European Association of Remote Sensing Companies

Sentinels Benefits Study (SeBS)

A Case Study

Grassland Monitoring in Estonia

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Setting the Scene

Viktoria woke from her nap to the sound of her father's mobile phone buzzing on the coffee table. He was outside tending to their cows in the field behind the milking parlour and must have left it behind. Usually she wouldn't care to check who was texting her father, but she couldn't help but notice that the partial piece of text on the screen didn't look like a regular message. From what she could gather, whoever was texting her father seemed to be telling him to do something, but the language seemed very formal, like it was coming from an important source. Maybe the Estonian Government was trying to warn its citizens of some sort of flash flooding? Maybe he was an undercover agent, and this was his top-secret mission briefing? Maybe they were in danger? Her curiosity got the better of her, so she called out her father's name.

Her father, Kaspar, came in from the July heat and slowly opened the fridge, poured himself a glass of milk, stretched his legs and turned on the television. Viktoria thought he seemed very relaxed for a person who could be about to discover that his life may never be the same again. She passed him his phone and he casually unlocked it, maintaining one eye on the television at all times. She waited for his reaction… "*Oh yeah, yeah, I should actually do that this evening….*" he mumbled to himself as he put the phone back down and finished his milk. Viktoria was confused. "*Do what?!*", she asked. "*Mow the grass*" he replied. Viktoria was even more confused.

"*Have I never shown you this? It's pretty cool, I get a text from the Estonian Agricultural Registers and Information Board every year to remind me to mow our grass meadows*" Kaspar explained. "*I had actually forgotten this year, so it's good they reminded me. If I don't do it before a certain date, I don't get my subsidy payment*". Viktoria's worry subsided.

That evening, Viktoria bumped into her father as he was returning from mowing the fields. "*So that's it?*" she asked, "*That's it!*" he quickly replied. "*So you text them back to tell them you've done it?*" Now Kaspar was confused, but he quickly realised why. "*Ah I forgot to mention an important part. I don't have to do anything now. I just wait. They use satellites to see if I've actually done it or not*". "*Really?!*" Viktoria replied, "*They can do that?!*" "*Sure! Satellites help them monitor a lot of things actually, checking if I comply with environmental regulation is just the tip of the iceberg*" Kaspar explained. "*Wow, I hadn't realised that… I wonder if they can tell that you missed a patch in the corner of the bigger field?*" Viktoria asked. Kaspar's head dropped in realisation… "*Satellites are great, but your attention to detail never fails to amaze me…*"

This story is entirely imaginary, although realistic based on our knowledge gained through the case interviews. The places are real, although the characters, the conversation and the situation are entirely fictional. It also depicts how the service in question is intended to work in the future.

Executive Summary

This case deals with the monitoring and enforcement of one of the EU's Common Agricultural Policy (CAP) initiatives, specifically, the maintenance of permanent grasslands. The CAP is regarded as one of the most economically and politically important policies the EU maintains. 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 supports farmers who maintain permanent grassland in good agricultural condition.

For farmers to receive subsidy payments, they must comply with certain rules and regulations. The standard way in which CAP compliance checks are conducted involves inspections being carried out on-the-spot (at the farm) by inspectors. The obvious issue with this is that it is hugely impractical, if not impossible, to conduct on-the-spot checks for every single beneficiary each year. As a result, member states generally can only check a sample of farms each year and rely on the honesty of all other farmers on the unchecked farms. A much broader, continuous and transparent monitoring system is clearly required, which is where Sentinel data comes into the picture. The Estonian Agricultural Registers and Information Board (ARIB), along with the help of KappaZeta, Tartu Observatory and CGI Estonia developed a service to address this clear inefficiency.

The introduction of EU Regulation No 2018/746 in 2018 encouraged EU member states to use satellite data in their CAP monitoring and verification activities. The algorithms developed by KappaZeta use both Sentinel-1 and Sentinel-2 data (SAR and optical imagery) to constantly and automatically monitor around 101,000 fields of grassland all across Estonia. There is a requirement to mow these fields at least once per year (within a certain time window) with the intentions of keeping them in good order. Farmers and landowners who apply for direct CAP payments for the preservation of these fields receive money for complying with this requirement. The service developed can automatically detect when a mowing event has taken place on each of the monitored fields. This in turn allows ARIB to issue direct payments to compliant claimants. The automatic nature of the software helps to reduce the need for in-person spot checks of mowing events of fields to take place.

The benefits associated with this Sentinel enabled service are significant. In Estonia, economic benefits amount to between €103,000 and €1.1 million annually; stemming from the employment of full-time workers and the avoidance of in-person compliance checks across the country. Substantial non-economic benefits are also found in this case. The synergy between KappaZeta's service and ARIB's operations helps to ensure the biodiversity of Estonia's ecosystems and the protection of its beautiful landscapes. It also contributes to the supranational environmental sustainability goals of the CAP's initiatives i.e. keeping EU agricultural practices sustainable, protecting natural habitats and aiding the sequestration of CO_2. The environmental benefits in this case are experienced right along the value chain, at both micro and macro levels, making it a prime example of how Sentinels can add huge value to our environmental sustainability efforts.

Society benefits from the transparency and open nature of KappaZeta's software. The fact that the interactive map and compliance data is completely free for anyone to interrogate online aids in the manifestation of a transparent check and balance dynamic between ARIB, the claimants (farmers and landowners) and the general public. This helps the creation of societal trust in ARIB's operations and their distribution of taxpayers' money. It also helps solidify public trust in the various EU CAP initiatives as people can see for themselves exactly where public money is going.

But perhaps the strongest benefit of all is the contribution that the Sentinel data can make to regulatory compliance. The motive behind the service is to monitor and verify CAP regulations in a more efficient and accurate manner. **Utilisation of the new sentinel-enabled monitoring system allows ARIB to monitor all registered fields, automatically and continually, compared to the 5% sample previously taken. As a result, they can fulfil their operational mandate in a more complete manner and help to distribute taxpayers' money more fairly.** The EU themselves incentivise the development of valuable and innovative methods of monitoring and enforcing regulation through the likes of satellite data. KappaZeta and ARIB both contribute hugely to upholding and driving forward how CAP regulation can be managed. Not only that, but the valuable lessons and rich data all parties have gained throughout the development and implementation of this service can help in moulding new regulation in the future. The lessons learned and innovative "know-how" discussed in this case provide valuable insights which can be used to inform the design of new regulations - particularly when it comes to the capabilities and limitations of the service.

The benefits within each tier of the value chain are shown in the graphic below.

1 Introduction & Scope

1.1 The Context of this study

The analysis of the case study *'Grassland Monitoring in Estonia"* 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?

The Common Agricultural Policy (often referred to simply as the CAP) is the EU's largest, most well-known and arguably most important policy. It dominates the European agricultural landscape and helps the EU to maintain its food production requirements as well as support the livelihoods of hundreds of thousands of people. A significant part of the CAP involves financially rewarding farmers for maintaining sustainable agricultural practices. In this case we study an innovative system, empowered by Sentinel data, which is used to ensure farmers in Estonia are abiding by CAP regulation and maintaining permanent grassland in the interest of biodiversity.

We investigate how the unique software KappaZeta has developed helps the Estonian Agricultural Registers and Information Board (ARIB) to replace the on-the-spot checks of compliance to CAP grassland mowing requirements with automated, remote mowing detection. The benefits emanating from this working relationship help 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.

In this report, you will discover both the story and the rigorous analysis around the benefits experienced by different value chain actors in this case. The analysis relies on clear and openly presented assumptions which have been shaped with the help of the stakeholders we interviewed (see 1.5 below). However, we encourage any reader to contact us if they think the assumptions are unreasonable for any reason by emailing us at info@earsc.org with any questions or observations. Also, the authors can be contacted directly (contact details in Annex 4).

1.3 How does this case relate to others?

This is our 4th SeBS long case linked to agriculture, however, it differs slightly from the previous agricultural cases. The others dealt with the growing of potatoes in Belgium and the growing of cereals in both Denmark and Poland, whereas this case deals primarily with the mowing of grasslands and regulatory compliance. This implies that the dynamics of this case are somewhat different to anything we have previously studied. As this case does not deal with increasing the efficiency by which produce can be grown and ultimately sold, it deviates from the benefits which are "traditionally" associated with the application of remote sensing in agriculture. The incentives behind actions taken within this value chain primarily revolve around the improvement of regulatory compliance as well as achieving environmental sustainability. This deviation from the typical dynamic of an agricultural case makes it a unique and interesting study into the application of remote sensing in the management of public agricultural funds.

We have a short case titled Assessing Geese Damage in The Netherlands which has some parallels with this case given it involves the monitoring of grasslands in The Netherlands for wild geese activity.

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.
- **Citizens:** The analysis conducted within SeBS is presented in an accessible language for the wider public. In particular, the powerful storytelling and the explanation of how the data is used help citizens to understand how public investments (in Copernicus Sentinels) return significant benefits to their everyday lives and to multiple neuralgic sectors for economy and society.

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:

Kaupo Voormansik – KappaZeta

Jürgen Lina - KappaZeta

Kai Raudvere – Estonian Agricultural Registers and Information Board

Roman Belov – Estonian Agricultural Registers and Information Board

Ahti Bleive – Estonian Agricultural Registers and Information Board

Due to COVID-19 travel restrictions all interaction with KappaZeta and ARIB was conducted remotely.

2 Grasslands in Estonia

2.1 The importance of grasslands

Grassland is of high importance for the maintenance of biodiversity all around the world. In the EU, grassland makes up over 20% of all land cover[1], providing beautiful landscapes and habitats for multiple species while simultaneously acting as a giant carbon "sink", helping to reduce the CO_2 levels in our atmosphere.[2]

In simple terms "grassland" can be defined as ground covered by vegetation dominated by grasses, with little or no tree cover.[3] In the EU, a distinction can be made between production grasslands, which have a primary fodder production function, and semi-natural grasslands that provide a large range of ecosystem services including biodiversity.[4]

Grasslands act as key habitats for many species including various plants, butterflies, reptiles, many birds and numerous mammals such as deer and rodent species. They also provide intrinsic ecosystem services such as watershed protection and grazing. In general, grasslands are particularly species-rich, with the table below showing the richness of species and variability of endemic species groups across various types of terrestrial biomes.

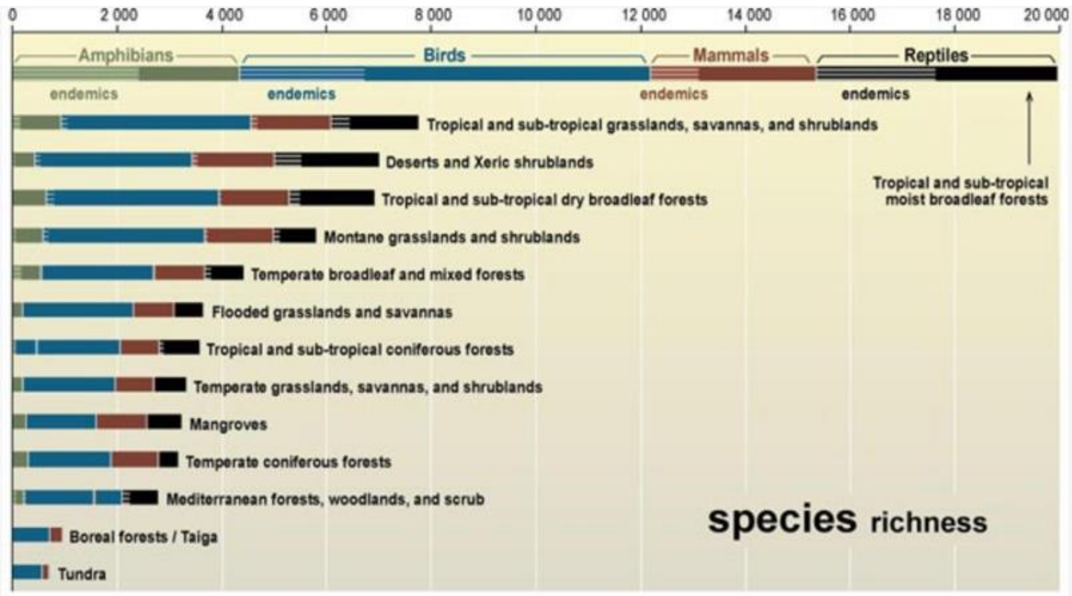

Figure 2-1: Comparison of species richness across terrestrial biomes[5]

1 https://ec.europa.eu/eurostat/statistics-explained/index.php/Land_cover_statistics#:~:text=artificial%20land%20cover-,Land%20cover%20in%20the%20EU,%25)%20was%20covered%20by%20grassland.

2 https://climatechange.ucdavis.edu/news/grasslands-more-reliable-carbon-sink-than-trees/

3 https://ec.europa.eu/environment/archives/life/publications/lifepublications/lifefocus/documents/grassland.pdf

4 https://ec.europa.eu/eurostat/documents/2393397/8259002/Grassland_2014_Task+1.pdf/8b27c17b-b250-4692-9a58-f38a2ed59edb

5 https://www.greenfacts.org/en/biodiversity/figtableboxes/1012-richness.htm

As already stated, grasslands also act as valuable carbon sinks. The worldwide carbon sequestration potential of grasslands is estimated to be between 0.01 and 0.3 giga-tonnes annually. In fact, soils under grassland and forestry act as much better carbon sinks compared to soils under arable land, so much so, that when grasslands are converted to arable lands it is estimated that their soil carbon stocks tend to decline by an average of 60%.[6]

There are multiple types of grasslands in Europe, ranging from almost desert types dry grasslands in Spain to humid meadows which dominate Northern Europe. Since almost all European grasslands are more or less modified by human activity and have to a major extent been created and maintained by agricultural activities, they are classed as the aforementioned "**semi-natural grasslands**", although their plant communities are natural. These grasslands are maintained through farmers' grazing and/or cutting regimes. There are also some more natural 'permanent grasslands' that occur in Europe. The distribution of these is determined by natural conditions including climate, topography and soil structure.[3]

Semi-natural grasslands include self-seeded herbaceous and shrub vegetation that can be used for livestock grazing or simply left untouched by agricultural practices. Semi-natural grasslands include the following:

- Lowland meadows and pastures including floodplain meadows, upland and alpine hay meadows, limestone grasslands, lowland acid grassland and heathland, steppe grassland;
- Alpine and other mountainous rangelands;
- Mediterranean scrub/grassland;
- Boreal grasslands and wooded grasslands such as Baltic wooded meadows;
- Maritime grasslands of dune, cliff and machair.[4]

[6] https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/fg9_permanent_grassland_profitability_starting_paper_2014_en.pdf

Figure 2-2: Distribution of grasslands in Europe[7]

Semi-natural pastures and meadows are typified by extensive farming using traditional breeds of livestock and have a relatively low productivity compared with intensively managed grasslands. They are profoundly valuable for the large range of ecosystem services they provide. For example, they support the majority of EU farmland biodiversity, the majority of EU farmland carbon, and provide the majority of water catchment services on farmland. Such grasslands cover approximately one quarter of all EU farmland, but most are in poor condition.[4]

2.2 Grassland in Estonia

As a small Baltic state situated towards the northern part of the world's temperate climate zone, Estonia has a geographically and biologically diverse landscape, boasting 2,222 islands along its Baltic Sea coast, over 1,400 inland lakes and due to its geographical location, almost 50% of its land area is covered by dense Scandinavian forest, consisting primarily of pine, spruce and birch. In addition to this, Estonia has around 1.3 million hectares of agricultural land, nearly 1 million hectares of which are arable. During the Soviet era, arable land decreased by nearly 405,000 hectares, with much of it being converted to forest.[8] Just a few generations ago agriculture was the

[7] https://www.eea.europa.eu/data-and-maps/figures/grasslands

[8] http://countrystudies.us/estonia/17.htm

primary occupation of most Estonians, whereas nowadays only about 3% of the workforce is engaged in agriculture. Cattle, pigs and poultry are the main farm animals raised in Estonia with the primary field crops being cereals, potatoes and vegetables. Plant products are mostly for internal use, however, a considerable amount of meat is imported.

