumed a market uptake of 80% is the maximum potential. Hence, if the system were to be applied to this whole market then the benefits would be as shown in the second column headed “full market”. These are assessed at €16.4m to €24.4m.

Tier		Today	Full Market	Full Technology	Full Market & Technology
1	Service provision	No direct financial benefit			
2	Reduced chemicals	125k	1.19m	250k	2.38m
	Increased Yield	800k – 1.2m	8.1m – 11.9m	4.5m – 7.9m	40m – 59m
	Better timing of harvest	270k	2.7m	395k	3.95m
3	Reduced agronomist kilometrage	150k – 180k			
4	Improved process management	425k- 850k	4.25m - 8.5m	1.6m – 2.2m	16.5m – 22m

TOTALS (min)	€1.78m	€16.4m	€6.9m	€63 m
TOTALS (max)	€2.6m	€24.5m	€10.9m	€87.6m

Table 5-6: Benefits in Euro coming from the use of WIG

Many of the benefits of WIG are yet to be realised as more data needs to be assimilated by the system and exchanged with the various players. A greater degree of trust and sense of mutual benefits are necessary so that the different actors work more closely together to realise the maximum potential. This is the goal of the “branch” platform.

We have given this the term “technology potential” as it is this realisation which will drive the full potential of the technology. This alone, applied to the current users, would lead to benefits of €6.9m to 10.9m across the whole of Belgium.

Finally, if both these potentials can be reached in full then the benefits are assessed as being €77m to €107.6m.

These calculations have been made for the WIG system to which satellite (Sentinel) data contributes. How much of this can we attribute to the satellite data?

Satellite data is at the heart of the system and, although other data sets are highly important, they would be difficult to apply if it were not for the satellite imagery providing the framework. Consequently, we consider that the benefits of the Sentinel satellite data are at a minimum 50% of the total and could be as high as 80% of the total. Applying this to the minimum and maximum figures given in Table 5-6, we arrive at the results shown in Table 5-7.

	Today	Full Market	Full Technology	Full Market & Technology
Totals for WIG (min)	1.78	16.45	6.90	63.05
Totals for WIG (max)	2.63	24.48	10.93	87.58
Total for Sentinel (min) - 50%	0.89	8.23	3.45	31.53
Total for Sentinel (max) - 80%	2.10	19.58	8.74	70.06

Table 5-7: Benefits (in mEuro) from the use of the Satellite data

It shows that the benefit today, due to the use of the Sentinel data as a part of the WatchITgrow platform, is between €0.9m and €2.1m which can rise to €8.2m to €19.6m with a full penetration of the market in Belgium. As the technology improves, more data is entered into the system and a co-operative platform or “branch” is created, the benefits rise sharply to a potential of €31.5m to €70m. This is shown illustratively in Figure 5-1.

