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EuroGEOSS Showcases: Applications Powered by Europe

D5.8 – First socio-economic value of EO in selected sectors report

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e-shape

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The services and products developed by the different e-shape pilots have the potential to deliver significant benefits to their engaged users but also to additional stakeholders in the associated value chains. Understanding and quantifying – where possible – these benefits can support both the development of solutions that are better fit-for-purpose, but also stimulate their wider uptake. This becomes more prevalent when considering the mission of e-shape with regards to upscaling the pilot outputs.

In view of this, e-shape will produce three reports on "**Socio-economic value of EO in selected sectors**". These shall function as a "marketing" support tool targeted at the different user communities and providing impetus to the policy making surrounding the uptake of Copernicus and the e-shape showcases.

Moreover, by extending the methodological framework developed within the Sentinel Benefits Study (SeBS), these reports provide a contribution to the body of knowledge of the European EO community when it comes to quantifying and presenting the benefits EO solutions enable. Specifics on our methodology is provided in the following chapter.

The expected output of this activity is three publications focussing on different sectors, delivered at M23, M30 and M40. The methodology described below will guide this process, which will follow these steps

- The first publication (i.e. the current report) focusses on the agriculture showcase for which the team has the best starting point (thanks to previous work on SeBS and well established metrics that allow extrapolation). The report combines inputs from previous work with a fresh look into the value chains served by the different pilots under the agriculture showcase, so that the potential benefits they yield can be highlighted. These "data points" serve our effort to put forward a robust extrapolation approach.
- Subsequent publications will target other showcases, and we shall follow the level of progress the pilots have in order to decide the sequence.

The work is being performed by Evenflow and EARSC.

2 METHODOLOGY

2.1 Understanding the impact of an EO-based service across a value chain

The use of EO-based services can significantly help actors in different domains and along the respective value chains to address the challenges that shape their own operational reality. To fully understand this value it is essential to identify the decisions and processes undertaken by the different actors in the value chain and pinpoint how the availability of EO data or derived services generates value. Thus, the starting point of our analysis is the identification of well-defined value chains and the evaluation of how EO benefits the involved companies, businesses, government stakeholders and, eventually, even society, the economy and the environment at large (i.e. increased efficiency, productivity, quality, etc.). A generic visualisation of a value chain is shown below.
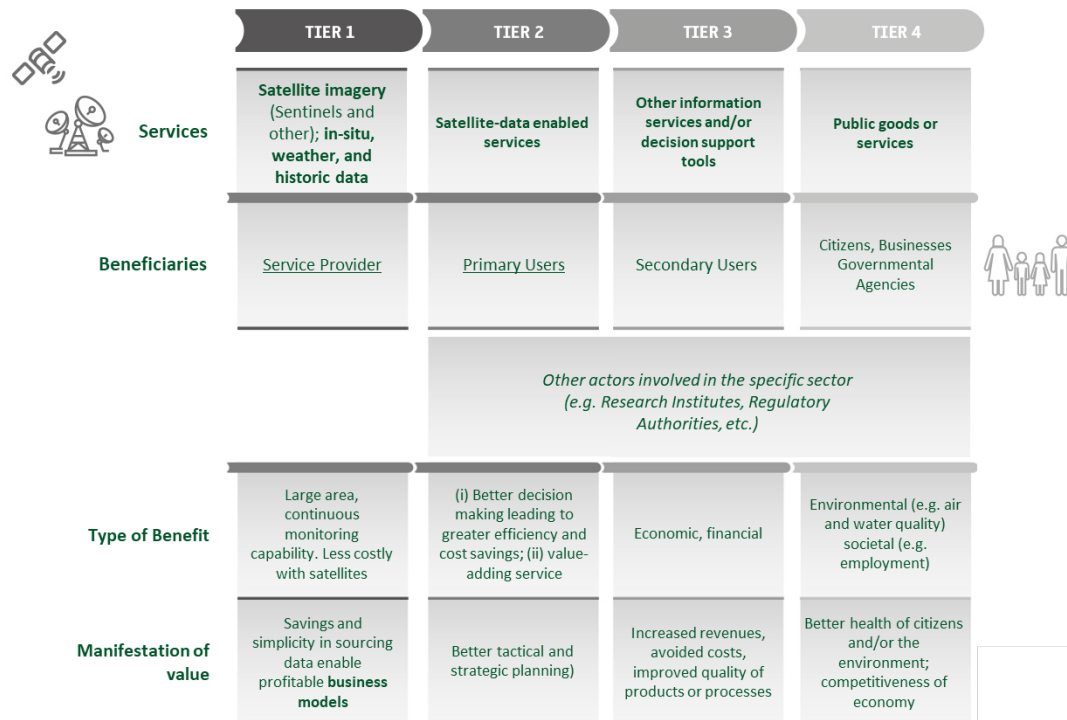
Figure 2-1: Visualisation of a "generic" value chain used to study the different cases

Studying each link of the value chain, we try to develop solid argumentation around the benefits the different actors experience thanks to the use of EO-based services, and where possible quantify these benefits.

Typically, each value chain consists of 4 "tiers". Short descriptions of what is generally dealt with in each tier are given below:

- **Tier 1**: **Service Provider** - In this tier the benefits experienced by the EO "service provider" are described. For example, a remote sensing company saving money by utilising free EO data as opposed to paying for EO data.
- **Tier 2: Primary User -** In this tier the benefits experienced by the primary user of the EO service are described. For example, a public body who use the EO service to help monitor farmers' compliance to CAP requirements in more efficient manner. **Note:** We are just using an example of a public body in this illustration. Tier 2 can also often describe private primary users.
- **Tier 3: Secondary Users -** In this tier the benefits experienced by the stakeholders downstream of the primary user are described. For example, farmers who get monitored and receive subsidy payments in a swifter and more transparent manner thanks to public body's efficient use of EO data.
- **Tier 4: Tertiary Users -** In this tier the benefits experienced by the stakeholders downstream of the tier 3 beneficiaries are described. Quite often tier 4 describes benefits experienced by citizens and society. For example, the benefits experienced by the general public who get to enjoy the rural landscapes maintained by the farmers in tier 3.

This **value-chain approach** has been developed by Geoff Sawyer and Marc de Vries (with 3 case studies analysed in 2015-2016), has been further honed through the SeBS study (reaching a current total of 19 cases with several more in the pipeline) and is strengthened through regular interactions with the GeoValue[1] community.

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[1] See here https://geovalue.org/

This report builds on the outputs of these efforts and attempts, for the first time, a consistent "upscaling" of the application of the value-chain approach. In this regard, **we shall draw from the very well understood value chains within the SeBS case studies to illustrate how value can be experienced across sectors, ideally in direct reference to the services produced by the pilots.** The methodological framework developed in SeBS, and in particular the 6 dimensions of benefit (see 2.2 below) will form the basis for our analysis, which is extended through an extrapolation approach (see 2.3 below).

2.2 Documenting the value of a given EO-based service along 6 dimensions

For each application/pilot, the availability of EO-based data/products at the entry point of the value chain, enables actors in each different tier to access and act on different types of information, helping them to make informed decisions and proceed with targeted interventions. Whilst each case has its own characteristics, certain commonalities with regards to the types of experienced benefits have been observed. In practice, we can identify 6 dimensions of benefit: **(i)** economic, **(ii)** environmental, **(iii)** societal, **(iv)** regulatory, **(v)** innovation and entrepreneurship-related, and finally **(vi)** science and technology-related. The definitions for each of these dimensions are provided below.

Dimension	Definition
ECONOMIC	Impacts related to the production of goods or services, or impacts on monetary flow or volume, such as revenue, profit, capital and (indirectly, through turnover generation) employment.
ENVIRONMENTAL	Impacts related to the state and health of the environment, particularly as regards the ecosystem services on which human societies depend.
SOCIETAL	Impacts related to societal aspects such as increased trust in authorities, better public health or secured geostrategic position.
REGULATORY	Impacts linked to the development, enactment or enforcement of regulations, directives and other legal instruments by policymakers.
INNOVATION-ENTREPRENEURSHIP	Impacts linked to the development of new enterprise and/or the introduction of technological innovation into the market.
SCIENCE-TECHNOLOGY	Impacts linked to academic, scientific or technological research and development, the advancement of the state of knowledge in a particular domain.

Table 2-1: Definitions of the benefit dimensions

Each of these dimensions represents an area where the use of EO-based services can produce a significant impact. The benefits for some of these dimensions cannot always be quantified (let alone monetised) but that should not stop those providing, using or analysing such services to try and identify the specific contribution that EO has. Therefore, in our effort to extrapolate the value generated by EO, we shall consider both the quantifiable and non-quantifiable aspects. The specific approach we introduce in e-shape is described below.

2.3   Extrapolating this value by looking into geographic extension and market penetration aspects

Assessing the benefits generated by the use of EO in a given sector (here agriculture) presents us with an important challenge: how can we ensure that the argumentation we develop and the numbers we estimate are a good and representative fit to the reality of that sector? Traditionally, the "easy" answer to this has been a top-down, macro-economic approach combined with a few case studies to highlight the non-quantifiable benefits. Such approaches, used for instance in the Copernicus Market Report[2], whilst offering a nice panoramic view, often suffer from a luck of accuracy when it comes to the underlying structure. On the other side of the spectrum, bottom-up approaches such as the one deployed in SeBS, are by construction focussing on specific, very well studied cases and attempt only a qualitative analysis of how their results can be seen in a wider perspective.

Here, we aim to build on the well-studied bottom-up cases and construct a broader, well-justified picture. <u>Please note:</u> The extrapolation method described is primarily applied to economic benefits.