Of Estonia's 45,347km^2 total land area (4.5 million hectares), 15.9% (7,210km^2 or 721,000 hectares) is classified as grassland.[9] Large efforts have been made in recent years to restore parts of Estonia's grasslands, particularly alvar grassland along its Baltic Sea coast. An alvar is a biological environment based on top of a limestone plain, with a layer of very thin soil (or sometimes no soil) that produces sparse grassland vegetation. Alvars are found predominately in Northern Europe, with one third of all alvar grasslands being situated in Estonia.

Figure 2-3: Alvar grassland in Northwest Estonia

LIFE to Alvars was a 5 year project, beginning in 2014 and ending in 2019 which aimed to restore 2500 hectares of alvar grassland in Estonia and create the necessary infrastructure to allow local farmers to manage these areas after restoration[10]. The project was funded by the European Commission's LIFE programme and won the 2018 Natura 2000 award in the socio-economic benefits category[11]. The project was carried out on 25 sites: 12 project sites on Saaremaal island, 6 on Hiiumaa island, 5 on Muhu island, 1 in Pärnumaa and 1 in Läänemaa in the west of the country. See map below.

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9 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Land_cover,_2015.png

10 https://life.envir.ee/english-project-life-alvars

11 https://ec.europa.eu/environment/nature/natura2000/awards/application-2018/winners/socio-economic-benefit/index_en.htm

Figure 2-4: Map of the LIFE to Alvars project sites on Estonia's western coast

The project was a success and reached its goal of increasing the amount of managed alvar grasslands in Estonia by over 2,500 hectares, in total bringing this number to 4,300 hectares as of 2019. The project also built the necessary infrastructure for grazing animals on restored plains, such as pasture gardens, collection gardens, shelters and ensured access for animals to water and access for people to the shoreline and pastures.[12]

The LIFE to Alvars project is a testament to the importance and reverence with which natural landscapes and grasslands are held in Estonia. Managing and maintaining all natural grasslands in Estonia is crucial to the flourishing flora and fauna that thrive amongst them, but also extremely valuable to the Estonian citizens who enjoy spending time in these beautiful parts of their country.

12 https://life.envir.ee/projekti-tulemused-results

2.3 The relevance of the CAP in the regulation of grasslands

2.3.1 The EU's Common Agricultural Policy

With a population of almost 450 million and a land area of 4.5 million km^2, the EU has a lot of mouths to feed and ecosystems to protect. The management of the food supply must remain reliable, healthy and affordable while the natural balance of sensitive biomes must be carefully controlled. The European Union's agricultural sector has the enormous responsibility of ensuring these requirements are met, day in, day out without fail. The vital role the agricultural sector plays in all of our lives cements the sector's standing as a perpetual economic powerhouse, meeting our daily needs while also supporting the livelihoods of millions of people. Given its positioning, the never-ending pressures and challenges the agricultural sector faces are immense and the economic environment it currently faces is set to remain uncertain for some time to come. Globalisation, financial crises, climate change and the volatile costs of farming inputs are only a few of the many threats it must grapple with on a constant basis. In that context, we must rely on the European Union's **Common Agricultural Policy**, (often referred to as the "CAP") to dictate how we meet all of our food production needs, support our economies and remain sustainable while simultaneously navigating the constant threats and challenges that present themselves.[13]

The CAP is one of the most overarching, ever-present and sometimes controversial EU policies in operation. Since its adoption in 1962, it has moulded how agriculture in the EU is managed, from keeping food production competitive and secure to ensuring farmers are supported and compensated fairly. The CAP is therefore regarded as one of the most economically and politically important policies the EU maintains. Due to the vital importance of its success, it's no wonder that we regard the missions of the CAP with such reverence while also holding its design and implementation up to such detailed scrutiny.

The new CAP, which will be in force for the period between 2021-2027, is driven by nine key objectives[14]:

- to ensure a fair income to farmers;
- to increase competitiveness;
- to rebalance the power in the food chain;
- climate change action;
- environmental care;
- to preserve landscapes and biodiversity;
- to support generational renewal;
- to maintain vibrant rural areas;
- to protect food and health quality.

[13] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy_en

[14] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/future-cap_en

Figure 2-5: The 9 CAP objectives for 2021-2027

As the name suggests, it is a common policy applied equally across all EU countries to ensure fairness in the EU's internal agri-food market. With around 10 million farms in the EU, and 22 million people working in the sector, the CAP must try its best to work for everyone, which is no small task. The following sections will discuss how the CAP works in practice and where it intersects with this case.

2.3.2 The CAP in practice

Farming is not like other businesses as there are certain considerations that position it in a uniquely fragile operational environment. For instance, the average farmer's income is around 40% lower than the average non-agricultural income. Farming also relies much more on weather conditions and the climate compared to other industries with its operability being much more uncertain due to the constant threats of extreme weather events and changing climates.[15] A further important distinction between farming and other "production" businesses is the inevitable time lag in farming. Crops and animals require more time to replenish their stocks and mature, often with crops this is in an annual or semi-annual cycle, whereas with livestock it can take years. Compare this to a factory producing components for the automotive industry; production can quickly and dynamically be increased or decreased depending on market demands. All of this means that farmers often require support to maintain a stable and sustainable business. There are three primary ways in which the CAP helps:

[15] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en

- The CAP provides farmers with **income support**, through both direct payments and through remunerations for maintaining environmentally friendly practices which would typically not be rewarded by the market.
- **Interventions are made in the market** to boost demand or prevent crises from escalating or becoming unmanageable. For example, certain products (such as wheat, barley or rice) are bought, stored and sold back into the market at a later date by EU countries to help maintain price stability.
- **Rural development measures** are put in place via national and regional programmes to help address region specific challenges. The European Agricultural Fund for Rural Development (EAFRD) is a funding instrument of the CAP which supports rural development projects and strategies which help maintain the prosperity of rural regions across Europe.

In 2020, the CAP budget was €58.12 billion, of which the vast majority (€40.6 billion) went to income support. To put the CAP budget into perspective, it makes up over one third of the entire EU budget (the entire EU budget was €168.68 billion in 2020). This fact alone emphasises the importance and prominent role of the CAP within the EU's framework.[16]

The laws and policies within the CAP are regularly reviewed and updated by the European Commission in consultation with agricultural committees and civil dialogue groups with the intention of shaping the CAP to best serve the agricultural sector. When planning to introduce new legislation for approval, the Commission will also conduct impact assessments to understand how the new legislation could affect agricultural practices in order to allow the decision makers (the European Parliament and Council) to make better informed decisions on such important topics.

The CAP is revised or "reformed" cyclically, following the setting of the EU's long-term budget, the Multiannual Financial Framework Package, or MFF for short. The last CAP was agreed upon in 2013 and came into operation for the period between 2014-2020. In 2018 the Commission proposed new legislative changes to the CAP for the period lasting between 2021-2027. These proposals hope to improve the CAP and allow it to contribute greatly to the European Green Deal, the Farm-to-Fork strategy and the biodiversity strategy. In October 2020 agricultural ministers from EU member states reached an agreement on reforming the CAP for the 2021-2027 period which places a strong emphasis on reaching climate and environmental commitments.[17]

The European Commission also regularly undertakes public opinion surveys to understand such metrics as the general public perception of the CAP, how the public understand the inner workings of the CAP and how much it matters to them.[18]

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[16] https://www.europarl.europa.eu/factsheets/en/sheet/106/la-financiacion-de-la-pac

[17] https://www.dw.com/en/eu-states-agree-on-agricultural-policy-reform/a-55343279

[18] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance/eurobarometer_en

2.3.3 Common monitoring and evaluation framework

In order to understand the effectiveness of the CAP and how to improve its efficiency, the European Commission has set up what is known as the **common monitoring and evaluation framework** (CMEF). Through this initiative, they can closely evaluate how the CAP is working in order to help design better policies in the future, help set programme objectives and allow for better transparency in accounting for public expenditure. This framework foresees that the CAP implementation is monitored via a large number of key performance indicators, which are grouped into the following indicator types[19]:

- **Context indicators describing general information relevant to the policy** (such as the amount of agricultural land available or information on the average age of farm managers);
- **Income support and market measure output indicators**, which provide information on, for example, the number of beneficiaries of CAP income support;
- **Output indicators monitoring EU policies on rural development**, for example, on the public expenditure for investment;
- **Results indicators for the income support** elements of the CAP measuring the direct and immediate effects of interventions (for example the percentage of farmers income which came from income support);
- **Rural development results indicators** assessing the effect of rural development policy, such as preventing soil erosion and improving soil management. Most of these indicators are also target indicators. In addition, rural development complementary result indicators aim to assess the net effect of CAP intervention;
- **Target indicators** used to set quantified objectives at the beginning of the programming period for the rural development policy (some of which correspond to result indicators);
- **Impact indicators** measuring the impact of policy interventions for the longer term and when there are effects beyond the immediate period (of which some are also included in the context indicator set).

Based on the groupings above, the Commission provides annual updates of key data indicators which reflect the current situation within which the CAP is operating. An excerpt of just some of the parameters which are monitored is shown in the figure below. Each indicator has an associated spreadsheet which provides further detailed information at both member state and regional level.

[19] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cmef_en

CAP CONTEXT INDICATORS – 2019 update

Indicators section		CMEF indicator	Tables	Data used in the tables (year)	Date of last update
1. Socio-economic indicators	C.01	Population		2019	06/2020
	C.02	Age structure		2018	06/2020
	C.03	Territory		2016	06/2020
	C.04	Population density		2016	06/2020
	C.05	Employment rate		2019	06/2020
	C.06	Self-employment rate		2018	06/2020
	C.07	Unemployment rate		2018	06/2020
	C.08	GDP per capita		2018	06/2020
	C.09	Poverty rate		2018	06/2020
	C.10	Structure of the economy		2019	06/2020
	C.11	Structure of the employment		2019	06/2020
	C.12	Labour productivity by economic sector		2019	06/2020
					06/2020
2. Sectorial indicators	C.13	Employment by economic activity		2019	06/2020
	C.14	Labour productivity in agriculture		2019	06/2020
	C.15	Labour productivity in forestry		2017	06/2020
	C.16	Labour productivity in the food industry		2017	06/2020
	C.17	Agricultural holdings (farms)		2016	06/2020
	C.18	Agricultural area		2018	06/2020
	C.19	Agricultural area under organic farming		2018	06/2020
	C.20	Irrigated land		2016	06/2020
	C.21	Livestock units		2016	06/2020
	C.22	Farm labour force		2016	06/2020
	C.23	Age structure of farm managers		2016	06/2020
	C.24	Agricultural training of farm managers		2016	06/2020
	C.25	Agricultural factor income		2019	06/2020
	C.26	Agricultural entrepreneurial income		2019	06/2020
	C.27	Total factor productivity in agriculture		2018	06/2020
	C.28	Gross fixed capital formation in agriculture		2018	06/2020
	C.29	Forest and other wooded land (FOWL)		2015	06/2020

Figure 2-6: Some of the CAP context indicators 2019[20]

Since 1993, The European Commission's Joint Research Centre (JRC) has used remote sensing and space technologies to contribute to agricultural monitoring. The JRC operate the **Monitoring Agricultural Resources (MARS)**[21] initiative, which uses satellite data to produce regular bulletins on crop yield forecasts and is a key part of the Integrated Agricultural Control System (IACS), which is at the core of CAP implementation in Europe. Within the CAP, the Good Agricultural and Environmental Conditions (GAEC) standard deals with issues regarding soil (erosion, organic matter and structure), minimum levels of maintenance, the protection and management of water resources, and the maintenance of permanent pasture areas. The JRC promotes the use of remote sensing and GIS in the implementation, management, and monitoring/control of the GAEC. It also works toward the optimisation of the definition and control of GAECs through the exchange of best

[20] https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/cap-context-indicators-table_2019_en.pdf

[21] https://ec.europa.eu/jrc/en/mars

practices and supports the development and promotion of methods using traceability, quality, certification and record-keeping at farm/parcel level.[22]

2.3.4 Income support and "Greening"

As already discussed, farmers receive income support to reward them for maintaining environmentally sustainable practices which typically would not be rewarded by the market itself. One such initiative within the CAP is known as "**greening**". The "green direct payment" (also simply referred to as greening) supports farmers who adopt environmentally friendly practices with direct payments and is covered under **EU Regulation No. 1307/2013**.[23] Ensuring farmers maintain environmentally friendly practices is of huge importance to the EU in terms of meeting its climate and environmental commitments, but also to the farmers themselves. Farmers' livelihoods depend on natural resources, such as soil and water, and their practices are greatly affected by the state of the environment in which they work, climatic conditions and the biodiversity of the ecosystems which provide them with both farming inputs and outputs. Therefore, the continuation and maintenance of so called "green" practices bring value to farmers in supporting the longevity of their operations.

What is often overlooked is the fact that the general public also benefit from greening. 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. The careful preservation of natural resources, beautiful landscapes and water sources is what is known in economics as a "public good", meaning it is a commodity that is made available to all members of society for "free", albeit paid through public taxation. The monetary compensation paid to farmers by the EU for the sustainable management of farmland is a prime example of a public good payment scheme in action.