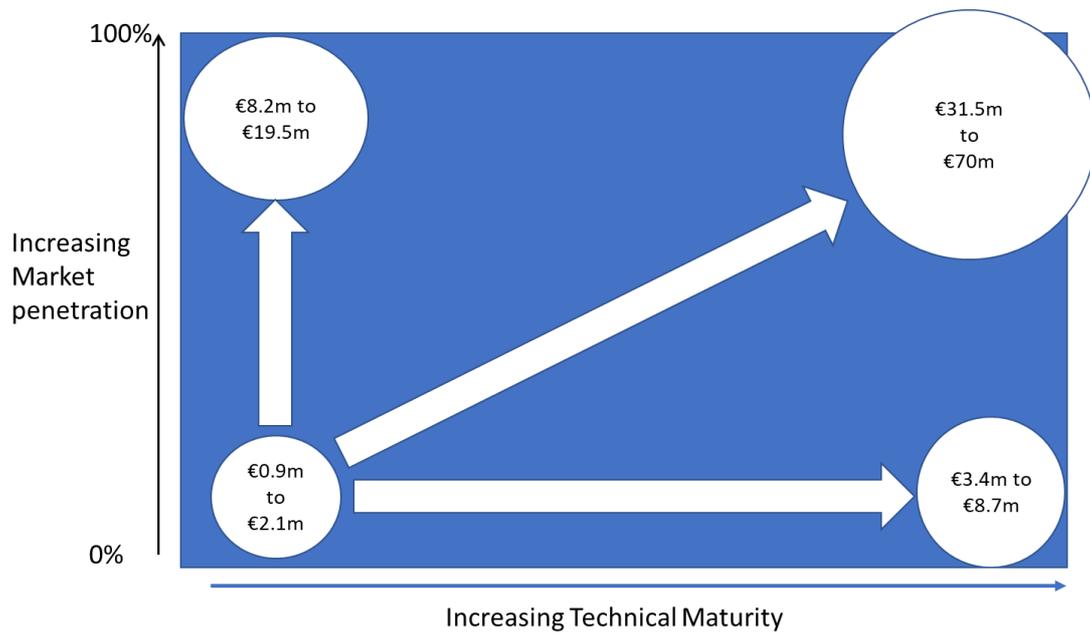


Figure 5-1: Representation of the potential benefits of using Sentinel data for Growing Potatoes in Belgium

6 Conclusions

6.1 Summary of Findings

The potato industry is an important part of the Belgian economy due to the presence of suitable fertile farmland (in the potato belt of northern Europe) and a processing industry that is number 1 in the world. Hence it is fertile ground also for the development of a digital platform which can help the sector to become more efficient.

The WatchITgrow service developed by VITO provides farmers with information on their fields and crops. Imagery from Sentinel 2 lies at the heart of the system which also integrates data coming from the Belgian meteorological service, data entered by the farmers themselves and potentially data from in-situ sensors or even drones in the future.

The data is used by the farmers, the processing industry and other actors in Belgium. As a result, there are some cost savings but also a potentially significant increase in yield. The benefits are calculated as being €1m to €2m today and could rise to as much as €70m in the future, if/when more farmers will use it and technological advancements will have been implemented.

That benefits are so high in Belgium is due to the presence of the processing sector which is several times larger than the growers. This creates benefits along the value-chain and not just focused on farmers as has been the case in other agriculture cases of Farm Management in Denmark. The downstream sector benefits from an increased local source of potatoes as well as better quality potatoes which can be processed into higher value processed products.

WIG, and the use of satellite technology, are also having an impact on the organisation of the sector. We have seen elsewhere, largely outside of SeBS cases, that the ability to develop a synoptic, wide-scale picture enables diverse organisations to overcome barriers to co-operation. The whole sector in Belgium is currently coming together to exchange and discuss the future and to improve overall production processes and revenues. It is not just the satellite data which makes this happen, but we are convinced that it is a strong factor for increased co-operation between the industry, the farmers, and the other stakeholders in the sector. Belgapom, as a common entity is playing a strong role here.

6.2 The Impact of Sentinel Data

The Sentinel data lies at the heart of WatchITgrow and whilst other data also plays an essential role in the performance of the system, the regular satellite updates are what make it work. Currently based on Sentinel 2 optical data, Sentinel 1 radar data will be introduced giving an additional source of information which is independent of the weather conditions.

Whilst WIG embraces many different data sources, including that coming directly from the farmers, the satellite imagery provides wide-scale updates on the field and crop conditions. The value of the satellite data in the overall system is high and we have estimated that between 50% and 80% of this would be lost if the satellite data would not be available.

In the future, other satellite data such as high spectral resolution could be introduced as could better data on soil moisture conditions (which can partly be derived from Sentinel 1). These may add to the overall value of the service to save farmers time, reduce losses and to increase yields.

More frequent observations and faster delivery could also enhance the role the Sentinel data could play. However, more work is needed to assess the capability to detect blight in time to react. The disease spreads very rapidly but greater sharing between farmers across Belgium could enable a more effective treatment to become possible.