To do so we start with the assessment of specific value chains, which we then try to generalise and extrapolate so as to present benefits tracked back to EO-based services for whole sectors. The figure below is graphic representation of our approach. It distinguishes between a "bottom-up" type approach to estimating value and a "top-down" approach. A "bottom-up" approach gains a very good understanding of benefits and value manifested at the micro level i.e. in a single value chain with a relatively small number of stakeholders. This approach only gains a limited understanding of the overall value and benefits manifested at the macro level i.e. at a regional, national or supranational level. A "top-down" approach is the opposite, it gains a good understand of benefits and value manifested at a regional, national or supranational level, but only a limited understanding of the benefits and value manifested at the micro level. Our approach is somewhere in the middle, whereby we take well understood micro-level cases, link and group them by application and then build a picture of various market segments. Taking the market segments as "building blocks" of the overall market, we aim to illustrate the potential magnitude of the overall macro-level benefits.
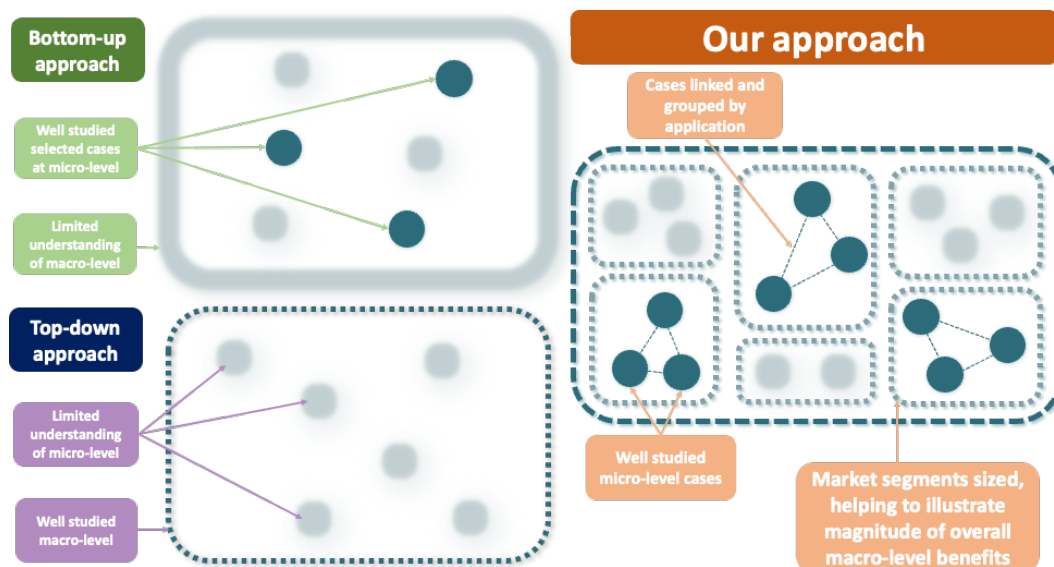

Figure 2-2: "Bottom-up", "top-down" and our approach to value estimation

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2 https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf
e-shape

In our extrapolation we will be looking into two perspectives: (i) geographic extension, (ii) increased market penetration.

2.3.1 Geographic extension

The global coverage of Earth observations, i.e. their ability to capture every spot of the Earth, allows service providers to offer solutions that address customers across borders. Therefore, in principle, the findings of a given case can be extended beyond the geographic borders of the country in which the case is being carried out. In practice, however, this also depends on multiple other factors:

- is the EO service addressing a problem that is – to a large – extent similar in different countries?
- Is the climatology, geomorphology and other relevant environmental conditions comparable, to the extent that a given solution is transferrable?
- Is the regulatory or business framework equally conducive to the uptake of a given solution?

Depending on the answers to such questions, we are able to project the benefits of a given case in a wider geographical scale. In essence, this is a market sizing exercise, whereby the questions above act as filters that allow us to zoom in from the total addressable market (TAM), potentially at a global level, into the serviceable addressable (SAM) and eventually serviceable obtainable (SOM) markets. This process is applied for each individual case and, naturally, case-specific parameters are taken into account to define the extent to which this extrapolation can be justifiably done. Yet, despite such case-specific parameters, when we look at the full portfolio of cases that have been analysed, we can already note that the feasibility of a meaningful geographic extension is strongly justified.

In practice, within e-shape, we shall estimate the SOM for the applications/pilots that are considered in the analysis of EO value for a given sector, by addressing precisely this geographic extension perspective.

2.3.2 Market Penetration

The cases analysed in SeBS but also in other activities all share a common denominator: a very committed primary user who can appreciate the value they receive because it enables them to deliver increased value themselves (further down the chain). These primary users are the ones that typically offer an entry point to a specific market for the service provider. But how many more such clients could the service provider target? And what is a reasonable market share that either the specific cases or a bouquet of similar services can capture?

These are the questions that characterise the market penetration perspectives. In this regard it is important to observe that most of the EO-services are offered to their users through widely spread user interfaces (i.e. web services, smartphone apps, etc.). This, in itself, means that such services have wider market potential. What is more, the back end of these services relies on the processing of different sets of data (satellite observations, in situ, meteorological) which are typically provided at scale. In the specific case of Sentinels, the extra "handling costs" might not be negligible but they are certainly not restrictive for companies that want to serve multiple users simultaneously. Moreover, thanks to the proliferation of automated workflows, there is large growth potential. This may well be supported by the recent rise of services (such as Copernicus DIAS[3]) offering cloud computing services "next to the data". These technological and service provision trends do not of course necessarily reduce the effort required by companies in business development and marketing of their solutions. They do however facilitate reaching out to a wider pool of potential users.
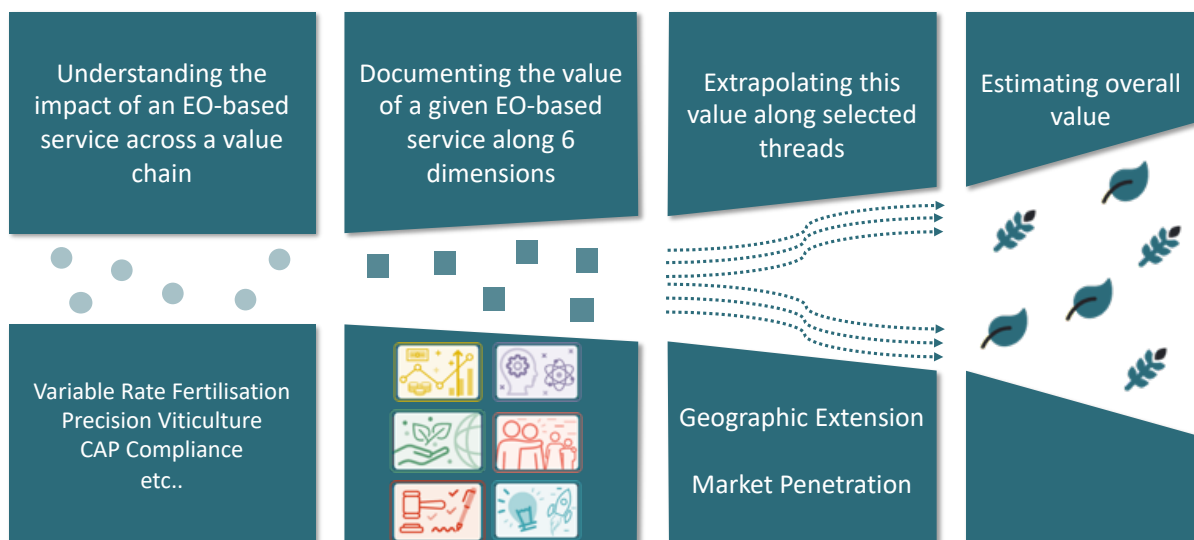
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[3] See here: https://www.copernicus.eu/en/access-data/dias

e-shape

In practice, within e-shape, we shall estimate the SOM for the applications/pilots that are considered in the analysis of EO value for a given sector, by addressing precisely this market penetration perspective.

2.4 Definition of "threads"

EO is adopted by so many users in such a large and varying number of applications that it is extremely difficult to estimate the true or total value it brings. As a result of its ever-increasing adoption and application, EO's benefits continue to branch across sectors and tiers in such a wide-reaching manner that to capture the almost fractal nature of its entire impact would be close to impossible. Instead, a different approach has been chosen.

As already described in our approach to extrapolation (see section 2.2 above) we are taking some already well-defined data points from SeBS as starting points for our analysis and will look at interesting "threads" of value. This will help to paint a picture of the value EO can bring to specific applications within agriculture, without attempting to capture the entirety of the complex and continually evolving value it brings. This is precisely the compromise between the "bottom-up" and "top-down" value quantification described in section 2.2. We take well understood micro-level cases, link and group them by application and then build a picture of various market segments. We then take these market segments as contributing "building blocks" of the overall market and use them to illustrate the potential magnitude of the overall macro-level benefits. Some threads will quantitatively illustrate value while others will qualitatively describe how value is added. This "bottom-up" approach to the quantification of value (as opposed to a top-down, meta-level approach) draws from real-world, well understood value, builds a strong and rational extrapolation model and helps to convey the possibilities EO holds in a plausible and easily understandable way.

| Understanding the impact of an EO-based service across a value chain | Documenting the value of a given EO-based service along 6 dimensions | Extrapolating this value along selected threads | Estimating overall value |

Variable Rate Fertilisation
Precision Viticulture
CAP Compliance
etc..

Geographic Extension

Market Penetration

Figure 2-3: Graphical representation of the approach to evaluating socio-economic value in e-shape

For example, when using a thread to demonstrate economic benefits, we will begin with a specific service or benefit for which we already have robust data on regarding its economic impact in a given country or region. We will then extrapolate this thread across geographic regions using market penetration as a moderating factor to understand the potential value this particular application could bring to agriculture at a macro level.

When demonstrating the benefits associated with particular societal or environmental threads, we will draw from already well understood case studies to describe the potential value this thread could bring at a macro level.

The following section illustrates how EO can aid agriculture and describes some chosen threads of value across the already discussed 6 dimensions of benefit.

3 VALUE ADDED BY EO IN AGRICULTURE

3.1 How EO can aid agriculture

Within e-shape, we hope to develop effective solutions which can make farmers' lives easier while simultaneously fortifying Europe's food security. But what exactly are the challenges faced by farmers or other actors in the agriculture value chain? And how can EO address them?

It can be quite difficult for farmers to know exactly what fields and which crops need their attention. Variations in both crop health and yield can materialise within the same field, soil conditions across farms can be difficult to monitor, and knowing exactly the correct amount and timing for the application of inputs such as fertilisers, pesticides, fungicides is no easy task.

These, and many other similar challenges are shaping the farmers' everyday reality, especially in relation to the most important interventions throughout the year (spreading/sowing, fertilising, spraying, irrigating, harvesting, etc.). Understanding what is happening, where and when is thus of utmost importance. To that end, EO data can allow for the collection and interpretation of a wide range of information on the different conditions that affect crop growth and quality (e.g. soil composition and moisture, weather and climate aspects, crop health, surface temperature, etc.).