EU member states must allocate around 30% of their income support to greening[24], with farmers receiving 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 followed. There are some high-level requirements to ensure diversification is maintained:
    - Farms with more than 10 hectares of arable land must grow at least two crop types.
    - Farms with more than 30 hectares of arable land must grow at least three crop types.
    - The primary crop on these lands must not take up more than 75% of the total land area.

[22] https://ec.europa.eu/jrc/en/research-topic/agricultural-monitoring

[23] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R1307&from=EN

[24] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/greening_en

- Some exemptions are also in place to these rules which are dependent on the circumstances, for example, maintaining large areas of grassland rather than the maintenance of multiple crop types can also be a viable alternative as grassland itself helps ensure biodiversity.

- **Ecological Focus Areas (EFAs):** 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 in 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.

Greening payments are also automatically paid to farmers who qualify as "organic farmers" as the nature of their work alone is seen as environmentally sustainable. Farmers who do not respect the greening rules do not receive greening payments and since 2017 national governments are also able to impose penalties (on top of the loss of greening payments) on uncompliant farmers.

In 2016, holdings subject to at least one greening measure covered 78% of all EU agricultural land area. The table below gives a breakdown of this at Member State level.

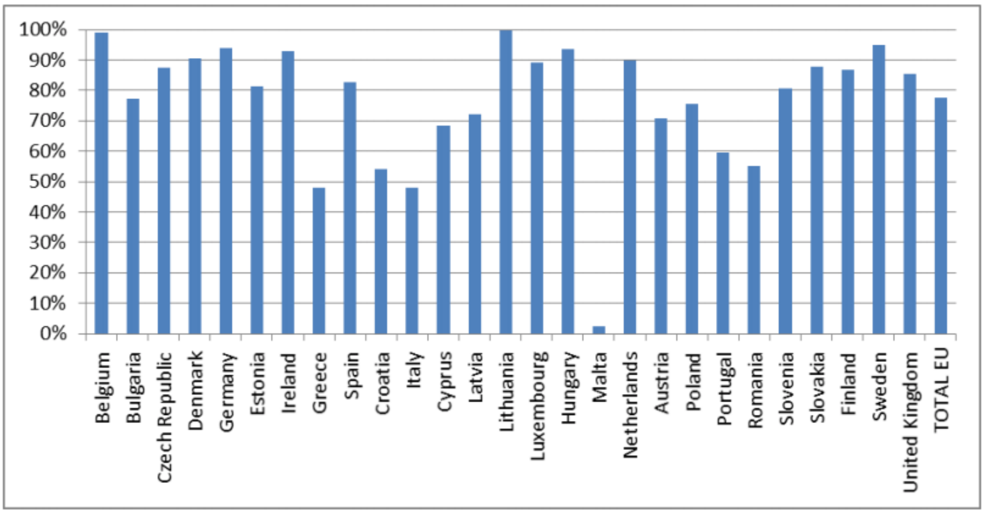

Figure 2-7: Percentage of holdings subject to one or more greening measure per member state[25]

The greening measures, however, are not without their criticisms. Numerous environmental NGOs have made their dissatisfaction over the CAP's impact on habitats, landscapes and biodiversity clear. They accused the EU of "greenwashing"[26] and selectively choosing only positive messages to

[25] https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/ext-eval-payment-practices-climate-leaflet_2017_en.pdf

[26] https://www.euractiv.com/section/agriculture-food/news/ngos-criticise-commission-over-cap-impact-on-biodiversity/

communicate from an EU funded but independently carried-out study entitled "Evaluation of the CAP on habitats, landscapes and biodiversity".

Amongst the numerous conclusions of this study[27], the following key conclusions were emphasised:

- The presence of the CAP has raised Member States' ambition towards addressing biodiversity objectives as well as the level of funding, although more could be done by Member States to ensure that their biodiversity priorities are reflected in their decisions concerning national agricultural policy;
- Member States have not made sufficient use of the available CAP instruments and measures to protect semi-natural features, in particular grassland, or ensured that all semi-natural habitats that have the potential to be farmed are eligible for direct payments;
- Member States could have used a wider range of CAP instruments and measures to support the co-existence of agriculture with biodiversity.

In addition to these conclusions, the following key recommendations were made:

- To maximise the benefits which can be achieved for biodiversity from available CAP funding, a higher priority should be given to focusing CAP instruments and measures that have biodiversity objectives on maintaining the extent and quality of semi-natural habitats that depend on agricultural or forest management (in particular habitats protected by the Birds and Habitats Directives and semi-natural habitats used by species protected under that legislation), where these are at risk, and especially within Natura 2000 areas;
- Member States should be required to ban ploughing/conversion of all permanent grassland in all Natura 2000 sites (unless it has been mapped as grassland of a type which does not require protection under the Habitats Directive) and on all permanent grassland outside the Natura 2000 sites which requires such protection;
- Member States should make CAP support available on all semi-natural grassland, heathland and wood pasture habitats which require agricultural management, by adopting a wider definition of "permanent grassland".

It is clear from this report and its findings that in future CAPs, the maintenance of biodiversity, landscapes and habitats will play a hugely important role.

2.3.5 Estonian subsidy payments for the maintenance of grassland

The management and distribution of CAP subsidies is handled at national level, with each Member State having at least one paying agency and the larger states often having multiple agencies covering different regions (or sometimes different commodities) within the country.[28] The Estonian Agricultural Registers and Information Board (ARIB) are the sole agency in charge of CAP payments

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[27] https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/ext-eval-biodiversity-final-report_2020_en.pdf

[28] https://ec.europa.eu/sfc/en/system/files/ged/Paying%20Agencies%20List.pdf

in Estonia. The following subsections describe the different types of grasslands that are monitored by ARIB and their corresponding payment schemes.

Producing lands

Under **EU Regulation 1307/2013 - "Establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy**"[29], ARIB manage subsidy payments for keeping grasslands in "good agricultural condition". This payment is distinct from the semi-natural habitat payment scheme as the applicant for this scheme must be an "*active farmer who carries out an agricultural activity involving the cultivation or production of agricultural products, including harvesting, dairy farming, breeding and keeping farm animals or keeping agricultural land in a state suitable for grazing or cultivation without preparatory activities requiring different farming methods or machinery."*[30]

The conditions of this support are provided by the **Estonian Ministry of Rural Affairs** – **Regulation No. 32**[31] which was adopted on 17/04/2015. The regulation was also established on the basis of the **European Union Common Agricultural Policy Implementation Act**[32] under numerous subsections.

Farmers must formally register their land and apply for the subsidy support through ARIB. They must also meet certain requirements to apply for and receive this payment support. Some requirements include:

- The land must be larger than 1 hectare.
- Land with no more than 50 trees per hectare is eligible.
- The land must be maintained in such a way that undesirable vegetation (burdock, thistle, willow, tubers and woody plants) do not spread.
- Permanent grassland **must not** be mowed **before the 5th of July**.
- Permanent grassland **must** be mowed **by the 20th of August**.

It must be noted that it is not a strict requirement that the only means of maintaining grassland in "good agricultural condition" is through mowing, animal grazing can also be used as a method for achieving this. How a Member State achieves this requirement is decided nationally. As will be discussed later, KappaZeta are working on grazing detection software.

In addition to these rules, the requirements for crop diversification in support of the aforementioned CAP "greening" rules must also be respected:

- If the size of the applicant's arable land is between 10 - 30 hectares, he/she must grow at least two agricultural crops, with the main crop not occupying more than 75% of the land.
- If the size of the applicant's arable land is more than 30 hectares, he/she must grow at least three crops, with the main crop not occupying more than 75% of the land and the two main crops not occupying more than 95% of the land in total.

[29] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0608:0670:EN:PDF

[30] https://www.pria.ee/toetused/uhtne-pindalatoetus-ning-kliimat-ja-keskkonda-saastvate-pollumajandustavade-toetus-2020

[31] https://www.riigiteataja.ee/akt/125042018015?leiaKehtiv

[32] https://www.riigiteataja.ee/akt/110072020043?dbNotReadOnly=true#para67lg2

- If the agricultural land used by the applicant is larger than 15 hectares, at least 5% of this active use must be excluded and dedicated to act as an Ecological Focus Area.

The support rate for farmers is calculated using various factors, with the estimated average unit support rate currently standing at **€114.95/ha per year**.[33]

Non-producing lands

Another CAP payment that ARIB hope to support in the future using Sentinel data (but currently do not) is known as the "**Support for the maintenance of semi-natural habitats**". Technical options for controlling these lands are currently being developed. The purpose of this support is to increase the size of managed semi-natural habitats, improve the condition of these habitats for relevant species and to preserve and increase biodiversity along with landscape diversity. **These semi-natural habitats are distinct from "productive" grasslands as they are not primarily used for food production or managed by a farmer** (this distinction is further explained in the following section).

The conditions of this support are provided by the **Estonian Ministry of Rural Affairs** – **Regulation No. 38**[34] which was adopted on 24/05/2015. The regulation was established on the basis of the **European Union Common Agricultural Policy Implementation Act** subsection 67 (2).[35]

The overall budget for this support in Estonia was €6,500,000 for 2020.[36] Landowners (or land managers) who maintain a semi-natural habitat must meet certain requirements to apply for and receive this payment support. Some requirements include:

- The land must be larger than 0.1 hectares.
- The land must predominately be covered by meadow vegetation which can be mowed or grazed for maintenance.
- The Estonian Environmental Register must be notified and the land registered in their system.
- A visually identifiable boundary around the area must be present.
- The land **must not** be mowed **before the 10th of July**.
- The land **must** be mowed **by the 1st of September**.

There are varying support rates available which are dependent on the type of semi-natural habitats being maintained. These include the following:

- Mowing a wooded meadow - €450/ha per year;
- Grazing of wooded meadow - €250/ha per year;
- Grazing of wooded pasture - €250/ha per year;
- Grazing of juniper meadow - €250/ha per year;
- Mowing of juniper meadows - €185/ha per year;

33 https://www.pria.ee/toetused/uhtne-pindalatoetus-ning-kliimat-ja-keskkonda-saastvate-pollumajandustavade-toetus-2020
34 https://www.riigiteataja.ee/akt/115052020009
35 https://www.riigiteataja.ee/akt/113032019050?dbNotReadOnly=true#para67lg2
36 https://www.pria.ee/toetused/poolloodusliku-koosluse-hooldamise-toetus-2020

- Grazing of other meadows - €150/ha per year;
- Mowing of other meadows - €85/ha per year;
- €232/ha per year for the maintenance of important coastal protection areas.

2.3.6 Compliance checks

As already discussed, in order for farmers to receive income support and various payments, they must comply by certain rules and regulations. This inevitably implies that checks must be conducted to ensure claimants are indeed abiding by the rules and are not receiving payments where they shouldn't be. The standard way in which CAP compliance checks are conducted involves inspections being carried out on-the-spot (at the farm) by inspectors. This means that inspectors generally have to travel to farms to check whether the relevant aforementioned requirements are being met. The obvious issue with this is the fact that each EU member state contains thousands of farms, meaning it is hugely impractical, if not impossible, to conduct on-the-spot checks for every single beneficiary each year. As a result, member states generally can only check a sample of farms each year and rely on the honesty of all other farmers on the unchecked farms.

EU Regulation No 809/2014[37] mandates that for the greening payments, a 5% sample of all beneficiaries within each member state must be subject to on-the-spot checks each year. The selection of this 5% sample is partially random and partially risk-based. **Regulation No 809/2014** also states that:

"Where on-the-spot checks reveal any significant non-compliances in the context of a given aid scheme or support measure or in a region or part of a region, the competent authority shall appropriately increase the percentage of beneficiaries to be checked on-the-spot in the following year."

The European Commission's working document **DS/CDP/2015/19**[38] provides further clarifications on the definition of "significant non-compliances" and explains how the appropriate percentage increase in the percentage of beneficiaries to be checked can be calculated. After inspections are complete, subsidy payments are granted to the farms which are deemed compliant and held back from the farms deemed uncompliant.

2.4 Informed decisions, coordinated actions and effective interventions

Ensuring CAP regulations are adhered to and grasslands are maintained efficiently requires that all actors involved work seamlessly together and that all available sources of information are effectively used. Thus, having the best possible situational awareness – i.e. where and when grassland maintenance activity occurs (or does not occur), is of utmost importance. This allows

[37] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0809&from=EN

[38] https://gdi.bmel.de/fileadmin/SITE_MASTER/content/Dokumente_InVeKoS/Leitf%C3%A4den_KOM/04_Leitf%C3%A4den_Kommission/DSC_DP_2015_19-FINAL_Increase_of_OTSC_greening.pdf

actors involved in CAP monitoring and enforcement to make informed decisions and effectively execute their mandate.

2.4.1 Collecting the necessary data

Having wide-ranging, accurate and impartial information on CAP activities helps any paying agency to make better informed decisions, correctly reward compliant claimants and avoid reimbursing fraudulent or incorrect subsidy claims. Wide range monitoring of farmers' grassland mowing activities is not something actors responsible for issuing CAP subsides would, or even could do. The collection of activity data had traditionally always been done using on the spot checks, as it was really the only practical option available.

2.4.2 Limitations of conventional methods

Using "conventional" methods to perform compliance checks i.e. conducting on-the-spot checks over a 5% sample of claimant locations is clearly not the most effective or accurate way in which to decide how subsidy payments should be distributed. Given that the vast majority of claimants would most likely not be checked, it was much easier for a claimant to "slip through the net" and receive a subsidy payment they didn't deserve. A much broader, continuous and transparent monitoring system is required, which is where satellite data comes into its own. The Estonian Agricultural Registers and Information Board (ARIB), along with the help of KappaZeta, a remote sensing company, developed a service to address the inefficiencies discussed We will look into this service in the next chapter, followed by a thorough account of how it was used by the different actors (chapter 4) and the concrete value it brought (chapter 5).

3 The Use of Sentinel Data

3.1 General introduction on the use of satellite data for agriculture

Remote sensing techniques are being increasingly used for the provision of timely and accurate data on several aspects related to agricultural operations and 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. These include crop growth monitoring (incl. crop damage, crop health), crop yield monitoring and forecasting, soil moisture estimation, soil mapping and biomass monitoring.

Before entering into the specifics of the agricultural monitoring services studied in Estonia, it is important to understand how satellites can capture changes on the surface of the Earth giving rise to information that is extremely valuable to entities involved in the monitoring of agricultural practices.

3.1.1 How can satellites enhance agricultural monitoring

Broadly speaking there are two main classes of Earth Observation satellites[39]:

- Those carrying **passive sensors** able to detect the sun's energy as it is reflected from the Earth's surface. These "optical" satellites are affected by cloud coverage (at it hinders solar radiation) and can only observe during day time. Typically used sensors in this category are radiometers (incl. imaging and spectro-radiometers) and spectrometers.
- Those carrying **active sensors** capable of emitting their own energy (in the form of electromagnetic radiation) to illuminate the scene (and objects therein) they observe. Such satellites send a pulse of energy from the sensor to the object and then receive the radiation that is reflected or backscattered from that object. 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.