6.3 Widening the Perspective

Potatoes are grown in many countries and the use of Sentinel's data and of applications like WIG could be extended to those quite easily. There are of course legislative and technical hurdles to adapt to different countries, but the technology is quite portable. In fact, VITO and the industry association Belgapom are already working hard to promote Belgian products elsewhere in the world.

The top 20 potato growing countries (see Figure 2-1) are potential targets for the export of the technology although the top 3 (China, India, Russia) will all be difficult to address. Just in Europe, Belgium is producing about 8% of the crop and if we simply scale the benefit of the use of satellite data across Europe we have a figure today of between €10m and €25m and with realisation of the full potential of the system an impressive €450m to €1b. Of course, not all of this would be possible given that the same leverage effects with the processing industry as exist in Belgium are not present in all countries, but even so a benefit of several €100m should be possible. And, whilst the processing industry is a driver it is also a barrier in that the farmers do not trust them. Hence, in other countries where there is no tension in the value-chain, there may be lower barriers to achieving the full potential.

Other root crops may also be addressed with perhaps sugar beet being the closest in nature to potatoes. Europe has significant production capability for sugar beet and a service could easily be extended.

Rank	Country	Production (million tonnes)
1	 Russia	51.36
2	 France	33.79
3	 United States	33.49
4	 Germany	25.50
5	 Turkey	19.46
6	 Ukraine	14.01
7	 Poland	13.52
8	 Egypt	13.32
9	 China	8.09
10	 United Kingdom	5.69
Total	World	277.23

Figure 6-1: Global sugar beet production (2016)⁶⁴

6.4 Final Thoughts

The story of the use of Sentinel data to support potato crop production in Belgium is indeed an interesting one. We see, as in earlier cases, the potential to deliver considerably more economic benefit as the technology becomes more mature and it is taken up by more farmers. Today only around 1 to 2% of the potential is being realised.

Belgium differs from many countries with the presence of a world-leading potato processing industry which acts as the spur for investment in the application WatchITgrow and the consequent use of Sentinel data. The industry is not fully aligned today due to unequal power within the value-chain and due to the political/administrative set-up in Belgium. So, it is particularly interesting that the use of satellite data and WatchITgrow is forging new alliances with the formation of a national level “branch” to provide a neutral platform for exchange between all the key stakeholders.

There is significant potential to expand the use of the Sentinel data to support potato farming and improve production, as well as reducing inputs, in Belgium and then elsewhere in the world.

⁶⁴ Source: Wikipedia/FAO statistical office.

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Annex 2: General Approach and Methodology

This is the seventh case to be analysed which looks at the value being created by the use of Sentinel data. It follows the same basic methodology⁶⁵, established during a previous study, which follows a value chain for the use of a single EO service. Additionally, the analysis includes a look at the environmental impacts.

For each case, a value chain is established with a service provider and a primary user. The value-chain is validated with these two key players. Through a combination of desk and field research we develop our understanding of all the actors in the value chain, the role that they play and how they may benefit through the use of the satellite-derived products.

Once written, the draft report is then shared with all the persons with whom we have spoken and their comments are incorporated or a further discussion is held to establish common understanding. At the end of this process, the report is made public.

For each new case, a comparison of details 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 the following points stand out:

- There are strong similarities between the use of Sentinel data to support farm management for different crops. The fundamentals are very close but the context and business model does vary.
- In this case, the processing industry is a strong driver and could have been considered as the primary user. Much of our discussion was with the Association Belgapom which represents this part of the sector.
- The potential for increase in value is high. Both the market penetration and the technical maturity will improve so driving higher potato yields, better information for the industry and overall production in Belgium. It seems likely that these characteristics will be present in all agriculture cases.

⁶⁵ 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.⁶⁶ 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.⁶⁷

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 innovation⁶⁸ 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.⁶⁹

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).⁷⁰ Similarly, 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.⁷¹ 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 1992–1997.⁷²

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.

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