Remote sensing techniques are being increasingly used for the provision of timely and accurate data on several aspects related to agricultural production. The combination of satellite imagery with meteorological data, agrometeorological and biophysical modelling and statistical analyses allows the continuous monitoring of agricultural areas and the extraction of valuable information that can guide efficient farming practices. In this context, the ability of satellites to gather information on different crop and soil properties as well as to identify pests or other threats (e.g. floods or droughts), over large areas and with a high revisit frequency, is leveraged in multiple applications. In this context, we provide below a short sample of some "traditional" agricultural practices that can be aided by EO-based services.

3.1.1 Crop monitoring

Being able to monitor the status and growth trends of their crops, helps farmers to maximise their yield and to react to potential threats. In practice, crop growth monitoring entails an observation of changes on the crop status in relation to abiotic factors such as water stress and biotic factors such as insect infestation. Thus, farmers seek to monitor specific crop growth parameters such as crop vigour, crop stage, biomass and leaf area index (LAI).

EO data can be particularly helpful in agricultural applications thanks to its ability to generate information in the form of widespread indices such as the Normalised Difference Vegetation Index (NDVI). NDVI techniques measure the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). Healthy vegetation (chlorophyll) reflects more near-infrared and green light compared to other wavelengths, and as a result, plant health status and vegetation coverage can be inferred easily.

Within e-shape, **Pilot 1.1 – GEOGLAM** is developing crop monitoring algorithms that can be used to derive information on crop calendars, i.e. specific field interventions such as harvest, planting or

e-shape

ploughing. **Pilot 1.3 – Vegetation-index crop-insurance in Ethiopia** will utilise crop monitoring technologies to help poorer farmers in Ethiopia to access financial protection against natural disasters and extreme weather events. **Pilot 1.4 – Agro Industry** will provide improved indicators for agricultural monitoring based on in situ, meteo, soil and remotely sensed data, addressing the needs of agro-industry and farmers. While **Pilot 6.4 – Resilient and sustainable ecosystems including agriculture and food** is also generating state-of-the-art disaster, meteorological and crop monitoring algorithms and downstream products to help contribute to ecosystem protection and food security.

3.1.2   Variable rate application

Precision Agriculture (PA) consists in the application of the "right treatment in the right place at the right time". Enabled by a combination of EO data, GNSS and various other technologies (e.g. proximal and remote sensors), PA enables fine-scale, site-specific management of agricultural production. This is implemented through an approach referred to as "Variable Rate Application" (VRA). Thus, by taking into account the variabilities of their fields observed through EO data, precisely guiding their farming machinery and accurately applying different inputs, farmers have been able to minimise soil compaction, reduce the use of fuel, pesticide and fertilisers, and increase productivity. Other significant benefits include the reduction of environmental impacts and increased work safety.

With particular attention to fruit farming, **Pilot 1.5 - Linking EO and Farm IoT for Automated Decision Support** aims to link EO data with ground measurements from Internet of Things (IoT) devices, to provide farmers and growers with actionable and timely information to improve their VRA activities.

3.1.3   Soil condition monitoring

Soil monitoring is one of the critical steps in crop management, given that the crop yield variability is strongly correlated to different soil characteristics in different sites within a field. In essence, by collecting accurate, site-specific information about soil characteristics such as fertility, soil-borne diseases and soil contamination, farmers can avoid over- or under-application of nutrients and other chemicals in different areas within their fields. In turn, this has a direct effect on increased yield productivity and reduced environmental impact.

EO can allow for soil moisture and condition monitoring over vast expanses through the use of active sensors, capable of emitting their own energy (in the form of electromagnetic radiation). Satellites carrying such sensors send a pulse of energy from the sensor to the earth and then receive the radiation that is reflected or backscattered from the ground. The signal received by these microwave sensors is sensitive to the amount of water contained in the first few centimetres of the soil and therefore can be used to help infer soil moisture and condition status. Typically used sensors in this category are radar, scatterometers and lidar. Satellites carrying such sensors – for example Synthetic Aperture Radar (SAR) satellites – are unaffected by cloud coverage.

Pilot 1.4 – Agro Industry hopes to develop improved indicators for soil condition monitoring.

3.1.4   Regulatory compliance

Within the European agricultural sector, the Common Agricultural Policy (CAP) is by far the most overarching and important regulation in existence. A core role of the CAP is to provide farmers with income support, through both direct payments and through remunerations for maintaining environmentally friendly practices. One such remuneration is known as "greening", which supports farmers who adopt environmentally friendly practices, such as the maintenance of biologically diverse farms and areas of permanent grassland. The traditional way in which CAP greening compliance checks were conducted involved inspections being carried out on-the-spot (at the farm) by inspectors, however, since 2018, this all changed thanks to EO.

The introduction of EU Regulation No 2018/746 in 2018 both allowed for and strongly encouraged EU member states to use satellite data in their CAP monitoring and verification activities, meaning both time and money could be saved. Automatic and continuous monitoring of European farmland and associated farm activities can be achieved through the use of EO, helping to holistically enforce CAP regulation and maintain environmentally friendly farming all across the continent.

From the examples above, it is clear that EO powered agricultural applications hold many advantages thanks to their ability to acquire rich data anywhere in the world, often in near-real time and without any limitation by weather conditions (when combining optical and SAR). Regular, detailed updates on plant and soil status can be retrieved at various scales (local, regional or national) and when combined with complementary in-situ data, airborne data or socio-economic data, invaluable insights can be generated to help farmers, food supply chain actors and key decision-makers maintain our food supplies efficiently and sustainably.

Pilot 1.2 – EU CAP Support is focussing on providing tools that will not only support farmers' in their compliance with CAP regulation, but also assist them with the adoption and implementation of smart farming practices.

3.2   Economic threads

When it comes to the impact of EO in agriculture, there is a plethora of varying case studies, impact assessments and scientific research regarding how EO data and EO based technologies can add value and help farmers or other value chain actors. In fact, by almost every metric, the agricultural sector has embraced EO based technologies more than any other sector. As a result, conducting an all-encompassing, meta-analysis of the true value EO brings to the agricultural sector is a very complex if at all attainable endeavour, and therefore goes beyond the scope of this publication. We can however try to shed light on some of the most important and widely adopted EO-based services, thus capturing a significant proportion of the overall value that EO can deliver in agriculture. To that end, we will take the approach of using the previously discussed "threads" of value to extrapolate some already well understood, real-world economic benefits from various SeBS case studies.

3.2.1   Understanding the impact of EO services across value chains

The table below is a summary of the agriculturally themed SeBS cases. "Extrapolatable" benefits from each case are listed and aggregated (where applicable) to provide data points regarding total value per hectare (€/ha/year) stemming from the case specific application of EO data in its respective region. By "extrapolatable" we mean that the benefit found in the particular case is generic enough as to allow one to reasonably assume that when applied in a different geographic location, a similar benefit would be achieved. Given that most cases have many situational nuances and uncertainties, both low and high estimates of value are provided, giving some parameters within which value was found to materialise. In most cases it is also evident that some type of variable rate application (VRA) technology is delivering value. As analysed in the recent JRC study[4], VRA technologies are the most prominent and commonly used among precision agriculture practices. This implies that even with the few cases we are building our model upon, the most representative value-adding applications of the sector are being used as baseline data points.

Case study	Primary crop	Benefit	Lower findings of value	Upper findings of value
MAKING WINE IN FRANCE[5]	Grapes	Variable Rate Application - Savings on fertilizer use	€20/ha/year	€40/ha/year
		TOTAL	**€20/ha/year**	**€40/ha/year**
GROWING POTATOES IN BELGIUM[6]	Potatoes	Variable Rate Application - Savings on pesticide use	€20/ha/year	€40/ha/year
		TOTAL	**€20/ha/year**	**€40/ha/year**
FARM MANAGEMENT SUPPORT IN POLAND[7] *	Cereals (various)	Variable Rate Application - Savings on fertilizer use	€3.10/ha/year	-
		Increases in yield	€4/ha/year	-
		TOTAL	**€7.10/ha/year**	-
FARM MANAGEMENT SUPPORT IN DENMARK[8]	Cereals (various)	Variable Rate Application - Savings on fertilizer use	€13/ha/year	€30/ha/year
		Time saving related to crop scouting	€0.60/ha/year	€1.50/ha/year
		TOTAL	**€13.60/ha/year**	**€31.50/ha/year**
GRASSLAND MONITORING IN ESTONIA**	N/A – Monitoring of permanent grassland maintenance	Cost savings – Reduction in person-hour requirements for in-field compliance checks	€0.07/ha/year	
		TOTAL	**€0.07/ha/year**	

*There are no upper findings of value in the Polish case as the economic model used was slightly different to other cases

**Not yet published – In this context the economic model in this case is also slightly different and does not use an upper or lower value

Table 3-1: Summary of extrapolatable benefits from SeBS cases

3.2.2   Grouping the crops

As we do not have more case studies to draw from regarding the benefits that can be accrued from the use of EO in many different applications with various other crop types, we will have to make some general assumptions regarding the translation of benefits from one type of crop to another. Grouping the case studies above into cases dealing with 1) fruits, 2) vegetables, 3) cereals and 4) grass, the following table displays the parameters we have set as lower and upper estimates of the magnitudes of value that can be realised through the use of EO across these generic crop types. Please note that the values we have chosen are evenly spaced inside the ranges of value in the previous table to help generalise for the many different crop types within each group.