[39] A nice overview of passive and active instruments on board earth observation satellites is provided in https://earthobservatory.nasa.gov/Features/RemoteSensing/remote_08.php

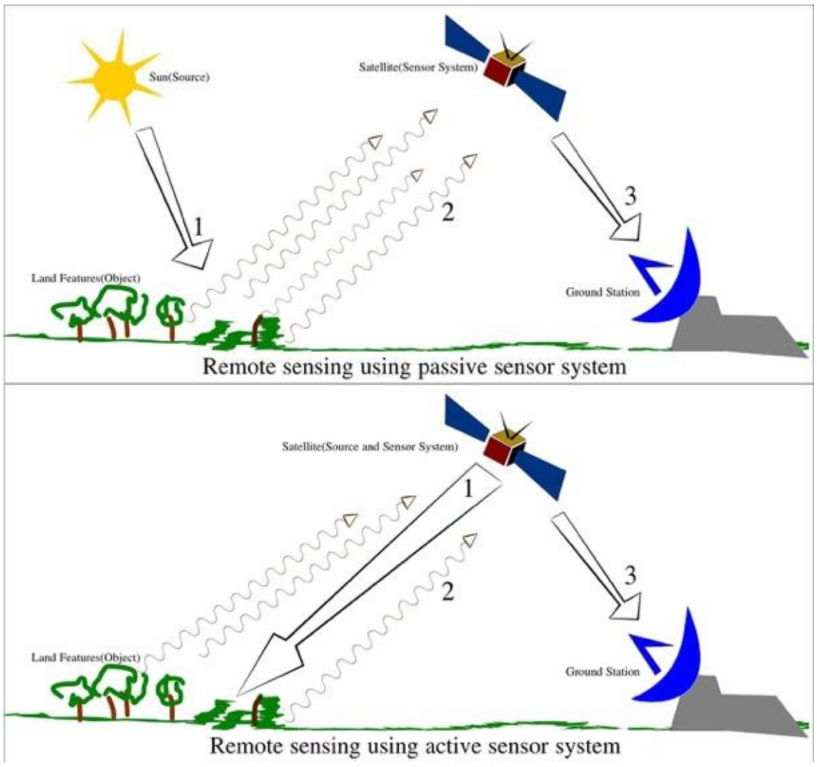

Figure 3-1: Illustration of passive versus active remote sensing[40]

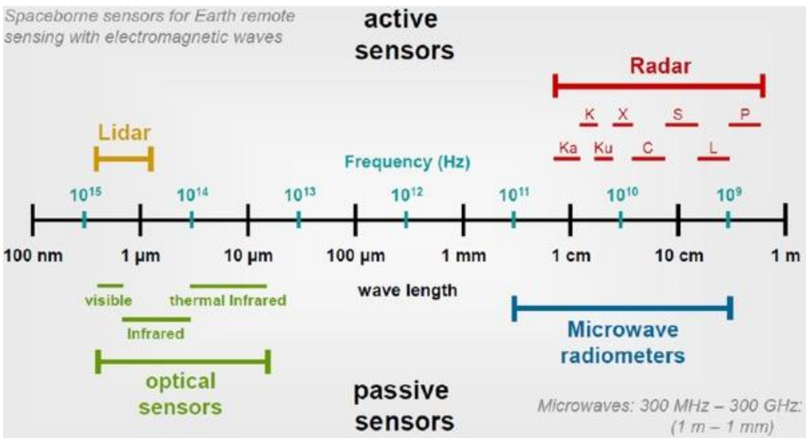

Figure 3-2: Active and passive sensors used for remote sensing[41]

As seen in Figure 3-1, active and passive sensors emit/collect electromagnetic signals of different wavelengths. In practice, different materials on the Earth's surface reflect electromagnetic waves in a different manner. These reflectance differences allow Earth Observation (EO) satellites to distinguish between grasslands, water surfaces, forests, buildings, etc. When more than two wavelengths are used, the separation among objects is even more evident. Thus, satellites

[40] Dall (2017)
[41] Lefeuvre, F & Tanzi, Tullio. (2014)

equipped with multispectral sensors (i.e. utilising different bands of the spectrum) can provide data that allow the quantitative classification of different types of land cover in a given scene.

During the cycle from sowing to harvest, agricultural vegetation changes as a function of variables such as temperature, sunlight, and precipitation. Soil and plant characteristics, as well as the impact of the specific farming practices in use can further affect the growth of vegetation. Changes in the health, density, vigour and productivity of crops affect the optical properties of the canopy. The use of remote sensing - especially in the red and infrared spectrum - and other proximal sensors enables the mapping of changes (essentially related to vegetation reflectance) across a field and with time, thus enabling the monitoring of crop development and growth. Land cover classification can also be achieved using SAR satellites. Contrary to optical satellites – which essentially produce photographs, the SAR imagery is a measure of how much energy is scattered back to the sensor after being reflected on different types of materials.

In all cases, the data collected by EO satellites is transmitted via radio waves to properly equipped ground stations. There they are translated into a digital image that can be displayed on a computer screen. Each satellite image is composed of pixels and each of these pixels represents a square area on the image that is a measure of the sensor's ability to resolve (see) objects of different sizes. The higher the resolution the greater the ability of the sensor to discern smaller objects, but also the narrower the strip of land that can be surveyed by the satellite.

Measuring plant properties

Thanks to this stream of data, a wide range of advisory services for agriculture can be developed. The most common entails the measurement of the Normalised Difference Vegetation Index (NDVI). NDVI quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). Healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths. But it absorbs more red and blue light. Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1). Knowledge of the distribution of this index across a given field and in connection to the applied farming practices (e.g. fertilisation), allow farmers to make informed decisions on what is needed where and when.

To ensure EO data's suitability in various applications, in-situ data can be used to validate the remotely sensed data. This is of utmost importance when relying on data to support CAP subsidy payments and regulation enforcement. The Sen4CAP project (further discussed at the end of this chapter) is also developing an EO grassland mowing detection product and validating its performance against in-situ data through demonstration projects across Europe to ensure robustness of the application.

3.1.2 Advantages

The most important advantages of satellite-based agricultural applications include:

- The **capability to acquire data anywhere in the world** without any limitation by weather conditions (when combining optical and SAR) or the impact of the phenomenon itself. Satellites offer a **robust source of near-real-time**[42] **information** to aid food production.
- The ability to generate **consistent, comparable and relatively objective** (i.e. not depending on individual interpretation/observation) information, collected **systematically on multiple scales, from local to regional to nation-wide;**
- The capability to **supply regular, detailed updates on plant status** on a local, regional or national basis. By combining different satellites, this can be even done on a **daily basis** offering an invaluable resource to farmers.
- Satellite images offer spatially continuous data coverage of the entire field, with no further interpolation required, in contrast to ground-based discrete sampling. As such, they can serve as a basis for interpolation of information gathered in situ.
- Finally, whilst EO satellite data are a complementary data source to in-situ data (as well as airborne data, socio-economic data, and model outputs) in most countries, they **can be the only reliable source of information in countries lacking the ground infrastructure.**

3.1.3 Limitations

When compared to alternatives such as on-site or aerial surveys, satellite-based agricultural mapping presents the following limitations:

- Resolution and active sensor limitations – spatial resolution may not be high enough to detect the required data at small scales or sensors may not be capable/suitable for certain applications.
- Non-daily revisit times for high resolution, non-commercial optical satellites – However, in the application of CAP grassland mowing detection, daily revisit times are generally not necessary. In Estonia, monitoring typically begins in May and ends in October, a revisit time of between 5 to 6 days in this period is good enough to detect a mowing event as there isn't enough time for grass to noticeably grow back between passes.
- Possibility of gaps in data availability due to cloud cover

On-site surveys in particular offer information about soil chemistry and physical properties at different depths below ground which cannot as of yet be fully replicated with either satellite or aerial remote sensing. These soil characteristics tend to be less dynamic by nature than crop growth and in consequence, do not have to be reassessed as often.

Until a few years ago, another potential limitation was the cost of acquiring satellite data. That has progressively changed, first thanks to Landsat, and then with the advent of the Sentinel era – producing vast amounts of data under the Copernicus full, free and open data policy.

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42 "Near real-time" has a different meaning based on the application being studied. In the context of agriculture, near real-time is understood to be a few days. For a comprehensive overview on this we recommend a recent publication by Defourny et al. (2019) https://www.sciencedirect.com/science/article/pii/S0034425718305145

3.2 Copernicus and the Sentinels

The service studied is based on the use of both Sentinel-1 and Sentinel-2 data coming from the European Copernicus programme, so we shall start with a simple overview of the programme to place the services into context.

Copernicus is an EU flagship programme[43]. Copernicus started out as GMES (Global Monitoring for Environment and Security) with the goal of meeting European geo-information needs. At its heart is the most complete, operational satellite system in the world; owned by the EU and operated by ESA and Eumetsat and currently comprising six types of satellites, see figure below.

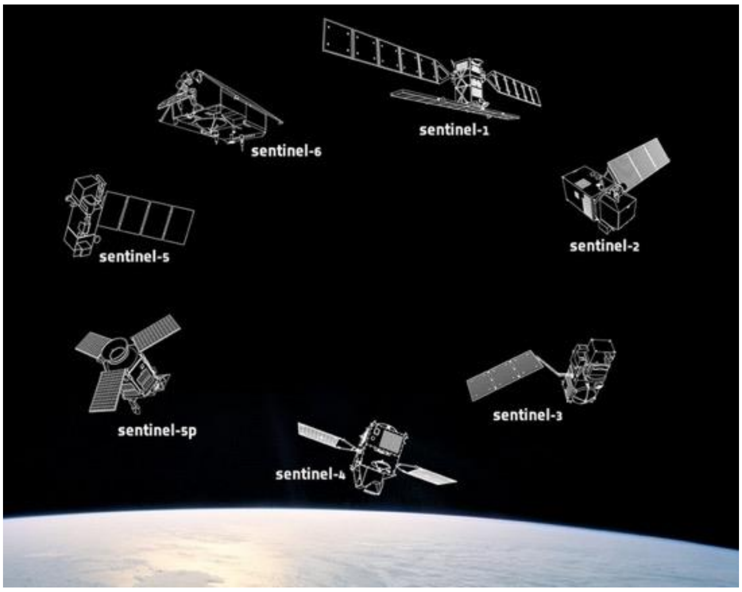

Figure 3-3: Current Sentinel satellites

This case is defined by both Sentinel-1[44] and Sentinel-2[45] (see the info boxes below).

[43] https://www.copernicus.eu/en

[44] https://sentinel.esa.int/web/sentinel/missions/sentinel-1

[45] https://sentinel.esa.int/web/sentinel/missions/sentinel-2

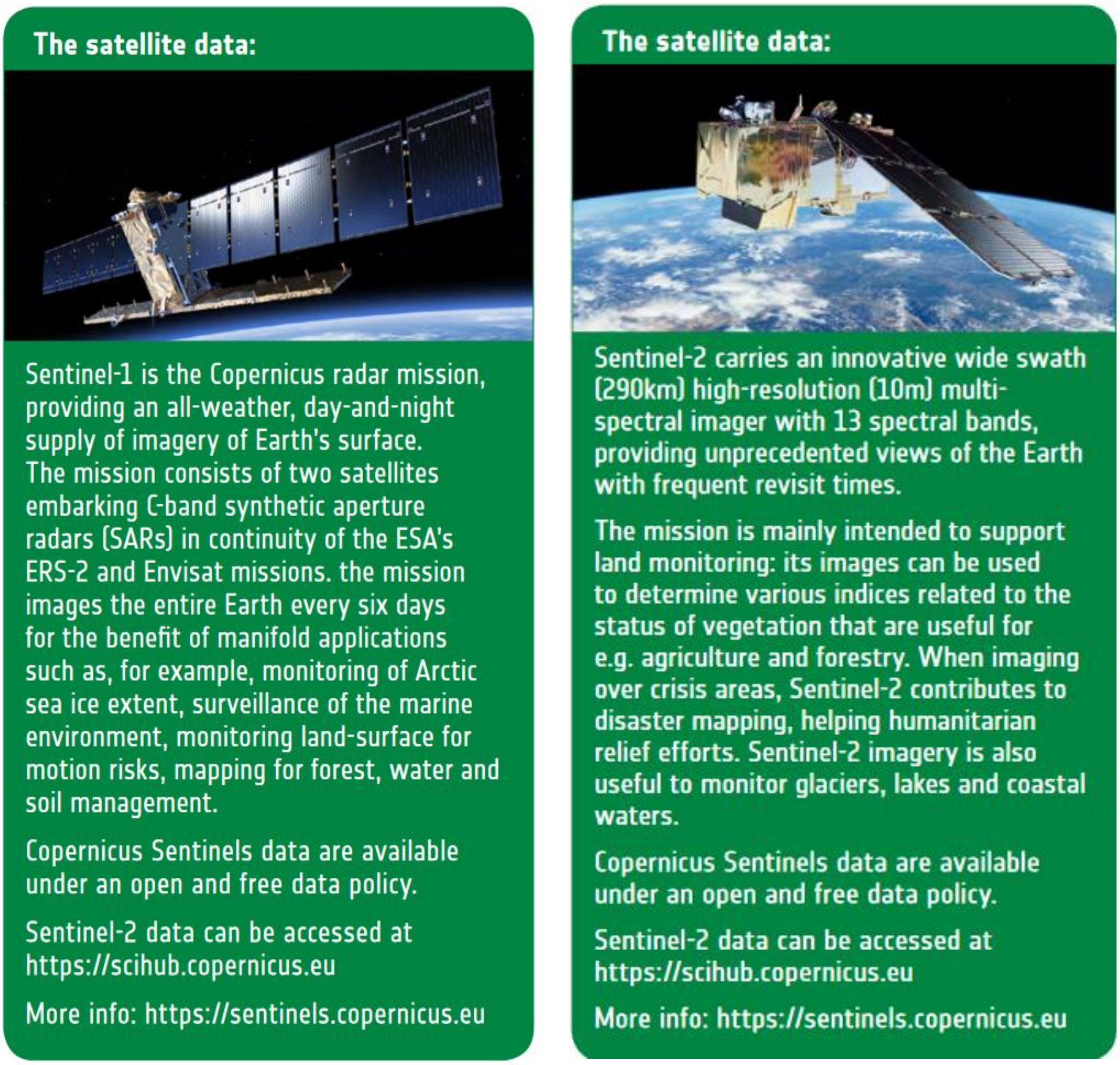

Figure 3-4: Sentinel-1 and Sentinel-2 satellites

Sentinel-1 carries a Synthetic Aperture Radar (SAR) operating in C-band. The two-satellites Sentinel-1A and 1B provide high-reliability data with a short revisit time, global coverage and rapid data dissemination to support operational applications. As already discussed, SAR is an effective and important technique in monitoring crop and other agricultural targets because its quality does not depend on weather conditions, cloud cover or day/night light coverage. Sentinel-1 SAR can be used to complement optical and NDVI data which is derived from Sentinel-2 (this will be further discussed in the following paragraphs).