[5] https://earsc.org/sebs/wp-content/uploads/2021/01/Making-wine-in-france-vfinal-1.pdf

[6] https://earsc.org/sebs/wp-content/uploads/2019/08/1_full-report-Growing-Potatoes-in-Belgium.pdf

[7] https://earsc.org/sebs/wp-content/uploads/2020/02/SeBS-Case-Agriculture-in-Poland.pdf

[8] https://earsc.org/sebs/wp-content/uploads/2019/03/Farm-management-in-Denmark-Full-case.pdf

The reason for the rather generic groupings of crops above is to allow for as wide extrapolation as possible. Data is readily available on the geographic coverage of these crop groups, therefore generalising some of the data from the previous table allows for further, relatively uncomplicated extrapolation and estimation of benefits. We acknowledge that the value of the benefits found in each case will obviously change from crop to crop, for example the €20/ha/year - €40/ha/year range of value found for grapes will most likely not be the same when applied to oranges. Studies in many parts of the world focussing on different crops have come up varying results regarding the economic benefit of precision agriculture technologies, from €5/ha[9] for certain applications and crops to €55/ha[10] for other applications and crops. Given the broad range of variables and continuing research and debate over the true value of precision agriculture, the generalisations and assumptions made in this report provide a solid approximation of the magnitudes of value that can be realised per crop group.
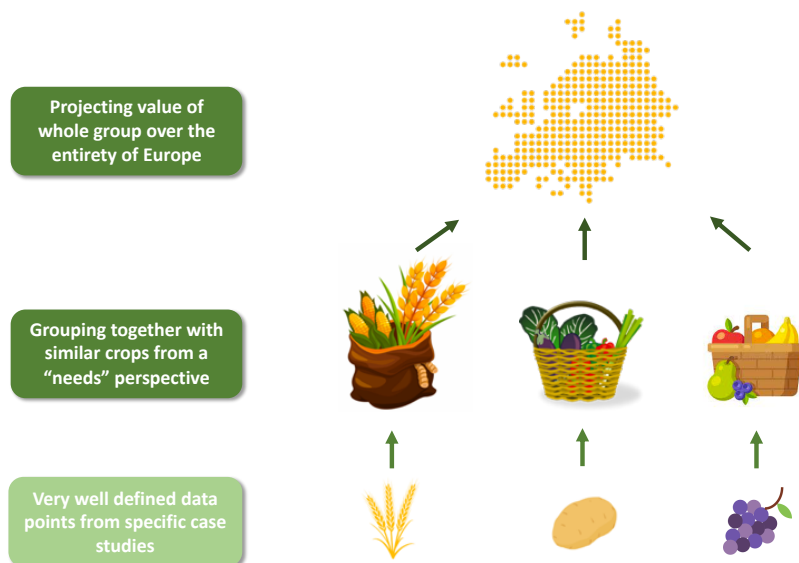
Figure 3-1: Visual representation of the "grouping" of crops approach

A non-exhaustive list of the produce included under the generic crop type groupings are as follows:

- **Fruit**: Apples, pears, peaches, apricots, cherries, plums, figs, kiwis, avocados, bananas, various berries, various nuts, oranges, lemons, limes, grapefruit, various grapes etc.
- **Vegetables**: Cauliflower, broccoli, brussels sprouts, cabbage, leeks, celery, lettuce, asparagus, artichoke, tomatoes, cucumber, eggplant, courgette, peppers, carrots, onions, beetroot, garlic, potatoes, sugar beet etc.
- **Cereals**: Wheat (spring/winter/durum), rye, barley, oats, maize, buckwheat, millet, rice, sorghum, triticale, canary seed etc.

Crop type	Based on	Lower estimate of value	Upper estimate of value
FRUIT	Making Wine in France	€27.5/ha/year	€42.5/ha/year
VEGETABLES	Growing Potatoes in Belgium	€25/ha/year	€35/ha/year

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[9] https://www.copernicus.eu/sites/default/files/2018-10/GMES_GIO_LOT3_Sector_Summary_Agriculture_final.pdf

[10] https://www.luxresearchinc.com/press-releases/precision-agriculture-is-cost-effective-for-farms-of-5000-acres

CEREALS	Farm Management Support in Poland & Farm Management Support in Denmark	€13.2/ha/year	€25.4/ha/year
GRASS	Grassland Monitoring in Estonia	€0.07/ha/year	

Table 3-2: Parameters of value per crop group

3.2.3 Extrapolating the data

The next step is to set our extrapolation parameters, based on both geographic extension and market penetration. The following parameters and assumptions have been set:

- **Geographic extension:** The geographic extrapolation is limited to the EU-27. All values are taken from aggregates of 2019 crop coverage data.[11]
- **Size of holdings:** Only agricultural holdings above 30ha are assumed suitable/eligible for effective EO based precision agriculture services. This is especially so since the Sentinel-2 resolution (and the quality of its data thanks to its multi-spectral instrument) enables services that can yield measurable benefits for farms over 30ha.[7] The percentages shown for agricultural holdings over 30ha are overall utilised agricultural area values per country, taking all farm and crop types into account in 2016.[12] More granular data regarding the breakdown of these value per farm or crop type are unavailable, therefore these percentages will be applied equally across all crop types (excluding grasslands).
- **Adoption rates:** There are a wide variety of precision agriculture technologies with varying degrees of adoption across different countries and regions:
    - One study indicated that by 2016, 15% - 40% of U.S. farms had adopted some form of variable-rate application technology, a technology often aided partially or completely by EO data. These figures were highly dependent on crop type, with corn showing the highest adoption rate (~40%), followed by rice and soybean (~20%) and then spring wheat (~13%).[13] (It must be noted that U.S. is further advanced compared to Europe in terms of precision agriculture adoption in general.)
    - A different study conducted in 2019 included European countries (primarily Denmark and The UK) and found that adoption of variable-rate technologies rarely exceeds 20% of farms. It also found the lower end of variable-rate technologies adoption for certain farms to be between 7% - 11% in Denmark and the UK respectively.[14]
- **Specificities of grassland monitoring:** The extrapolation calculation for grassland monitoring is slightly different to the others and is done in relation to the total grassland area in each given country.[15] It does not take market penetrations into account. The full detail behind this will be published in the upcoming SeBS case entitled "*Grassland Monitoring in Estonia*".

Given the range of economic, climactic and geographical differences between the 27 EU countries, agricultural market penetration rates of EO technologies will undoubtedly vary quite dramatically from country to country. In the interest of remaining conservative with our estimations and as there is a lack of data on exactly what adoption rates look like at national level, we will divide the EU into four

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[11] https://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_production_-_crops

[12] https://ec.europa.eu/eurostat/statistics-explained/index.php/Farms_and_farmland_in_the_European_Union_-_statistics#Farms_in_2016

[13] https://www.ers.usda.gov/webdocs/publications/93026/eib-208.pdf?v=2348.3

[14] https://www.researchgate.net/publication/333335891_Setting_the_Record_Straight_on_Precision_Agriculture_Adoption

[15] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Land_cover_statistics#Land_cover_in_the_EU

regions based on their European Innovation Scoreboard 2020[16] rankings. The European Innovation Scoreboard provides a comparative assessment of research and innovation performance of in EU countries and for the purposes of this publication, will serve as a proxy for the adoption levels of innovative EO based technologies in agriculture in each country. The 2020 scoreboard is as follows:

- **Innovation Leaders** – Denmark, Finland, Luxembourg, The Netherlands and Sweden.
- **Strong Innovators** – Austria, Belgium, Estonia, France, Germany, Ireland and Portugal.
- **Moderate Innovators** – Croatia, Cyprus, Czechia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia and Spain.
- **Modest Innovators** – Bulgaria and Romania.

Taking the information from the scientific studies regarding market penetration into account, we will assign low and high market penetration estimations per group as follows:

- **Innovation Leaders** – 11% - 20%.
- **Strong Innovators** – 8% - 17%.
- **Moderate Innovators** – 5% - 14%.
- **Modest Innovators** – 2% - 11%.

The following table shows the extrapolation data used in our calculations.

Country	Cereals (ha)	Fruits (ha)	Vegetables (ha)	Grassland (ha)	Agricultural holdings > 30ha*	Market Penetration - low*	Market Penetration - high*
Belgium	313110	18240	229920	950708	80.9%	8%	17%
Bulgaria	1927570	72920	38700	2086706	91.0%	2%	11%
Czechia	1352530	30750	93430	1758890	95.2%	5%	14%
Denmark	1373700	3060	103530	755335	91.1%	11%	20%
Germany	6380000	59610	821160	7847361	88.7%	8%	17%
Estonia	364360	2350	6530	721017	89.5%	8%	17%
Ireland	266660	770	25050	3974836	74.4%	8%	17%
Greece	728140	288280	88700	2559093	49.6%	5%	14%
Spain	5975710	2296110	491830	9471576	79.4%	5%	14%
France	9394030	922570	940170	14659902	93.6%	8%	17%
Croatia	490880	51480	30650	1079895	66.6%	5%	14%
Italy	3066520	1247110	495150	6538015	55.9%	5%	14%
Cyprus	23070	15230	6610	122087	42.4%	5%	14%
Latvia	733900	6510	13970	1474178	74.5%	5%	14%
Lithuania	1349570	21910	45710	1628759	70.3%	5%	14%
Luxembourg	27390	1590	840	74996	94.8%	11%	20%
Hungary	2458450	147680	119700	1850959	80.7%	5%	14%
Malta	0	420	690	7371	0.0%	5%	14%
Netherlands	178160	19640	343010	1373011	80.0%	11%	20%
Austria	776400	58100	71170	2073417	61.4%	8%	17%
Poland	7891430	319370	790050	7093033	42.3%	5%	14%
Portugal	226300	401800	72430	2096789	73.0%	8%	17%
Romania	5572510	312030	354090	6478743	53.4%	2%	11%
Slovenia	98620	19710	10440	440011	23.3%	5%	14%

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[16] https://ec.europa.eu/commission/presscorner/detail/en/QANDA_20_1150

e-shape

Slovakia	769120	12530	37440	956007	94.0%	5%	14%
Finland	946500	2690	48410	1485207	83.3%	11%	20%
Sweden	977050	2150	65860	2429438	84.8%	11%	20%

*not relevant to grassland monitoring

Table 3-3: Extrapolation parameters

Taking all data points and extrapolation parameters into account, the following table displays the results of our calculations for potential added value of EO in agricultural applications across the EU. It must be noted that due to the generalisations and assumptions made, the range of value is relatively large. However, due to the fact that all estimates of potential value are regarded as conservative, the values in the following table help to convey (by orders of magnitude) just how impactful EO could be for Europe's agricultural sector.

Crop type	Lower estimate of value	Upper estimate of value
FRUIT	€ 7,136,074/year	€ 28,405,998/year
VEGETABLES	€ 6,891,364/year	€ 22,057,608/year
CEREALS	€ 32,982,845/year	€ 154,095,595/year
GRASS	€ 5,685,532/year	
TOTALS	**€ 52,695,816/year**	**€ 210,244,733/year**

Table 3-4: Potentials for threads of EO added value in the agricultural sector

It is clear from the values presented above that EO holds huge promise for the agricultural sector. Even the extremely conservative lower estimate of almost €53 million per year is a significant benefit to the EU's agricultural sector. Within the context of this study, the €53 million per year added value is considered an absolute minimum, with real added value certainly higher in practice.

Again, the figures above represent only some "threads" of economic value that can be realised through the implementation of EO in agriculture. Whilst these threads represent the most widely adopted EO-based services, there are several other parallel threads also delivering economic value in tandem. To be clear, our approach and resulting figures are quite conservative. Through the adoption of EO-powered precision agriculture applications, many other benefits are also experienced which have not been accounted for here due to the appropriateness of generalising and extrapolating their value. For example, we have not included the economic benefits associated with reductions in fuel usage, savings in time, savings in labour costs or even increases in the quality and yield of produce. Rather than attempting to truly quantify the impact of EO in agriculture, by simply taking a small number of robust data points from well-established real-world applications, the narrative above gives an idea of just some of the efficacy and possibilities with regards to EO in agriculture as well as conveying just how pervasive and impactful it can be.

3.3 Environmental threads

The main challenge for the agriculture sector is to feed an increasing global population whilst at the same time minimising its considerable environmental footprint. This footprint is observed across several different areas[17]:

- Agriculture is a **major contributor to global greenhouse gas** (GHG) emissions accounting for approximately 23% of the total anthropogenic emissions
- Half of the world's **habitable land** is used for agriculture[18]
- **Soil erosion** from agricultural fields is estimated to be currently 10 to 20 times (no tillage) to more than 100 times (conventional tillage) higher than the soil formation rate
- Agriculture currently accounts for ca. 70% of **global fresh-water use**
- 78% of **global ocean and freshwater eutrophication** (the pollution of waterways with nutrient-rich pollutants) is caused by agriculture[19]

Against this backdrop, it becomes apparent that sustainable food production lies at the heart of any effort to tackle climate change, reduce water stress, diminish pollution and protect biodiversity. In Europe, this is driven by the Farm to Fork Strategy[20] and the Common Agricultural Policy[21], both of which are tightly connected to the overarching framework of the European Green Deal[22]. Beyond setting the strategic goals for sustainable agriculture, these policy initiatives provide also the practical framework through which this is to be pursued (see more in section 3.4). Part of this practical approach is connected to the use of EU Space technologies and in particular Copernicus. How this works is presented in the following sub-sections.

3.3.1 Reduced water pollution

Agriculture is not only responsible for the majority of water abstractions worldwide (44% in Europe[23] and up to 70% globally[24]), but also plays a major role in the pollution of water. This is associated with the vast quantities of agrochemicals, drug residues, sediments and saline drainage discharged by farms into water bodies. In fact, nitrate pollution associated with the excessive use of fertilisers is the main source of chemical contamination in the world's aquifers. This results not only in degraded groundwater quality but also in the excessive growth of harmful algae (eutrophication) in lakes and coastal waters which impacts biodiversity[25], human health and economic activities (e.g. tourism). These effects highlight the importance of sustainable use of fertilisers and pesticides – both critical for the improvement of yield. In response to this, the EU has adopted appropriate legislation starting with the Nitrate Directive back in 1991 and then embedded in the regular revisions of the Common Agriculture Policy.

In one of these recent amendments the utilisation of Earth Observation data, and in particular Copernicus, was put forward. By providing accurate and frequently updated knowledge that

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[17] Most points below are derived from the latest IPCC report; when otherwise the sources are directly referenced

[18] https://ourworldindata.org/land-use#breakdown-of-global-land-use-today

[19] "Reducing food's environmental impacts through producers and consumers" by J. Poore and T. Nemecek - February 22, 2019

[20] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/farm-fork_en

[21] https://ec.europa.eu/info/food-farming-fisheries/sustainability

[22] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

[23] https://ec.europa.eu/info/food-farming-fisheries/sustainability/environmental-sustainability/natural-resources/water_en

[24] http://www.fao.org/3/i7754e/i7754e.pdf

[25] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Eutrophication

empowers efficient crop monitoring, **EO data are a key enabler for variable rate application of fertilisers and pesticides.** As a result, EO-based solutions can play a significant role in reducing water pollution, eutrophication and biodiversity loss. Consequently, the use of EO-based solutions for agricultural practices is also contributing to the sustainable developments goals, and in particular target 6.3: *"By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally"*.

This environmental benefit has been present in all the agriculture-related cases analysed in the Sentinel Benefits Study, applying at a different extent based on the specific crops and their fertilisation needs (for instance cotton has higher needs than cereals or orchards/vineyards[26]). The reduction of fertiliser use can extend to 10-15% reduction in the quantity used in the 2nd application and 5-10% reduction in the 3rd application[27]. Similarly, discussions with experts in eco-hydrology and toxicology yielded a safe assumption of an overall 15% reduction in the use of plant protection products (only fungicides).

In e-shape, the work performed under Pilots **1.2 on EU CAP support,** 1.4 on **Agro-Industry** and **1.5 on Automated Decision Support** for vineyards and orchards is contributing to the reduced use of inputs and thus to the reduced footprint of agriculture on water pollution.

3.3.2   Reduced GHG emissions

The demand for more food has seen a continuous intensification of agriculture; more heavy machinery is being used, more and more fertilisation is occurring[28]. This, in turn, results in a continuous increase in GHG emissions generated by agriculture, a sector already contributing one quarter of global emissions[29]. As documented in the extensive work done by the World Resources Institute on this subject[30], the bulk of emissions is associated with raising livestock whilst rice cultivation, fertilisation and energy consumption are important contributors too (see graph below – credit WRI)
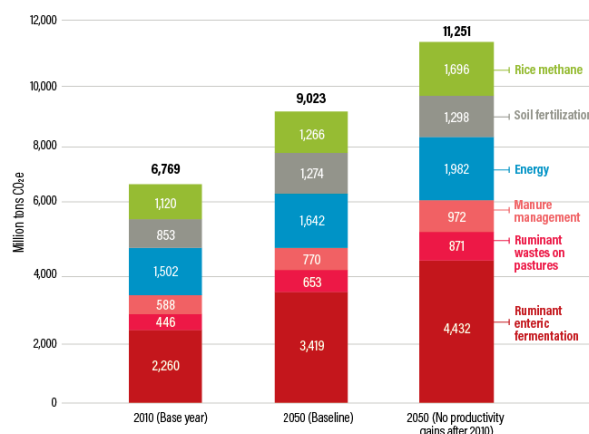
Figure 3-2: GHG emissions from agriculture are expected to reach 9 gigatons by 2050

The solution to this issue consists in wide-ranging and deep-cutting changes in the way agricultural practices are conducted and in the way food is consumed. An important part of this solution involves the reduction of emissions associated with the use of nitrogen fertilisers. This starts with the

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[26] See for example http://www.fao.org/3/Y4711E/y4711e07.htm. The data is not recent but the relative needs between crops are still fully applicable.

[27] See for instance https://earsc.org/sebs/wp-content/uploads/2019/09/SeBS-Case-Farm-Management-in-Poland.pdf

[28] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_mineral_fertiliser_consumption

[29] https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

[30] See for instance https://www.wri.org/blog/2018/12/how-sustainably-feed-10-billion-people-2050-21-charts

production and transportation of these fertilisers resulting in CO_2 emission. But, even more importantly, N-fertilisers contribute to nitrous oxide (N_2O) emissions, a gas with much greater impact on global warming that CO_2. In that regard, it is worth noting that less than half of the applied nitrogen is actually absorbed by the crops, with the rest with the rest emitted to the atmosphere or lost as run off. This makes excessive nitrogen use (see graph below) a very important environmental threat.
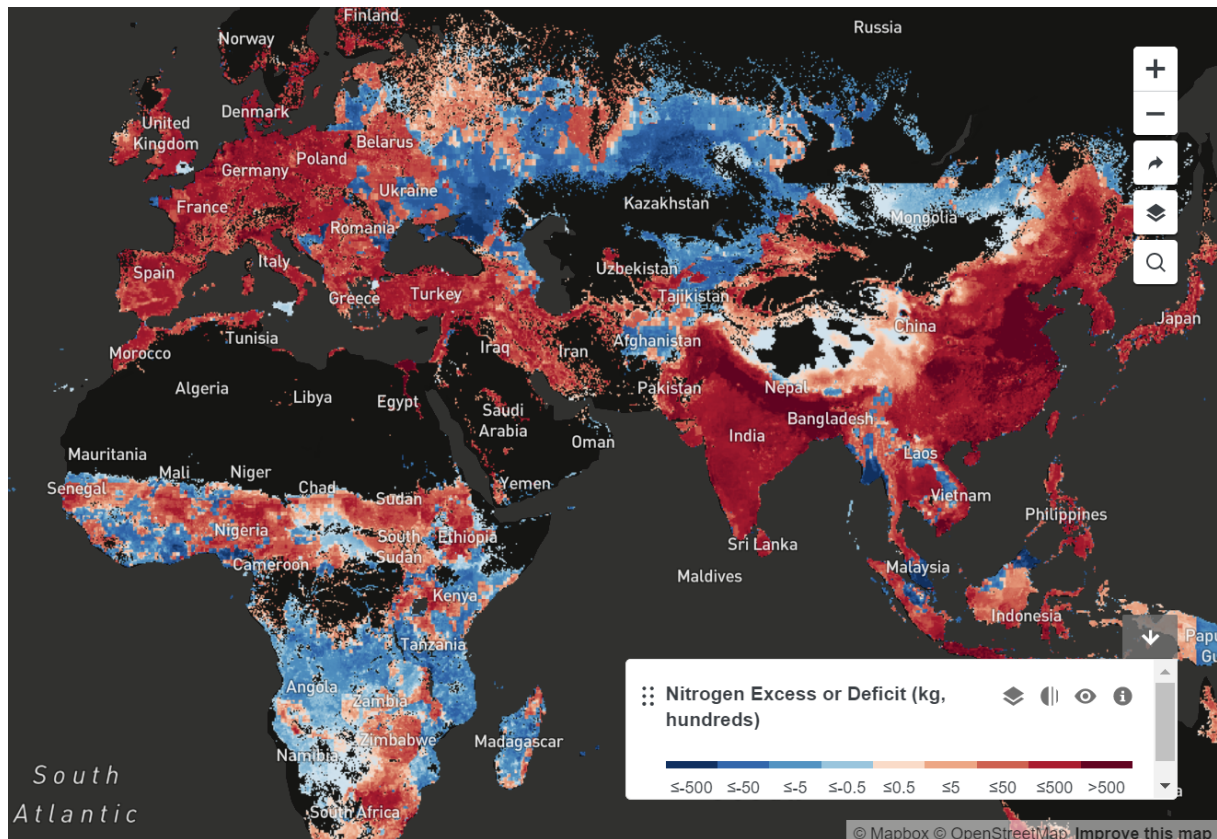
Figure 3-3: Excess or deficit of nitrogen across the globe[31]

All this underpins the importance of precision agriculture and in particular variable-rate nutrient application (VRNT) technologies. As analysed in the recent JRC study on this subject[32], VRNT is the most prominent – among precision agriculture practices – when it comes to potential reduction of GHG. As discussed earlier, this approach is relying heavily on prescription maps produced with the help of satellite EO data. All cases analysed in the Sentinels Benefit Study and virtually all pilots under the agriculture showcase in e-shape incorporate EO as a means to reduce inputs and thus confine emissions.