Sentinel-2 is a wide-swath, high-resolution, multi-spectral imaging mission. Sentinel-2 carries an optical instrument payload that samples 13 spectral bands: four bands at 10m, six bands at 20m and three bands at 60m spatial resolution. Normalized difference vegetation index (NDVI) is a simple graphical indicator that can be derived from Sentinel-2 data which helps to assess plant vegetation health based on how the vegetation reflects light at certain frequencies. Sentinel-2 helps in monitoring soil properties as well as crop conditions. It helps farmers to assess land use, predict harvests, monitor seasonal changes and assist in implementing policies for sustainable development.

The sentinels already power a number of agricultural applications. Sen4CAP is an ongoing 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. Another example of a sentinel powered agricultural application is The Sen2-Agri System, which uses Sentinel-2 and Landsat 8 time series data to provide useful products for agricultural monitoring through a free and open graphical user interface.

3.3 The KappaZeta Service

KappaZeta are a fast-growing, science-driven radar remote sensing company which were founded in 2015 as a spin-off from Tartu Observatory and are based in Tartu, Estonia. In 2018, KappaZeta launched the first nation-wide system for automated monitoring of agricultural practices in Estonian named "SATIKAS" which helps the Estonian Agricultural Registers and Information Board (ARIB) to replace the on-the-spot checks of CAP grassland mowing requirements with automated, remote mowing detection.

The introduction of **EU Regulation No 2018/746**[46] in 2018 then paved the way for KappaZeta and ARIB to fully embrace and commit to the application of this new service. The regulation in question encouraged EU member states to use satellite data in their CAP monitoring and verification activities, specifically mentioning the relevance of the Copernicus Sentinel programme for this application thanks to the free and open nature of its data. KappaZeta develops and maintains the SATIKAS service along with the underlying software, CGI Estonia have developed much of the user interface, while ARIB uses the software to conduct all mowing compliancy checks in-house.

How did the KappaZeta/ARIB relationship begin?

"The story goes back to my PhD studies. We first met in 2011 while I was doing my doctoral studies in cooperation with Estonian GIS company Regio. We were looking for promising applied research projects and found the ARIB case really interesting as they were a very strong client with clear vision about what they want. During the coming years we did several joint research projects and limited area pilots. The initial SATIKAS grassland mowing detection infosystem was actually built by Tartu Observatory (Estonian research institute) and CGI Estonia. The team and I represented Tartu Observatory then, but as the application case was so clear and it was less and less pure research, we decided to establish a spin-off company. KappaZeta was established in late 2015 and we became economically active in 2017. Then, gradually, the work for ARIB was transferred to our spin-off company KappaZeta. Today we operate as totally independent entity from Tartu Observatory, though the cooperation with the research community is still very much alive and we plan to keep it like this."

- **Kaupo Voormansik** - KappaZeta

[46] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R0746&from=EN

KappaZeta's software uses both Sentinel-1 and Sentinel-2 data (SAR coherence and optical NDVI) to constantly and automatically monitor around 101,000 fields of grassland all across Estonia. Farmers or landowners of these fields are required to maintain this land as permanent pasture and not convert it to arable land, with the purpose of maintaining the biodiversity of Estonia's countryside. There is a requirement to keep these fields in "good agricultural condition" to encourage the growth of the natural grass and avoid the chance of these fields becoming overgrown with unwanted plant species. How each Member State ensures the condition of fields in maintained is decided nationally. In Estonia, it has been decided that these fields must be mowed at least once per year, within a certain time window. Farmers and landowners who apply for direct CAP payments for the preservation of these fields receive money for complying with this requirement. KappaZeta's software can automatically detect when a mowing event has taken place on each of the monitored fields.

The image below is a screenshot of the SATIKAS service developed by KappaZeta. The map shows Estonia with an array of green and red markings, each of which corresponds to a field being monitored for CAP mowing compliance. The map is interactive and can be zoomed in and out by the user, with the green indicating fields that have been flagged as having complied with the mowing requirements and the red indicating fields which are potentially uncompliant. The map itself can be found at https://demodev.KappaZeta.ee/demo/.

Figure 3-5: KappaZeta's EU Subsidy-Check, interactive map

The user of the map can click on any field and an associated time-series trend known as the "Mowing Chart" will be presented. The Mowing Chart of a randomly selected compliant field is shown below. The date is displayed along the x-axis with the probability of a mowing event having occurred being displayed along the y-axis. Sentinel-1's interferometric coherence SAR data (both VH and VV polarisation) for this field is displayed in light and dark blue. Sentinel-2's Normalized Difference Vegetation Index (NDVI) data is displayed along the green line. An algorithm then uses these three data sources to calculate the probability of a mowing event having taken place. In the image below, the spike in the yellow line with the tractor icon present at its peak tells us that there is around an 80% probability that a mowing event took place just after the 16th of June. Currently, 50% is the threshold on this scale to indicate compliance. The user can also click on any of the NDVI points to see the Sentinel-2 image of the field at any stage. The red vertical line on the right indicates the particular deadline for mowing (in this case the 31st of August).

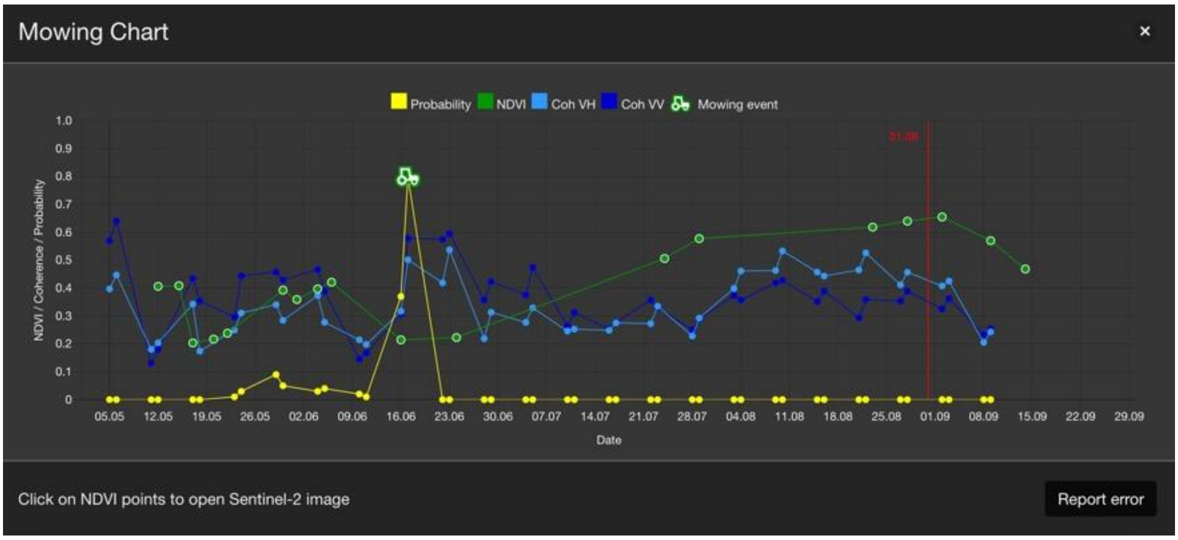

Figure 3-6: The Mowing Chart of a randomly selected, compliant field

Thanks to the user-friendly functions of this map, ARIB can much more efficiently distinguish the compliant fields from the uncompliant ones through the automatic detection of mowing events. Should they want to further investigate any given field, with the click of a mouse they can pull up the associated Sentinel-1 and Sentinel-2 time-series data in the Mowing Chart along with the corresponding Sentinel-2 images.

The two images below show true colour and NDVI Sentinel-2 images of the same randomly selected field. Users of the service can view an entire time-series of these Sentinel-2 images for any selected field.

Figure 3-7: True colour Sentinel-2 image of a randomly selected field

Figure 3-8: NDVI Sentinel-2 image of a randomly selected field

An upcoming feature of the service will be the ability to send automated early warning reminders via SMS and e-mail to farmers or landowners who have not yet complied by the mowing requirement as the deadline approaches.

3.3.1 Future Evolution of the Service

Given the geographically expansive and rich nature of Sentinel data, there are huge opportunities for KappaZeta to extend the geographical application of their service across multiple countries due to the fact that all 27 EU member states are required to monitor, maintain and report on their CAP related activities. This is something that is currently being looked into with some promising leads in some other Northern European countries. In addition to the ongoing maintenance, improvements and expansion of their grass mowing detection software, KappaZeta is building upon the knowledge gained in developing this service by also working on other agricultural and CAP monitoring projects and services. These include:

- **National Programme for Addressing Socio-Economic Challenges through R&D (RITA) (2019-2020)** – KappaZeta along with the University of Tartu, Tallinn University of Technology and the Estonian University of Life Sciences are developing the use of remote sensing data by public sector services.
- **Harvesting Time Recommendation for maximum crop Yield (HaTRY) (2020-2021)** – Funded by the European Space Agency, KappaZeta, in collaboration with the University of Tartu, Tallinn University of Technology and the Estonian University of Life Sciences are developing a service for predicting the best time to harvest crops using remotely sensed data.
- **Grazing detection from Copernicus data for agricultural subsidy checks (2020-2021) -** Funded by the European Space Agency, KappaZeta, in collaboration with Gisat are developing a satellite-based monitoring system for the detection of animal grazing activity on grasslands.

More overarching market trends such as advances in Artificial Intelligence, machine learning, and Big Data handling may also result in better processing techniques which KappaZeta can use to further enhance their offerings in the future.

4 Understanding the Value Chain

4.1 Description of the Value-Chain

The use of satellite data for the development of services supporting more efficient CAP monitoring in the form of grass mowing detection gives rise to a concrete value chain. In this particular case, KappaZeta makes use of Sentinel-1 and Sentinel-2 data to provide the Estonian Agricultural Registers and Information Board (ARIB) with accurate and continuous mowing detection over grass fields all across Estonia. In turn, ARIB can fairly distribute CAP income support payments to compliant farmers or landowners who mow their fields within the given timeframe, reducing the need for in-person spot checks of fields and lowering the likelihood of incorrectly paying uncompliant farmers.

Thus, the use of satellite data at the entry point of the value chain results in enhanced information or improved operations that bring value for each link further down the chain. Ultimately, the implementation of more accurate grass mowing detection (from an economic, environmental and societal point of view), results in benefits experienced by compliant farmers and citizens at the far end of the value chain. But before we dive into the individual links and attempt to quantify the benefits (this is done in chapter 5) it is instructive to understand how the use of satellite data helps actors along the value chain to address the challenges that shape their own operational reality. Thus, in the following sections, we provide details on the interests and responsibilities of the stakeholders in each tier.

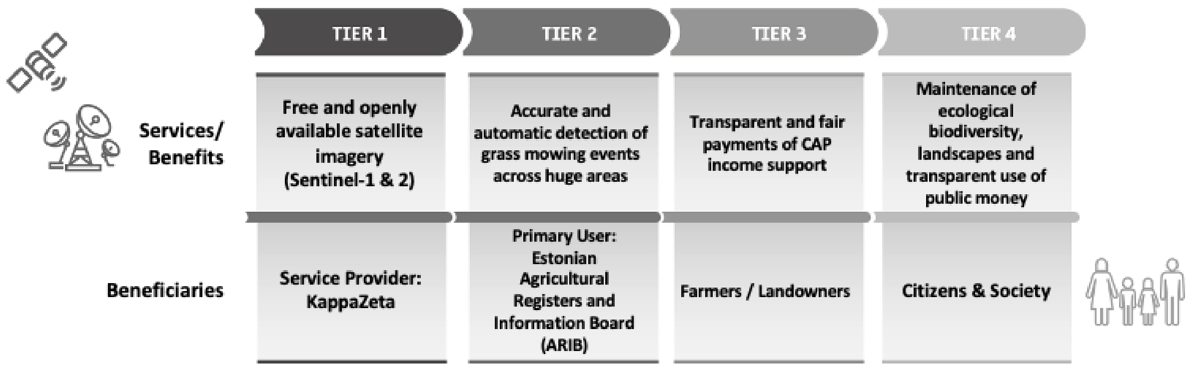

Figure 4-1: The value chain for Grassland Monitoring in Estonia

4.2 The Actors

4.2.1 Tier 1: Service Provider – KappaZeta

KappaZeta is an exciting and fast-growing remote sensing company based in Estonia, now employing 10 people and boasting a constantly expanding business enterprise. By offering ready-to-use high-quality time series data, Kappazeta is enabling the AI revolution for daily monitoring of the Earth. The key area KappaZeta focus on is agriculture and through the use of timely information extracted from satellite data they aim to help actors in the agricultural sector make better decisions, earn more profit and ultimately grow better food. KappaZeta's grassland mowing detection service has been one of their greatest successes so far, with ARIB operationally using their software since 2018 to conduct their daily business.

Figure 4-2: The KappaZeta team

Figure 4-3: KappaZeta's mowing detection map showing compliant and non-compliant fields

The development of a nation-wide system for automated monitoring of agricultural practices (SATIKAS) began in 2015 in collaboration with Tartu Observatory, CGI Estonia and ARIB themselves. This is what eventually led to the mowing detection software now in operation today. There is no doubt that the fact of Sentinel data being both free and open contributed massively to the initiation and development of this service. The free and open data also now helps KappaZeta maintain a sustainable business model and empowers them to expand their enterprise. In addition to the EU Subsidy Check software, KappaZeta also offers professionally noise corrected Sentinel-1 time-series data for scientific and industry use as a supplement to optical data.

In this case study, KappaZeta is the service provider. They provide ARIB with the mowing detection software and maintain the front-end visualisations (the interactive map) and back-end software including all processing of Sentinel data to determine CAP compliance. ARIB conduct the actual compliance checks and interpret the information themselves in-house.

4.2.2 Tier 2: Primary User – Estonian Agricultural Registers and Information Board (ARIB)

The Agricultural Registers and Information Board (ARIB) are an Estonian government agency established in 2000. The overarching goal of the organisation is to support rural development in Estonia with all of its activities ultimately aiming to improve the quality of life in the countryside. A further aim of their work is to ensure that living in the Estonian countryside provides a plethora of opportunities for all Estonian citizens.