Another practice that can significantly contribute is variable-rate irrigation (VRI). This has a dual impact; firstly, by optimising the use of water for irrigation it decreases the energy needed for extracting water from the aquifer; secondly, the establishment of an optimal irrigation schedule can prevent extreme soil water availability, which boosts N_2O emissions. Sentinel-1 based solutions for precision irrigation are being developed by projects and start-ups over the last few years, so as soon as these efforts become fully operational we can expect an additional benefit related to reduced GHG emissions.

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[31] Source: Resource Watch

[32] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC112505/final_technical_report_pat.pdf

3.3.3   Improved protection of biodiversity

As agricultural practices shape much of our landscapes, ensuring our farmlands uphold sustainable and biologically diverse ecosystems is key to maintaining biodiversity in Europe. Almost half of the EU's land area is classified as farmed land, therefore a huge responsibility lies with EU farmers in the management and maintenance of European land for all citizens living amongst it. Biodiversity in agriculture encourages the growth of natural habitats for many species and provides us with resilient ecosystems. To take one niche example, the European Landscape Convention[33] highlights the importance of viticulture as vines can provide fire protection thanks to the low density of their rootstocks preventing fires from spreading and, as they are often planted on hillsides, they help limit soil erosion.

Through the Common Agricultural Policy (CAP), farmers can receive income support rewarding them for maintaining environmentally sustainable practices. One such initiative within the CAP is known as the "green direct payment" (also simply referred to as greening) and supports farmers who adopt environmentally friendly practices with direct payments. This, in turn, helps the EU meet its climate and environmental commitments. Farmers receive direct payments if they comply with three mandatory environmentally beneficial practices:

- **Crop diversification**: Maintaining a diverse range of crops on land helps ensure soils remain resilient and don't get drained of nutrients, which can happen when monocultural practices are upkept.
- **Ecological Focus Areas:** Farmers with more than 15 hectares of arable land must dedicate at least 5% of this to what is called an Ecological Focus Area, these include hedgerows, trees and fallow land. This in turn helps ensure biodiversity of the area.
- **Permanent grassland:** Grassland helps maintain biodiversity, protect the habitats of multiple species and even sequester CO_2 from the atmosphere. Grassland is therefore seen as an extremely beneficial commodity when it comes to greening. A careful balance must be maintained between farmed land and grassland (or permanent pasture) within a country, with this ratio being set by EU member states themselves at either national or regional level.

Pilot 1.2 – EU CAP Support is focussing on providing tools that will encourage and aid farmers in CAP compliance, which will ultimately help in meeting the environmentally sustainable missions of the EU.

The role EO can play in monitoring and maintaining biodiversity is huge. Through remote sensing, crop classification can be mapped over vast areas, meaning crop diversification can be monitored easily. Grasslands and even grassland maintenance activities can all be monitored, helping to ensure permanent grasslands are maintained where needed. In fact, the land cover and health status of many types of natural ecosystems such as arable land, forests, wetlands and shrublands can all be better understood thanks to EO-based technologies. Additional benefits for the protection of biodiversity arise from the reduced use of pesticides and fertilisers which, as described previously, is greatly aided by EO-based services.

3.3.4   Soil carbon sequestration

As already discussed, thanks to the continued intensification of agriculture, GHG emissions and in particular, carbon emissions are a major drawback of our agricultural practices. With the right farming practices, agricultural land can absorb more carbon from the atmosphere. Such practices include winter soil cover, long-term grasslands and reduced tillage. In addition to climate benefits, the

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[33] https://www.coe.int/en/web/landscape/text-of-the-european-landscape-convention

accumulation of soil carbon has many other advantages; it can improve soil quality and thus improve productivity. Keeping soil in good condition also helps farmers in adapting to climate change and extreme weather events.

Through the use of EO we can both monitor and encourage the sequestration of CO_2 in land to counteract some of agriculture's negative effects. "Carbon Farming" involves implementing practices that are known to improve the rate at which CO_2 is removed from the atmosphere and converted to plant material and/or soil organic matter. Similar to the aforementioned biodiversity practices, some carbon farming practices include permanent grassland maintenance, reduction of soil tillage, mulching/compost application, biomass planting, tree/shrub establishment, hedgerow planting[34]. Multiple initiatives related to carbon farming are ongoing, with a key expected outcome of the Carbon Farming Project being the delivery of a remote sensing based service to evaluate carbon sequestration activities in Europe.

3.3.5   Reduced soil degradation

Regenerative agricultural practices hold huge potential for boosting soil productivity and can increase the resilience of soils to floods and droughts. Regenerative techniques can include rotational planting of crops, utilisation of agroforestry and rotational grazing patterns[35]. A recent study by the EU entitled "**Evaluation support study on the impact of the CAP on sustainable management of the soil**" concluded that activities such as "*the targeted application of manure, maintenance of cover on arable land, maintenance and creation of permanently covered areas (e.g. forest, grasslands, wetlands), and the establishment of landscape elements (hedges, buffer strips, etc.) – have a positive impact on soil quality in any context and could thus be fostered at EU level.*"[36]

This study explicitly mentions how satellite imagery can be used to better monitor and control the agricultural practices associated with the maintenance of soil quality. Similar to the maintenance of biodiversity in agricultural ecosystems and soil carbon sequestration, EO can be used to aid the enforcement of CAP policies which promote soil health. With soil health being a key component of one of the 5 missions of Horizon Europe[37], we can expect increased activity on EO-based services developed and deployed in this domain. Again, **Pilot 1.4 – Agro Industry** hopes to develop improved indicators for soil condition monitoring.

3.4   Regulatory threads

3.4.1   CAP monitoring

Within the context of regulatory related benefits of EO in agriculture, the EU's Common Agricultural Policy (CAP) is by far the most relevant and wide-reaching policy which can benefit from the utilisation and increased adoption of EO. In 2018, new rules from the European Commission came into force, which allow EO data to be used as evidence when checking farmers' fulfilment of requirements under the CAP for area-based payments. As a result, multiple initiatives are currently driving the use of EO in CAP monitoring and enforcement. National paying agencies, with the help of EO companies, all over Europe are adopting the use of EO in monitoring and verifying CAP compliance, reducing the need for in-person field inspections and saving both time and money.

Within e-shape, **Pilot 1.2 – EU CAP Support** is focussing on providing tools that will not only support farmers' in their compliance with CAP regulation, but also assist them with the adoption and

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[34] https://northsearegion.eu/carbon-farming/what-is-carbon-farming/carbon-sequestration-techniques/

[35] https://www.earthday.org/land-management-and-carbon-sequestration/

[36] https://op.europa.eu/en/publication-detail/-/publication/85bd465d-669b-11eb-aeb5-01aa75ed71a1/language-en

[37] https://ec.europa.eu/info/horizon-europe/missions-horizon-europe/soil-health-and-food_en

implementation of smart farming practices. This pilot's mission is to deliver a set of customised and fine-tuned smart farming products and services to CAP stakeholders i.e. farmers, agricultural consultants, insurance companies etc. The outputs of this pilot will include crop classification, crop growth indices, dynamic phenology estimation, phenology forecasting, yield estimation, yield damage assessment products and services.

Outside of e-shape, some other ongoing CAP related initiatives include:

- **Sen4CAP** - Sen4CAP is an ESA funded project which aims to provide European and national stakeholders with CAP validated algorithms, products, workflows and best practices for agriculture monitoring relevant for the management of the CAP. The overall approach of the Sen4CAP project is completely user-oriented to ensure user needs and requirements and met. The project will pay particular attention to provide evidence how Sentinel derived information can support the modernisation and simplification of the CAP in the post 2020 timeframe.
- **FaST Platform** - The FaST digital service platform is supported by the European Commission's DG Agriculture and Rural Development, DG DEFIS and the ISA2 Programme and will make available capabilities for agriculture, environment and sustainability to EU farmers, Member State Paying Agencies, farm advisors and developers of digital solutions. The vision is for the FaST to become a world-leading platform for the generation and re-use of solutions for sustainable and competitive agriculture based on space data and other public and private datasets. The platform will support the Common Agricultural Policy by also enabling the use of solutions based on machine learning applied to image recognition, as well as the use and reuse of IoT data, various public sector data, and user generated data.

A clear, real-world example of just how effective EO can be in aiding the implementation and monitoring of agricultural regulation can be found in the as yet unpublished SeBS case entitled "*Grassland Monitoring in Estonia*". This case investigates how EO powered software developed by KappaZeta, a remote sensing company, helps the Estonian Agricultural Registers and Information Board (ARIB) to replace on-the-spot checks of grassland mowing requirements with automated, remote mowing detection. The use of this EO-powered service helps to save both time and money in identifying and paying CAP compliant farmers, while protecting the natural resources, habitats and landscapes of Estonia for its farmers to thrive in and citizens to enjoy for years to come.

Figure 3-4: Screenshot of the CAP grassland monitoring tool - Compliant fields in green[38]

The utilisation of the innovative service in this case contributes to upholding and driving forward how CAP regulation can and should be managed. Not only that, but the valuable lessons and rich data all

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[38] https://demodev.kappazeta.ee/demo/

parties have gained throughout the development and implementation of this service will serve to help mould new regulation in the future. The lessons learned and innovative "know-how" developed in this case, particularly when it comes to the capabilities and limitations of the service, is exactly the kind of information that the European Commission strive for when designing new regulation.