ARIB are responsible for organising the granting of national subsidies, European Union agricultural and rural development subsidies, European Maritime and Fisheries Fund subsidies, and market management subsidies in Estonia. ARIB is also responsible for maintaining national registers and other databases related to agriculture. ARIB operates under the authority of the Estonian Ministry of Rural Affairs and currently employ around 340 people. Over 53,000 people currently avail of their various services.[47]

With particular relevance to this case, one of ARIB's many roles is to monitor around 101,000 fields of grassland (equating to just over 410,000 hectares) for which 13,000 applicants apply for subsidies each year in return for managing and maintaining these habitats. As previously stated, ARIB enforce the mowing of these fields at least once per year (within a certain time window) with the intentions of keeping them in good order and avoiding the chances of these fields becoming overgrown with unwanted plant species. As already discussed, ARIB would traditionally send inspectors to conduct in-field checks across a sample of fields to ensure compliance with grassland maintenance requirements. Now thanks to the Sentinel-enabled system, their compliance checking operations have changed dramatically, with all fields being monitored remotely and automatically.

4.2.3 Tier 3: Farmers / Landowners

The third-tier beneficiaries in this case are the farmers and landowners themselves. The vast majority of farmers and landowners who apply for CAP income support will comply with all requirements asked of them, such as the mowing requirement for grasslands. Complying with these measures takes time and effort on behalf of the farmer or landowner. However, in this case, prior to the use of Sentinel data, distinguishing the compliant claimants from the uncompliant claimants was an extremely challenging job. In theory, it was relatively easy for a claimant to apply for the grass mowing subsidy, then not comply by the requirement and still receive the payment based on the assumption alone that they had remained compliant. This was clearly unfair on compliant farmers and landowners who spent time and effort in meeting the CAP requirements asked of them. Moreover, it also meant that taxpayers' money was not being used correctly.

4.2.4 Tier 4: Citizens & Society

As the final beneficiaries of the food produced and the environments maintained by the sustainable agricultural practices already discussed, citizens and society form the final tier of this value chain.

Thanks to the increased vigilance of farmers and landowners in meeting the greening requirements set out by the CAP and enforced by the Estonian Government, the countryside and landscapes within Estonia are being better and more sustainably maintained. This helps ensure that Estonian citizens will enjoy the beautiful scenery, the biologically diverse habitats, and the preserved natural resources and water sources present in their country for years to come.

As already discussed, KappaZeta's service allows subsidy money to be more fairly distributed to the farmers or landowners who deserve their subsidy payments. Anyone can access KappaZeta's mowing subsidy data and map online for free, with all compliant and non-compliant fields clearly visible. Therefore, society as a whole also benefits from the fact that the use of public money is more transparent and more fairly distributed thanks to the KappaZeta and ARIB collaboration. After

[47] https://www.pria.ee/en

all, the money that is provided to farmers as subsidies is directly linked to EU taxpayers' contributions. Therefore, its fair and transparent distribution contributes to social cohesion and accountability.

5 Assessing the Benefits

Now that we know which effects the Sentinel-enabled service is causing in the subsequent tiers of the value chain, we can establish the different types of benefits that are generated through its use. Which financial value can we attribute to the availability of the service? Which environmental or regulatory benefits can we identify? Are there any other social or scientific impacts that we can track? These are the questions we are addressing in this chapter. In this regard, it is useful to recall our value chain picture whilst adding the last two layers to it.

	TIER 1	TIER 2	TIER 3	TIER 4
Services	**Free and openly available satellite imagery (Sentinel-1 & 2)**	**Accurate and automatic detection of grass mowing events across huge areas**	**Transparent and fair payments of CAP income support**	**Maintenance of ecological biodiversity, landscapes and transparent use of public money**
Beneficiaries	**Service Provider: KappaZeta**	**Primary User: Estonian Agricultural Registers and Information Board (ARIB)**	**Farmers / Landowners**	**Citizens & Society**
Other Actors	***The European Union** – Developer and manager of the Common Agricultural Policy*			
Type of Benefit	Access to free and high-quality datasets allowing the delivery of valuable services	Ability to distribute CAP payments more accurately and fairly. Reduced requirement for in-person field inspections. Efficient regulation monitoring.	Transparency and accuracy in the evaluation of their greening activities.	(i) **Environmental protection**; (ii) increased **trust** in public authorities;
Manifestation of value	Savings and simplicity in sourcing data enables a profitable and expanding business **(revenues)**	**Enhanced ability** to fulfil compliance check mandates. **Savings** on in-person man-hours associated with fields inspections.	Portion of subsidy budget not distributed to uncompliant claimants now distributed evenly as extra subsidy to compliant claimants. **(revenues)**	Increased sustainability of natural resource management, maintenance of landscapes and transparency in public spending.

Figure 5-1: Benefits along the value chain

5.1 Overview

Before we dive into the discussion for each of the tiers it is instructive to make some high-level observations:

1. This case has macro-level benefits which apply across all tiers of the value chain

This case presents overarching benefits which are experienced at the supranational level by the European Union. As the developers and managers of the CAP, the EU benefit from the actions of KappaZeta (in developing an innovative service for CAP monitoring which could be encouraged in other member states) and the actions of ARIB (in utilising this service to monitor CAP activity and distribute CAP payments accurately). The benefits felt by the Tier 3 and Tier 4 beneficiaries (farmers and citizens) are also shared by the EU as the targets of the EU's own agricultural initiatives are being met more effectively i.e. sustainable practices are being reinforced, natural habitats and biodiversity are being preserved and CO_2 sequestration is being aided. In addition to this, CAP subsidies are being granted in a fairer and more transparent manner, helping to ensure that public trust and confidence in the CAP is upheld. When compared to previous studies, the manifestation of value across all tiers of the value chain at an additional, singular, macro-level is somewhat unique, making this case particularly interesting.

2. Winners and losers

In our study – as we did in previous ones and will do in future ones - we are concentrating on the positive effects brought about by the availability and subsequent usage of the Sentinel data in the value chain. That being said, one needs to realize: where there are winners, there can sometimes also be losers. Put differently, innovation and subsequent benefits will partly come at the expense of existing stakeholders. In this case, there are not many stakeholders who could be considered "losers". One may consider that the inspectors who previously visited farms and conducted CAP compliance checks are becoming less and less needed. However, as ARIB has strongly underlined these inspectors have multiple responsibilities and visit farms for other CAP requirement compliance checks, not just grassland mowing requirements. There are also other regulatory compliance checks to be conducted, for example, inspecting fertilizer usage. The fact that most of these other checks are still done on-the-spot means that the inspectors are indeed still needed. Moreover, the hours they save in not having to conduct mowing compliance checks are simply reallocated elsewhere, meaning they can perform their duties in a more efficient manner overall. More generally, recent studies demonstrate that 'on balance' and at macro level, there is a distinct positive effect. Annex 3 holds some further observations on this subject.

Another group who are negatively affected in this case are the uncompliant farmers. They cannot receive the subsidy payments which they previously could have received under the traditional compliance checking system. Unfortunately for them, this is one of the primary reasons for the implementation of the EO powered service.

All that said, the next section presents a systematic analysis of the economic value ("adding a price tag") and other types of benefits arising from the use of Sentinel data in each tier.

5.2 Benefits along the Value-Chain

5.2.1 Tier 1: Service Provider – KappaZeta

KappaZeta massively benefit from the use of Sentinel data thanks to its free and open nature as well its qualitative elements (i.e. resolution, revisit time) that allow them to perform the monitoring activities. The Sentinel-1 and Sentinel-2 data being processed is central to the utility of the software that has been developed. The fact that KappaZeta's primary input data source is completely free means they consistently save large amounts of operational costs. Should KappaZeta be required to pay for such huge amounts of rich data continually, their business model would have to change dramatically and ultimately, profits would be reduced. The use of Sentinel data also contributed to the initiation of the development of a nation-wide system for automated monitoring of agricultural practices back in 2015. As discussed, this is what then evolved into the sophisticated software service currently in use today. Building and then expanding KappaZeta's business may not have been possible without the use of Sentinel data as its free and open nature helps to unshackle the burden of large financial liabilities, which can often obstruct young start-ups from getting off the ground, or can even disincentivise the initiation of a service or innovation entirely.

There are two ways in which we can quantify the economic value added at the service provider level as a direct result of using Sentinel data;

1) Measuring an increase in KappaZeta revenues which can be directly tied to the utilisation of Sentinel data;
2) Quantifying the economic added value associated with the number of workers employed by KappaZeta and whose employment can be directly tied to the utilisation of Sentinel data.

To use the first metric, an in-depth analysis of KappaZeta's accounting figures would be required, which is somewhat outside of the scope of this study. KappaZeta themselves also do not have an estimated value of exactly what portions of their revenues can be directly linked to the use of Sentinel data. We will therefore use the latter metric. As previously stated, since 2015 KappaZeta has expanded its enterprise and now employ 10 people. From discussions with KappaZeta, they estimate that **the annual employment of 2 to 4 full-time workers could be directly attributed to the use of Sentinel data**.

For our lower and upper estimations of value, we will therefore use the average annual labour costs associated with 2 and 4 full-time employees in Estonia (lower and upper) as the Tier 1 economic added value which can be directly attributed to the adoption of Sentinel data. The reason we use labour costs and not annual gross or net salary figures is due to the fact that labour costs account for both wage and non-wage costs such as employers' social contributions. This gives a better approximation of the overall economic added value associated with the employment of a worker. The diagram below summarises the relation between net earnings, gross earnings/wages and labour costs.

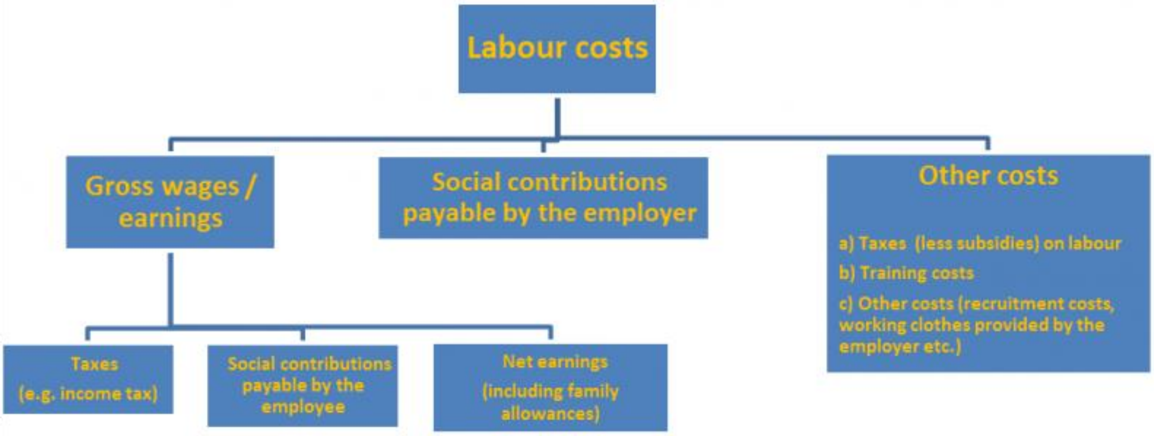

Figure 5-2: Labour cost components

In Estonia, the average hourly labour cost is €13.36/hour[48] with the number of average annual working hours being 1981 hours[49]. This implies that the average economic value of a full-time employee in Estonia is €26,466/year. **As a result, our lower estimate of value is €52,932/year (2 employees) and our upper estimate of value is €105,864/year (4 employees).**

Beyond the economic aspects, it is important to note that KappaZeta contribute greatly to the EU's innovation and entrepreneurial landscape thanks to their innovative use of Sentinel data to develop an extremely valuable and cutting-edge software tool. This service is one of the first of its kind to reach full commercial operability in the EU. As one of the first fully operational demonstrations of Sentinel data being used for CAP verification, the impact this service could have across the entirety of the EU is quite large. In particular, it serves as a flagship innovation in the context of remote field mowing detection and the work undertaken in its development and operation is paving the way for further innovations to flourish. See section **3.3.1 – Future Evolution of the Service** for some related innovative developments KappaZeta are currently working on.

Similarly, through the years of research associated with the development of this service, KappaZeta has also made some significant contributions to science. They have had four research papers related to the grass mowing detection service published:

- **Observations of Cutting Practices in Agricultural Grasslands Using Polarimetric SAR** - The IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (K. Voormansik, T. Jagdhuber, K. Zalite, M. Noorma and I. Hajnsek, 2016).

48 https://ec.europa.eu/eurostat/statistics-explained/index.php/Wages_and_labour_costs#Gross_wages.2Fearnings

49 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Hours_of_work_-_annual_statistics#:~:text=When%20only%20employees%20are%20considered,employees%2033.7%20hours%20per%20week.

- **Monitoring of Agricultural Grasslands With Time Series of X-Band Repeat-Pass Interferometric SAR** - The IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (K. Zalite, O. Antropov, J. Praks, K. Voormansik and M. Noorma, 2016).
- **Relating Sentinel-1 Interferometric Coherence to Mowing Events on Grasslands** - Remote Sensing (Tamm, T. Zalite, K. Voormansik, K. Talgre, L., 2016).
- Voormansik, K., Zalite, K., Sünter, I., Tamm, T., Koppel, K., Verro, T., Brauns, A., Jakovels, D. and Praks, J., 2020. **Separability of Mowing and Ploughing Events on Short Temporal Baseline Sentinel-1 Coherence Time Series.** Remote Sensing, 12(22), p.3784.

5.2.2 Tier 2: Primary User – The Estonian Agricultural Registers and Information Board (ARIB)

As previously stated, ARIB monitor around 101,000 fields of grassland (equating to just over 410,000 hectares) for which 13,000 applicants apply for subsidies each year in return for managing and maintaining these habitats.

Traditionally, ARIB would use on-the-spot-checks to understand whether claimants of subsidies were abiding by the requirements of the various regulations and payments schemes. This would involve inspectors actually travelling to fields and visiting farmers or landowners to inspect the condition of grasslands. It is obviously very difficult to know for sure if a field has been mowed or maintained within the allocated time window, unless it is very obvious to an inspector that the grass has recently been cut prior to an on-site visit. It is also impossible for inspectors to travel to each of the 101,000 monitored fields meaning only a 5% sample of fields received on-the-spot checks, as mandated by the previously discussed **EU Regulation No 809/2014**[37]. This all meant that uncompliant farmers could still receive payments despite not abiding by the rules. ARIB wanted a more accurate, more transparent and more encompassing system to help them monitor as many fields as possible in an efficient manner. This is where they teamed up with KappaZeta to develop a satellite-based monitoring system to do so.

Through the use of the Sentinel enabled KappaZeta service, ARIB have managed to reduce (but not totally eliminate) the need for in-person spot checks across Estonia, saving time for inspectors whose efforts can be better used elsewhere. **ARIB have reported savings of €50,000/year in person-hours as a direct result of the use of KappaZeta's Sentinel enabled software. Therefore, this figure will be used as our lower estimate of economic value in Tier 2.**

Thanks to the use of Sentinel data, 100% of the grassland registered for CAP monitoring can now be monitored, as opposed to the 5% sample of fields previously checked each year. This raises an interesting counterfactual: **Could this level of coverage be achieved through traditional means, and at what cost?** Practically, the answer is no. Checking 100% of registered fields through traditional in-field inspections would be massively impractical, time consuming and bring with it a large financial cost. **As roughly €50,000/year is saved by not conducting the in-field inspections on 5% of registered fields, this implies that if inspections were mandated on 100% of registered fields using traditional methods i.e. in-field inspections, it would bring with it an associated cost**

of roughly €1 million/year. It is notable that thanks to the use of this Sentinel-enabled service, ARIB are achieving **20 times better coverage** and continuous monitoring of fields, improving their operational efficiency in an extremely cost-effective manner. As ARIB's role is to monitor CAP activity, enforce regulation and distribute payments fairly, their use of this sentinel-powered service single-handedly increases the execution and effectiveness of their role massively, allowing them to fulfil their grassland monitoring mandate almost completely. **We will therefore count the counterfactual figure of €1 million/year as our upper estimate of economic value in Tier 2 as ARIB are experiencing the benefit of roughly 20 times better operational execution of grassland monitoring across the entire country.**

ARIB are also better able to enforce CAP monitoring and more accurately issue incentive payments through the use of the mowing subsidy check software. This in turn contributes to the all-encompassing benefit of upholding environmental sustainability and helps to ensure biodiversity across Estonia.

The increased situational awareness achieved thanks to the continuous and accurate **monitoring of CAP-related variables through the use of Sentinel data also lends significant direct support to the reinforcement of CAP regulations**. Ultimately, ARIB are able to monitor regulatory compliance in a much more efficient manner thanks to the use of KappaZeta's software. There is also undoubtedly some efficiency gains for ARIB in generating and providing data in the form of reports to the EU regarding national level grassland maintenance.

The fact that ARIB's monitoring information is openly available to anyone allows for transparency as well as the manifestation of a type of "check and balance" dynamic between ARIB, the claimants and the general public. This allows ARIB to benefit from increased societal trust regarding their work and the manner by which they ensure fair distribution of taxpayers' money This benefit can be fully attributed to the use of Sentinel-based KappaZeta services.

ARIB's use and reliance upon such a cutting-edge service contributes to the EU's innovation ecosystem. ARIB now act as operational proof and an example that can be pointed to of an organisation who made a success of adopting new, exciting and sustainable technologies to improve the ways in which they work.

5.2.3 Tier 3: Farmers / Landowners

The compliant farmers and landowners in this case receive their subsidy payments from ARIB as specified in Chapter 4. The way the system works is that the entire grass mowing subsidy budget is set each year and once it has been verified who the compliant claimants are, they will be entitled to their relevant subsidies. The remaining budget (the money left that will not be paid to uncompliant claimants) is then evenly distributed among all of the compliant claimants in addition to their already allocated subsidies, which in effect acts as a further incentive to remain compliant and is a nice monetary benefit for all compliant claimants in the system. The budget not paid to non-compliant claimants varies each year, obviously depending on the rate of non-compliance. **In 2019 €234,316 was held from uncompliant claimants and distributed evenly back amongst**

compliant claimants, in 2020 this figure was €312,493. With the use of satellite data, it is hoped that compliance rates will increase and the amount of money which must be held back from uncompliant claimants reduces over time to zero. As the service has only been operational for 3 years, it is difficult to quantitively measure exactly how compliance rates are changing over time. However, ARIB has qualitatively reported that claimants are now even withdrawing their claim before their incompliance is registered by the system to avoid possible sanctions (withdrawal of a claim is allowed prior to a cut-off point). ARIB believe the increases in withdrawn claims is a direct result of the introduction of the new monitoring system. In 2020, around 531 hectares had their claims withdrawn prior to the cut-off point with another 880 hectares being found to be uncompliant after the cut-off point through the use of the Sentinel enabled system. As the amount of money held back should decrease each year, and hopefully reach close to zero, we cannot quantify a year-on-year economic benefit in this tier. However, the overall economic benefit of the system being in place is that more compliant claimants receive the monetary reward they deserve.

The profound consequence of all of this is that public investment (in the form of taxpayers' money) is, with the help of the Sentinel-based service, meeting its stated goal, i.e. the provision of subsidies to those that deserve it. Thanks to Sentinel data, fraudulence is quickly reducing to zero and taxpayers' money is being channelled in a much fairer manner. The CAP monitoring activities and subsidy payments are therefore working as they should be. This is a key and standout benefit in this case.

As before, the performing of the CAP requirements by claimants contributes to the environmental sustainability goals of the CAP and helps to ensure biodiversity across Estonia. However, the question remains as to whether or not the net environmental benefit in this scenario is positive or negative due to the fact that the majority of machinery used to mow the fields (e.g. farm machinery and tractors) have associated greenhouse gas emissions, and in particular, carbon emissions. As previously stated, grasslands act as good carbon sinks, but to calculate the overall mass balance of emissions versus sequestration at a macro level is an extremely complex task. A report published by the European Commission in 2018[50] that evaluated the impact of the greening direct payment found that there is "*strong evidence of added value*" when it comes to the greening measures addressing "*the common EU objectives of reducing greenhouse gas emissions, sequestering more carbon and maintaining and improving biodiversity*". Developing a detailed model on the weighing of emissions versus sequestration in this application is outside the scope of this study, therefore we will assume that the net environmental impact, with particular relevance to greenhouse gas emissions, remains positive in this case, or at least does not have a net-negative impact. There is, however, some debate regarding the maintenance techniques themselves i.e. when it comes to grassland maintenance, is grazing more environmentally sustainable in comparison to mowing? A 2016 study found that "*grazing generally had a more positive effect on the conservation value of semi-natural grasslands compared to mowing, but effect sizes were generally small to moderate for most contrasts. Furthermore, effects varied across some grassland characteristics e.g. for different grassland types, with grazing and mowing having a similar effect or mowing having a more positive*

[50] https://ec.europa.eu/info/sites/info/files/swd_evaluation_greening_in_direct-payment_en.pdf

effect in certain cases."[51] Another study recommended a combination of both grazing and mowing to maintain optimum nutrient levels in the underlying soil.[52]

Again, the increased situational awareness of claimants which has been achieved thanks to the continuous and accurate monitoring of CAP-related activities also helps to reinforce the CAP regulations. ARIB has qualitatively reported that since the introduction of this process, fraudulent and incorrect claims are reducing and compliance is indeed increasing as claimants become more and more aware of the fact that it is virtually impossible to have incompliance go undetected. Overall, when it comes to CAP regulations, a "compliance culture" is being forged thanks to the use of the Sentinel-enabled system.

5.2.4 Tier 4: Citizens & Society

The activities undertaken in the previous three tiers of this value chain bring various benefits to the citizens and society of Estonia.

On the economic side, one particularly interesting perspective is related to the economic value associated with the upkeep of Estonia's grassland landscapes, which ultimately is for citizens to enjoy. Whilst it is difficult to put a "price tag" to it, in a paper entitled "**The value of EU agricultural landscape**" some researchers set out to do just that. In their paper[53], Pavel and Paloma studied citizens' willingness to pay for the maintenance of different landscape types across the EU. They concluded that "*grassland and permanent crops report higher mean values (€200/ha) than arable land (€117/ha)*" (Pavel & Paloma, 2011). From the findings of this paper, one may be inclined to conclude that there is an €87/hectare economic benefit associated with maintaining each of the 410,000 hectares monitored by KappaZeta and ARIB as permanent grassland rather than allowing it to be converted to arable land. This assumption would provide us with an enormous economic value figure of **€35.7 million per year**. However, in our analysis we must try to understand the value that is derived as a consequence of the use of Sentinel data specifically. Once this is considered, we cannot claim that the €35.7 million per year is a result of the use of Sentinel data. This is due to the fact that prior to the use of KappaZeta's software, the maintenance of this grassland was ongoing anyway, with the primary incentive for conducting the maintenance activities being the CAP subsidy payments themselves. Attributing a monetary value to the citizens and society of Estonia for grassland maintenance is an extremely difficult task, which would require its own dedicated in-depth economic study which is deemed outside the scope of our analysis. We will therefore not quantify and attribute an economic benefit within the final tier of this value chain, however, as will be explained below, there are other non-economic benefits experienced.

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[51] Grazing vs. mowing: A meta-analysis of biodiversity benefits for grassland management: https://www.sciencedirect.com/science/article/abs/pii/S0167880916300809

[52] https://ec.europa.eu/environment/integration/research/newsalert/pdf/high_nature_value_grasslands_can_be_maintained_by_alternating_between_mowing_and_grazing_425na1_en.pdf

[53] Pavel, C. and S. G. Y. Paloma. "The Value of EU Agricultural Landscape." (2011).

As with the previous tiers, citizens and society benefit as a whole from the better management of farmers and landowners in meeting the requirements set out by the CAP. The sustainable maintenance of Estonia's countryside and landscapes is being reinforced, which helps ensure that citizens will enjoy the beautiful scenery, the biologically diverse habitats, and the preserved natural resources and water sources present in their country for years to come.

Furthermore, society also feels the benefit of the fact that through ARIB's use of KappaZeta's service, public spending is fairer and more transparent since all mowing activity data is accessible online for free, with all compliant and non-compliant fields clearly visible. This helps increase public trust in the governmental agencies associated with the distribution of subsidies and in the CAP itself. It also ensures that taxpayers can see how the money they pay into EU programmes is being used. This refers not only to CAP but also to major infrastructure projects such as Copernicus which is enabling valuable applications that bring material benefits to society, such as ARIB's use of KappaZeta's software helping to make sure farmers are reimbursed fairly for their efforts.

5.2.5 Other beneficiaries

The European Union can be considered another, high-level beneficiary in this case. Due to the innovative use of Sentinel data, the goals of the EU's CAP are being met in a sustainable and economically efficient manner. The EU themselves have actually been pushing for further use of Sentinel data when it comes to monitoring and managing CAP requirements in all member states. In 2018, the European Commission introduced **Regulation No 2018/746** which allowed for Sentinel data along with other earth observation data to be used as evidence when checking farmers' fulfilment of requirements under the CAP for area-based payments (either direct payments to farmers or rural development support payments)[54]. At the introduction of these new rules, the then Commissioner for Agriculture and Rural Development, Phil Hogan remarked:

"This new satellite technology will significantly reduce the number of field inspections, removing the climate of fear, which causes significant stress for farmers. It will also benefit public administrations, by reducing the costs of administering controls and checks. It is thus a win-win for farmers and administrators."[5554]

ARIB's use of KappaZeta's software is therefore a prime example of exactly the type of technological practices that the EU are encouraging when it comes to CAP monitoring.

The benefits felt by the Tier 3 and Tier 4 beneficiaries (farmers and citizens) are also experienced at the supranational level by the EU as their own greening initiatives are being met more effectively i.e. sustainable practices are being reinforced, natural habitats and biodiversity are being preserved and CO_2 sequestration is being aided. In addition to this, CAP subsidies are being granted in a fairer and more transparent manner, helping to ensure public trust and confidence in the CAP and the EU itself is upheld.

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[55] https://ec.europa.eu/info/news/modernising-cap-satellite-data-authorised-replace-farm-checks-2018-may-25_en

The EU can also use the products KappaZeta and ARIB's work to increase the transparency of their spending. Using the mowing subsidy check software as an example, the EU can easily demonstrate to citizens how money going into Copernicus is helping to ensure that CAP money is distributed in a fairer manner.

5.3 Summary of Benefits

In this chapter, we draw together the different benefits to the stakeholders identified along the value chain, grouping them by six dimensions of value-chain analysis. A summary of the degree of the benefits as applicable to this case, taking into account previously studied cases, is shown below. The assessment is subjective; the basis for it is given in Annex 2.

5.3.1 Economic

The use of Sentinel data brings direct economic benefits to both KappaZeta and ARIB. We have also analysed the potential benefits which could be experienced should the system used in Estonia be adopted across the entire EU-27. Below is a summary of the findings of our economic analyses.

Tier	Benefits identified	Annual economic value stemming from the use of Sentinel-enabled services (in €)	
		Low	High
Tier 1 (KappaZeta)	Employment of full-time workers	**€53,000**	**€106,000**
Tier 2 (ARIB)	Savings on person-hours associated with in-field inspections	**€50,000**	**€1,000,000**
Tier 3 (Farmers/ Landowners)	CAP subsidy payments better distributed to correct recipients	**N/A**	**N/A**
Tier 4 (Citizens & Society)	Upholding countryside biodiversity and maintenance of landscapes	**N/A**	**N/A**
TOTALS		**€103,000**	**€1.1 M**

Table 5-1: Summary of economic benefits

At first glance, it may seem counterintuitive that the low Tier 2 economic benefit is slightly less than the low Tier 1 economic benefit (€50,000 compared to €53,000). When analysing this, one must remember that the Tier 1 benefit is associated with increased employment for KappaZeta and the Tier 2 benefit is associated with operational cost savings for ARIB. KappaZeta are indeed paid by ARIB for their services, however, the amount has not been disclosed for confidentiality reasons and is ultimately irrelevant with regards to our analysis as it counts as a cost for ARIB and a revenue for KappaZeta, thus cancelling itself out across the value chain. Therefore, the table above does not imply that ARIB are paying for a service for which they receive a lower economic benefit in return. In fact, when one considers that ARIB can do a much better job in executing their grassland monitoring mandate, achieving almost 20 times the geographic coverage for their field inspection operations, along with the increased vigilance and compliance of farmers and landowners, which in turn brings with it environmental and societal benefits, one can understand how it is not solely economic benefits that are of interest to the likes of ARIB in this scenario.

- Employment of full-time workers (tier 1)
- Cost savings from person-hours associated with in-field inspections (tier 2)

5.3.2 Environmental

Not only does KappaZeta and ARIB's collaboration **help ensure the biodiversity of Estonia's ecosystems and the protection of its beautiful landscapes**, but it contributes to the supranational environmental sustainability goals of the CAP's initiatives i.e. **keeping EU agricultural practices sustainable, maintaining the good condition of agricultural land, protecting natural habitats and aiding the sequestration of CO_2**. The environmental benefits in this case are experienced right along the value chain, at both micro and macro levels, making it a prime example of how Sentinels can add huge value to our environmental sustainability efforts.