The ultimate goal with this service will be to extend the functionality to monitoring of grazing detection, harvesting detection, crop classification, flooded fields mapping, and eventually reach a level of capabilities that allow for all relevant CAP related subsidy decisions to be made without any field visits whatsoever. Thanks to solutions such as this, spending of the EU can be reduced, and those freed resources can be utilised for future technological developments.

3.5   Innovation and Entrepreneurship threads

EO-based services and data can help to stimulate the creation of new businesses. As agriculture is often considered an economic sector that is not at the forefront of innovation, there is still a lot of potential and room for innovative services based on EO data to make processes for farmers more efficient and effective. In particular, there are three distinct indicators as represented in the table below that stand out in representing the potential for innovation and entrepreneurship of EO in agriculture[39].

Innovation & Entrepreneurship	Impacts linked to the development of new enterprise and/or the introduction of technological innovation into the market and/or business processes.
Changed Business Practice	Improvement of efficiency or effectiveness in existing business processes
Start-ups	Creation of new businesses as a result of the use of EO data (importance of the data in that process)
Patents	Are there any patents taken out relating to the service or the user business processes?

The following elaborates on these three indicators and how they were present (or not) in the SeBS cases.

3.5.1   Changed Business Practice

Whilst an increasing trend of adoption for EO-based services in the agriculture sector is observed, there is still a big part of the community that is not using such innovative solutions. Thus, farmers that use an EO service are often considered innovators and early adopters. In several SeBS cases, we have seen that this often implies strong benefits for both the supplier of the service in terms of new employment and for the primary user, in terms of more efficient business practices.

In many instances, EO services are developed within new companies (i.e. start-ups creating wholly new business practices) or through a new business line within an existing company (e.g. engineering companies; making processes more efficient). Both can lead to new jobs which fall under the economic dimension.

EO services for the agricultural sector can often be offered outside the supplier's home market as an export business as is the case in the Making Wine in France case study, where the Oenoview service is developed in France but has customers throughout Chile to balance relatively quiet periods in

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[39] See here https://earsc.org/sebs/wp-content/uploads/2020/12/SeBS-Methodology-2020.pdf

European winters with simultaneous summers in the southern hemisphere.[40] This is considered in this dimension as a change of the supplier's business process. In the agricultural sector especially, this is a clever way of ensuring a regular stream of revenues and efficient allocation of the workforce within an EO company.

It is important to understand that the increasing use of EO services in the agricultural domain including its actionable insights dramatically change the traditional role of the farmer. With the average farm in Europe increasing in size, the modern farmer has the potential to turn into a tech-savvy manager with a small staff working in the field. The trend towards larger farms is both a driver and a consequence of increasing digitalisation and connectivity. Farmers are not directly inspecting or scouting their fields and crops on the spot daily; even the workers will only physically visit a field when there is a task to be performed. Many farmworkers are also not skilled to recognise disease or plant problems which is why EO services can deliver so much value. Satellites can provide imagery on a sufficiently regular basis that anomalies can be detected, without having to be in the field. And this is only the beginning; soon tractors are expected to drive themselves, relying on in-situ sensors on-board, providing additional data so complementing that coming from the satellites.[41]

Similar impacts on business processes can be observed with agricultural consultants and advisors of farmers who turn to EO-based services to help farmers make smarter decisions as they themselves are not experts on every aspect of farm management. A very tangible and easy-to-understand change of business practice is exemplified in the Growing Potatoes in Belgium case study whereby independent consultants in the Belgian potato industry are saving around 1/3 of their annual field visits to farmers and can use this saved time to pursue other productive activities such as consulting more farmers. Similar to the independent consultants, the processing industries (as well as distributors, traders/exporters, logistics) are getting access to wholly new quasi-real-time market information about how the farms of their suppliers are "doing" and what yield (and when exactly) to expect at the end of the season. This allows them to plan more strategically and effectively for their storage capacities and efficient utilisation of their processing machinery.

In the case of the potato industry in Belgium, where many fields are leased by farmers, historical EO data archives allow farmers to understand the history of any given field, meaning they can select fields that have resulted in historically high output and will presumably give the highest return on investment, making their business processes even more efficient. This information was very difficult to obtain in the past, if not impossible. This will most likely also be the case for other crops and countries in Europe. As these leases are often in very remote and distant locations, the farmers also only need to travel to their fields when the EO service is alerting them to take action.

Returning to the Making Wine in France case study, perhaps the most innovative aspect of the Oenoview service is how it is helping to change the business practices of the growers / wine-makers themselves. By providing better information on the vines and the quality of the harvest, to a degree that is difficult to achieve through other methods, and not being visible to the naked eye, Oenoview is allowing the wine-makers to better understand which grapes should be mixed together to provide higher quality wine. This is information which varies each year according to the weather and growing conditions.

Finally, as showcased in the case of Farm Management Support in Poland, EO-based services can become a powerful tool even for agrochemical companies who seek to diversify their portfolio and strengthen their corporate profile. In that case, Grupa Azoty, a major producer of fertilisers, has partnered with SatAgro to bring satellite imagery and derived services into the hands of the farmers with whom it was cooperating. This represents a new strategic outlook allowing Grupa Azoty to

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venture into innovative, environmentally friendly endeavours, whilst at the same time expanding into new markets.

3.5.2   Creation of Start-Ups

Satellite data are helping to create wholly new types of businesses. It is especially the free and open data such as Copernicus Sentinel data that are making this development possible. While remote sensing companies and value-added services have existed before this "revolution" of the last decade, with more and more EO companies entering the market of digital agriculture, these overtook other types of remote sensing data (e.g. airborne) or commercial data that were relatively expensive.

Thanks to the availability of Copernicus Sentinel data in particular, several new companies have been created such as SatAgro[42] or Fieldsense[43] that would not exist without the Copernicus programme and its Sentinel fleet. It is the availability of free Sentinel data that makes these young EO companies and their business models viable as the programme ensures continuity including sufficient frequency of fresh data, adequate spatial resolution and accuracy as well as zero-marginal cost per hectare for automated solutions. This drives down the cost and makes it possible for less solvent or financially strong businesses or organisations in the agricultural sector to purchase EO-based services.

Throughout Europe, the EO sector had a company-creation-rate of about 11% over the last year. A great share of these new companies can be certainly attributed to the free-of-charge Sentinel data that make operating costs for beginning a new company low and help in developing cost-effective solutions for the agricultural sector, which is the second biggest market.[44]

3.5.3   Patents

The registration of patents is hard to monitor, particularly in the EO sector. However, given its innovative and entrepreneurial nature and ability to offer wholly new services that were not possible before, it is almost certain that EO companies focused on agriculture will patent their innovative products and services based on EO with a national authority or the European Patent Office. With a quick research and as a rough indicator, the EPA's database finds some 7,000 registered patents related to Earth observation and agriculture.[45] Some of those are certainly related to equipment or devices, but it shows that patents are used to protect innovations from agriculture-related EO services, an indicator of the positive socio-economic impact since patents and employment are often correlated in high-tech sectors.

3.6   Science threads

3.6.1   Better science

EO can provide new and unique sources of data to provide invaluable insights which can contribute to furthering scientific understanding. In the context of agricultural science, one application in which EO is uniquely positioned to provide extremely rich data is in understanding the "Fraction of Absorbed Photosynthetically Active Radiation" (FAPAR) over the canopy of a given region. The FAPAR technique quantifies the fraction of the solar radiation absorbed by live leaves during photosynthesis. As a result, it helps scientists in understanding where the green and alive elements of a given canopy are. FAPAR

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[42] https://earsc.org/sebs/wp-content/uploads/2020/02/SeBS-Case-Agriculture-in-Poland.pdf

[43] https://earsc.org/sebs/wp-content/uploads/2019/03/Farm-management-in-Denmark-Full-case.pdf

[44] https://earsc.org/industry-facts-figures/#1596545548651-66cabfab-6f39

[45] https://worldwide.espacenet.com/patent/

is one of the 50 Essential Climate Variables[46] recognized by the UN Global Climate Observing System (GCOS) as necessary to characterise the climate of the Earth.

A clear example of how the FAPAR can help in pushing forward our understanding of agricultural science is in the European Drought Observatory's (EDO) monitoring of the impacts of agricultural drought on the growth and productivity of vegetation across Europe. Every ten days, the FAPAR maps produced by EDO give a spatially continuous, up-to-date picture of the vegetation productivity and/or health status, at a high spatial resolution (about 1 kilometre) for the entire European continent.[47] Such wide ranging and high-quality data could not be achieved without the use of satellites. Thanks to remote sensing, the EDO can now easily aggregate the EO-derived FAPAR data over administrative or natural entities such as hydrological watersheds, allowing both qualitative and quantitative comparison of the intensity and duration of FAPAR anomalies with recorded impacts such as crop yield reductions and reduced groundwater levels. **Pilot 6.4 – Resilient and sustainable ecosystems including agriculture and food** are using FAPAR to help develop products which will contribute to ecosystem protection and food security.
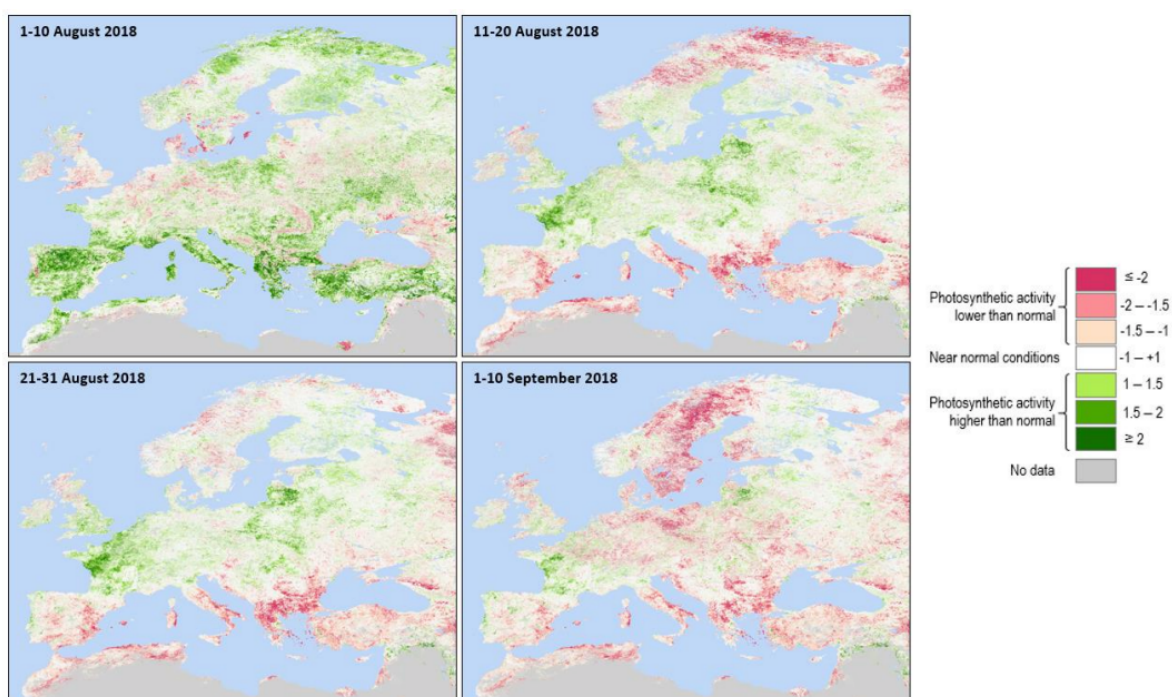
Figure 3-5: Example of the continuously updated FAPAR map, highlighting the conditions of relative vegetation stress (negative anomalies) during a severe drought in 2018

3.6.2   More high quality data

EO can bring value to scientific research into agricultural practices by providing a wealth of rich data to better feed scientific models and algorithms. It is a common misconception that scientists and technology developers are "drowning" in data. In the field of agricultural science, complex Artificial Intelligence (AI) powered algorithms are constantly being developed to better predict crop yield, weather patterns and the possibility of disease outbreaks, however, often huge amounts of data are required to train these algorithms. Despite the growth in "big data" in recent years, a lot of scientists

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[46] https://library.wmo.int/doc_num.php?explnum_id=3417

[47] https://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_fapar.pdf

involved in R&D can still lack the quantity of high-quality, real-world data they need, which hampers the development of high-value agricultural applications.

Thanks to the growing abundance of rich, high-quality EO data, agricultural science and technology R&D efforts are gaining huge traction in developing extremely sophisticated prediction models thanks to the ability to train on available EO data. The more data fed to the models, the smarter they become, meaning agricultural technologies and scientific research can accelerate like never before.

3.7   Societal threads

Agriculture is so closely linked to the fabric of society that the impacts of changing agriculture practices on society are many and varied and vice versa. Despite this, the use of satellite-based information to help farmers has its main impact on the farmers themselves and in the cases studied in SeBS, the social benefits have not been so strongly addressed. Future cases will go deeper in this respect.

The indicators used to judge the societal impacts as well as their descriptions, all drawn from the SeBS methodology, are shown below. Not all apply to all types of case, and we can consider them for agriculture.

Societal	Impacts related to broader societal aspects, such as public health, citizen security and welfare.
Public Health	Improvements to public health through reduced exposure to pollutants, reduced disease etc
Civil Security	Reinforcement of citizens' sense of safety and protection
Geostrategic Value	Support to broader political or strategic goals
Public Awareness	Provision of information to the general public with the aim of supporting public duties, raising awareness of hazards or danger, or improving transparency
Public Utility	Provision of increased access to a public utility, or reduction of withdrawn access (e.g. mobility, energy, water)
Community and Quality of Life	Increasing sense of community and the quality of life through enhanced perception of the country/region/town etc as a place to live.
Improved Oversight	Contribution to stakeholder coordination and improved governance through a common operational picture

These are not exhaustive and shall evolve with time as additional cases yield more insights and lead to further indicators.

In evaluating these indicators of benefits for agriculture, we note that there are no real geostrategic benefits nor is there any public utility. Some elements of each of the others is present and will be described.

3.7.1   Public Health

One of the main uses of the EO-based services in all of the agricultural SeBS case studies is to reduce the amount of fertilisers and other chemicals (pesticides and fungicides) being applied to the crops.

Reduced use of chemicals is universal and applies to all three crop types which have been studied; cereals, root crops and grape vines. As well as helping the farmer make better use of the chemicals, this has a societal benefit in reducing the potential run-off of excess chemicals into water catchment zones and hence has an impact on public health.

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The degree to which agricultural chemicals can leach into ground water depends on a number of factors. These include the extent to which the chemicals are absorbed into organic matter (soil), the rate of degradation within the soil, their solubility in water and the amount of water which is filtering though the soils. The extent of the pollution depends strongly on the amount of rainfall, the underlying soil, and the amount of excess chemicals. The use of satellite-based observations reduces this last factor by enabling farmers to apply only the needed amounts of agrochemicals.

Reduced nitrates and phosphates in the water, reduces the risk of Harmful Algal Blooms (HABs) in open waters (lakes and rivers), exposure to which can cause serious illness to people bathing in the contaminated waters.

Reducing the level of nitrates is generally desirable even if in Europe levels in drinking water are generally lower than the designated health limit by the World Health Organisation. This is in part due to legislation which dictates their reduced use by farmers. Thus, reducing these and other chemicals such as pesticides, lowers the exposure of humans to these trace chemicals in drinking water.

3.7.2   Civil Security

Increasing the security of food supply has shown to be a crucial issue during the COVID-19 pandemic. Tracking the harvest both in terms of quantity and timing are important contributions that satellite derived information can make.

For example, in Spain, the government used forecasts derived from satellite images to monitor the evolution of the harvest and to predict the size of the crops. This information was used to help manage the winter cereals crops by ensuring that there were adequate materials, machinery and labour available at the times they were needed. The cumulative production was calculated, and the cropping compared with previous years. The satellite data enabled this to be used as a prediction of harvest in order to prepare ways to overcome any obstacles.

In Germany, the asparagus crop was monitored to predict when the harvesting would begin and how it would evolve. This enabled border controls to be smoothed to allow farm workers from Poland to enter the country during the crisis and to travel easily to the fields. In both Spain and Germany, knowing the location and pattern of harvesting, matched to the evolution of the pandemic, enabled easier transit of works and essential supplies.

The main impacts of these measures were to help stabilise food prices and to provide some transparency on the situation, so reducing social pressures during the crisis. **Pilot 1.1 – GEOGLAM's** crop monitoring algorithms will be used to derive information on crop calendars, i.e. harvesting, planting and ploughing in an effort to help with food security planning.

3.7.3   Public Awareness

The use of digital technology including crop stress maps and Variable Rate Maps for the application of fertilisers has the potential to transform farming. It has been expressed many times and for the different crop types that such a perspective increases the farmer's awareness of his/her fields and how they behave under different conditions. A farmer is said to have 40 seasons in his/her farming career so that each is worth 2.5% of his/her total life income. Hence, farmers are very traditional in approach and several analyses recognise the reluctance to introduce new farming methods.

This slows the transformation as it is greatly depending on the transfer to a new generation of farmers, who are more technology savvy and ready to adopt new methods. Satellite-based mapping, which provides a wider picture of a farm has the potential to increase the pace of change as the direct benefits become more evident. Fields are often quite widespread, and farmers are visiting them infrequently unless activities are planned. This means that problems can remain untreated for too long – hence the interest in the technology.

Such information, shared amongst farmers, also raises the public awareness of the digitalisation of farms. These are changed with much more time being spent behind a computer, or on a tablet, than in the fields. Indeed, one of the benefits to farmers is to make their use of time more effective.

3.7.4   Community / Quality of Life

Farming is almost by definition a rural activity and is often associated with communities which have lower population densities compared to urban areas. Work can be limited in these areas and consequently, measures which can increase the revenues of farmers are positive and feed more money into local businesses and the community. One of the benefits coming from the use of Oenoview for vine monitoring in the Making Wine in France case, is to provide information to improve the quality of the wine being produced and hence its value. This increases the revenues from the vines by up to 30%.

For other crops, there is some small increase in crop yields but not the same level of contribution to revenues. For cereals the impact is very small, whilst for potatoes and other root crops, the value is higher but not significantly so. Grapes may be a special case in this respect where the potential increase in revenue is enough to really make a difference.

In addition, improving the quality of the wine has a reputational value which brings more visitors to the region so increasing tourist revenues as well.

Other ways in which the quality of life may be improved are linked to the improved environmental management. In the case of grasslands, better management improves the rural landscape. With other crops, more optimal use of chemicals also reduces negative affects on the environment leading to less pressure on biodiversity and local pollution. These are very much long term effects with a secondary impact.

Pilot 1.3 – Vegetation-index crop-insurance in Ethiopia aims to improve the quality of life and aid poor communities in Ethiopia through the utilisation of crop monitoring technologies which will provide financial protection to low-income farmers.

3.7.5   Improved Oversight

From the Growing Potatoes in Belgium SeBS case, the use of WatchItGrow, and the information which the service provides, has enabled the formation of a platform at national level bringing together experts and stakeholders from many parts of the country. As the political landscape of Belgium is rather complex, creating such a platform has proven very difficult. Responsibility for the potato sector in Belgium lies primarily at federal level but with strong interests from regional levels in Wallonia and Flanders.

This cross-regional platform enables decision making for the benefit of the whole country. Visibility of issues in one region can help bring solutions from others. The knowledge and needs of one part of the value chain, perhaps the potato processing factories become more visible and more credible to other parts of the value chain perhaps the farmers. The overall impact is hoped to be improved awareness of best practices leading to an increase in the total potato crop and a valuable export from Belgium.

4   CONCLUSION & NEXT STEPS

It is clear that the impact EO is having in agriculture is massive and will only continue to grow. We are witnessing the rapid emergence of widespread and innovative EO applications in the agricultural sector which are revolutionising the way farming is being practiced. Moreover, the positive economic, environmental and societal impacts that these changes are having in the agricultural sector and beyond serve as both a testament to the excitement surrounding the technology and a justification of the continued funding into its research and development.

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Building upon some concrete, real-world examples of EO added value, this document illustrates just some of the possibilities of EO in agriculture. The pilots within e-shape will undoubtedly impact the sector in their own way, contributing the continued success of the EO/agriculture innovation ecosystem. This document is the first of three socio-economic value analysis reports within e-shape. Subsequent publications will target two more of the remaining showcases in M30 and M40 of the project. The progression status of pilots within the project at the given times will dictate which showcase and sector is chosen next.