- Upholding of sustainable CAP regulations (tier 2 & 3)
- Maintainance of rural biodiversity and landscapes (tier 4)

5.3.3 Regulatory

This case in particular contributes very strong regulatory benefits. **The motive behind the service is to ensure that CAP regulations are enforced in as complete and efficient a manner as possible**. Using this sentinel-enabled service, ARIB can accurately monitor 100% of registered grasslands, something which would be impossible to do without satellite data. **KappaZeta and ARIB both contribute to upholding and exemplifying how CAP regulation can be managed.** Not only that, but the valuable lessons and rich data all parties have gained throughout the development and implementation of this service could serve to help mould new regulation in the future. The EU themselves continue to incentivise for the development of innovative methods of monitoring and enforcing regulation through the likes of satellite data**. Therefore, the lessons learned and innovative "know-how" developed in this case, particularly when it comes to the capabilities and limitations of the service, could provide valuable insights to policymakers and aid them when designing new regulation.**

- Better monitoring and enforcement of CAP regulation (tier 2)
- Increased regulatory vigilance and compliance (tier 3)

5.3.4 Entrepreneurship & Innovation

KappaZeta's initiative in designing a valuable and cutting-edge service through the use of Sentinel data contributes greatly to the EU's innovation and entrepreneurial landscape. KappaZeta have built an entire business around the development of this innovation and now have 10 employees working on improving their products and services as well as building new ones. **As one of the first fully operational demonstrations of Sentinel data being used for CAP verification, the KappaZeta service acts as a flagship innovation in the context of remote field mowing detection.** ARIB's use and reliance upon such an inventive service also contributes to the EU's innovation ecosystem. ARIB now act as operational proof and an example that can be pointed to of an organisation who **made a success of adopting new, exciting and sustainable technologies to improve the ways in which they work.**

- Creation of innovative services (tier 1)
- Changed operational practices (tier 2)

5.3.5 Science and Technology

As already discussed, KappaZeta have **had a number of scientific research papers published** throughout the development of the grass mowing detection service. **These primarily focus on the use of Sentinel-1 SAR data in grassland monitoring applications.**

- Publication of scientific research (tier 1)

5.3.6 Societal

Society benefits from the transparency and open nature of KappaZeta's software. The fact that the interactive map and compliance data is completely free for anyone to interrogate online **aids in the manifestation of a transparent check and balance dynamic** between ARIB, the claimants (farmers and landowners) and the general public. This helps the creation of **societal trust in ARIB's operations and their distribution of taxpayers' money**. It helps **solidify public trust in the various EU CAP initiatives** as people can see for themselves exactly where public money is going. **Moreover, this service helps to highlight and justify the operations of public bodies in delivering value to citizens and society as a whole.**

- Transparent use of public funds (tier 3 & 4)

5.4 Synoptic Overview

The information reported separately within each dimension is brought together in a summary form to provide a synoptic overview. This gives a clearer view of how the benefits are arising in each of the tiers.

Tier	Benefits identified	Type	Value where economic (annual)
Tier 1 (KappaZeta)	**Employment of full-time personnel**	Economic	€53k – €106k
	Creation of innovative services	Entrepreneurship and innovation	
	Improved understanding of the application of remote sensing techniques	Science and Technology	
Tier 2 (ARIB)	**Savings in person-hours**	Economic	€50k – €1 million
	Better monitoring and enforcement of CAP regulation	Regulatory	
	More efficient operational practices	Entrepreneurship and innovation	
	Enhanced public trust	Societal	
Tier 3 (Farmers/Landowners)	**Fair and swift subsidy payments / Increased regulatory vigilance and compliance**	Regulatory	
	Environmentally sustainable farming practices maintained	Environmental	
Tier 4 (Citizens and Society)	**Maintenance of rural biodiversity and landscapes**	Environmental	
	Transparent use of public funds / Protection of rural landscapes	Societal	
TOTALS			**€103k – €1.1 million**

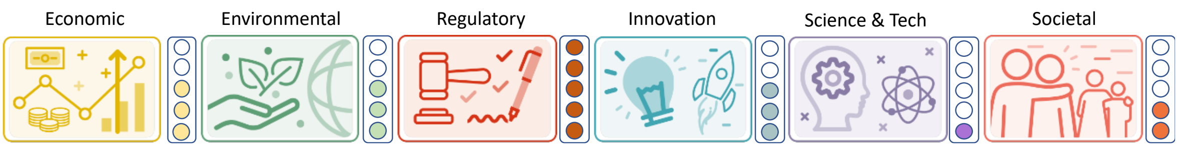
Table 5-2: Overview of the benefits from using Sentinel data

6 Conclusions

6.1 Summary of Findings

This case provides a perfect example of how the combination of both Sentinel-1 and Sentinel-2 data can enable innovative solutions that directly address user needs. By using KappaZeta's software, ARIB can more efficiently and more effectively uphold their CAP verification and payment operations, saving time and money in doing so. The relationship between KappaZeta and ARIB also **serves to protect grassland ecosystems, ensuring farmers' livelihoods will be sustained for years to come and the citizens of Estonia can enjoy the beautiful landscapes their own country has to offer well into the future**.

In particular, the regulatory benefits in this case are some of the strongest we have ever studied. The KappaZeta and ARIB working relationship is a prime example of how the monitoring and verification of regulation can and should be conducted. The software KappaZeta have developed is precisely the type of innovative technology that the EU are incentivising for the future of the CAP.



6.2 The Impact of Sentinel Data

In most cases analysed under the *Sentinel Benefits Study* the question of attribution arises, i.e. what percentage of the produced benefit can be attributed to the use of Sentinel data? In this case, we can certainly attribute the saving in ARIB's person-hours associated with spot checks completely to the Sentinel data. This same is also true for the regulatory benefits. Moreover, we can also say that a huge factor in the initiation of the research into the mowing detection service, as well as the expansion of KappaZeta's business is due to the fact that Sentinel data is free and openly available.

Of course, there are certain benefits, for instance the environmental ones, which do not directly rely on the use of Sentinel data. Instead, they rely on the decisions made and practices exercised by the stakeholders who use Sentinel-enabled products. In other words, the more accurately and efficiently ARIB reward environmentally sustainable behaviour, the more this behaviour is reinforced and incentivised. However, in order to gain accuracy and efficiency in their operations, the use of Sentinel-enabled technology is required.

6.3 Widening the Perspective

The main focus of this case has been the use of Sentinel-1 and Sentinel-2 data in Estonia. However, the application of the technique used is by no means specific to Estonia. Instead, it has a much wider perspective. This can be studied along three dimensions: (i) geographic extension, (ii) increased market penetration and (iii) improved technological maturity. Below we discuss these dimensions in the context of this case:

- **Geographic Extension**

The possibility of geographic extension in this case is quite obvious and vast. Estonia is not the only EU member state who must monitor CAP activities, every member state is obliged to do so. Whilst Estonia is one of the first to operationally use such a service, several other member states are in varying degrees of operationality when it comes to using satellite-enabled grassland mowing detection services. Combining this with the fact that Sentinels capture the entirety of the EU's land surface area every 5 – 6 days, geographically extending this service to other EU member states is a straightforward next step. In fact, KappaZeta have tested their methodology on grasslands in Poland, Denmark and Sweden and as a result have concluded that their methodology is highly applicable for the whole Baltic Sea region.

An extrapolation calculation has been undertaken with the aim of projecting the value manifested in Estonia across the remaining 26 EU member states in an effort to understand to potential value a sentinel-powered service such as this could bring across the entire EU.

The average hourly labour costs in each EU member state are given below in **Figure 6-1** along with average weekly hours worked in each member state in **Figure 6-2**. To calculate the average annual labour costs associated with **one** full-time employee in each EU member state the following calculation has been performed; the values from **Figure 6-1** have been multiplied by the corresponding average annual working hours in each EU member state, which have been extrapolated from the values presented in **Figure 6-2**.

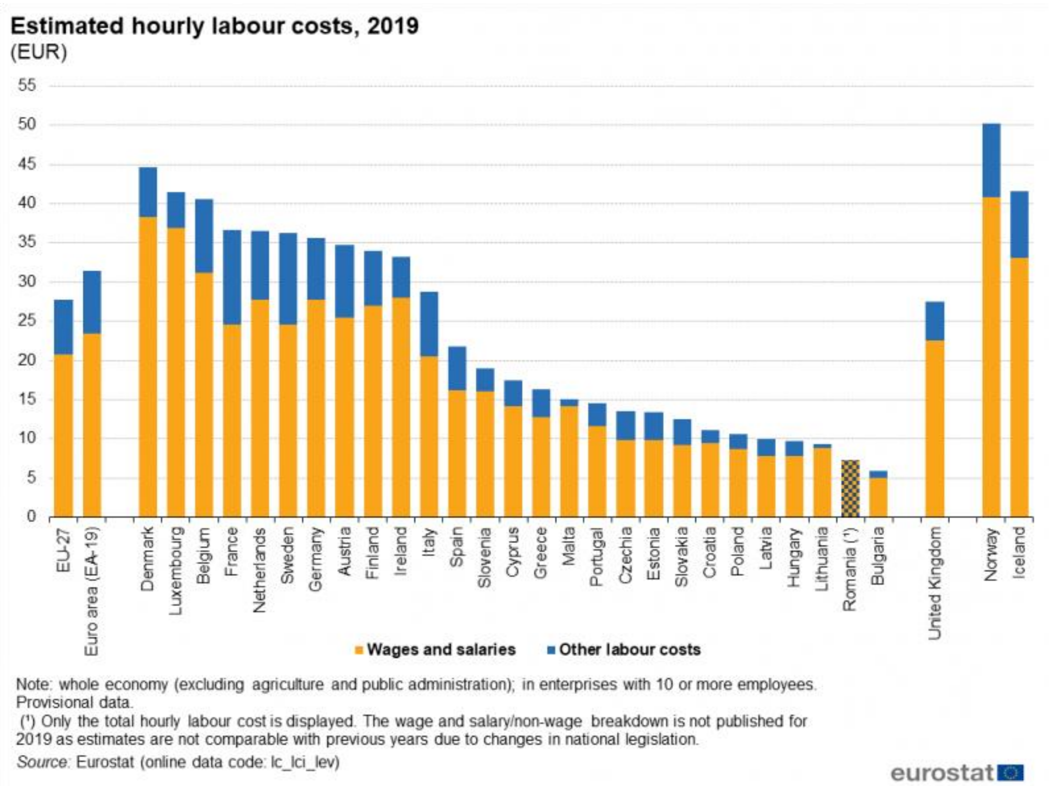


Figure 6-1: Estimated hourly labour costs in each EU member state[56]

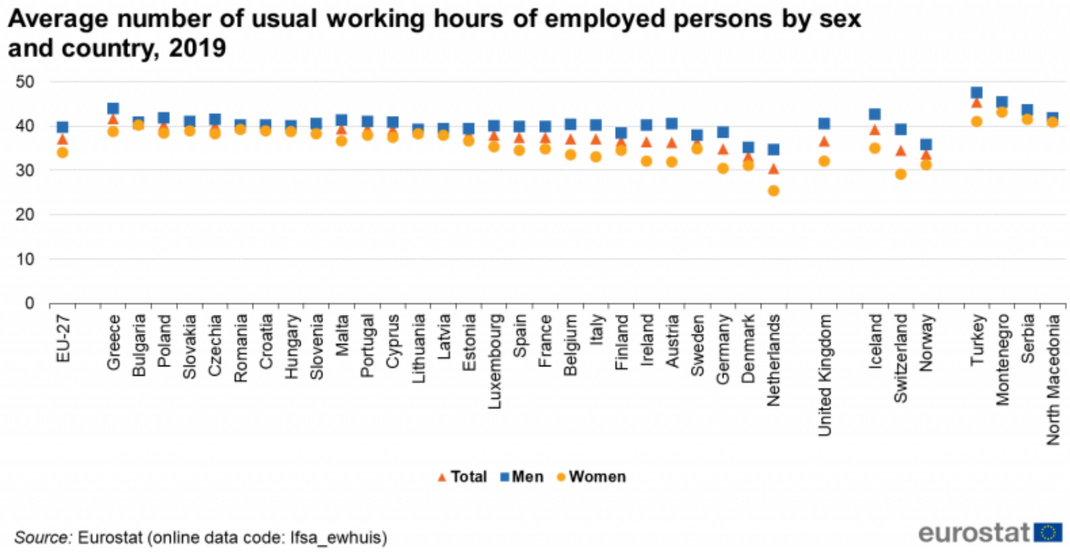


Figure 6-2: Average weekly working hours in each EU member state[57]

<u>Note:</u> As the lower and upper estimates in Tier 1 of our value chain were based on the labour costs associated with 2 employees and 4 employees respectively, <u>in this extrapolation we have assumed 3 full-time employees in Estonia.</u> As each EU member state has varying sizes of grassland areas in comparison to Estonia, it is logical to assume that relatively more or less full-time employees will be required to build and maintain a service similar to what KappaZeta provide in Estonia, depending on grassland area coverage. For example, France has over 20 times the grassland area coverage of Estonia, while Malta only has around 1% the grassland area coverage of Estonia.[58] However, we cannot simply linearly scale the number of employees based on grassland area due to the fact that the algorithms developed by KappaZeta can be scaled across large geographic regions relatively easily, thanks to the vast area coverage of the Sentinels, and the associated services can be provided with a high degree of automation. This implies that France does not really require 20 times the number of employees as Estonia to achieve the same outcome. We have therefore applied an assumed correction factor; for every tripling of grassland area relative to Estonia, one extra employee shall be added. For example, Portugal has almost three times the grassland area coverage of Estonia, therefore we will assume a KappaZeta type service in Portugal would require 4 full-time employees (3 + 1). There are only 4 EU member states with less grassland area than Estonia; Cyprus, Luxembourg, Malta and Slovenia. For each of these we have assumed only 1 full-time employee would be required. See table below for a full breakdown of the calculations.

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56 https://ec.europa.eu/eurostat/statistics-explained/index.php/Wages_and_labour_costs#Gross_wages.2Fearnings

57 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Hours_of_work_-_annual_statistics#Average_working_hours_by_country.2C_sex_and_occupation

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

	Total labour cost €/hr	Average hours/week	Average hours/year	Average labour costs/year	Number of fulltime employees in Estonia	Ratio of grassland to Estonia	Number of fulltime employees (with correction factor)	Total labour costs/year
Austria	€ 34.73	36.4	1892.8	€ 65,737	3	2.876	4	€ 262,948
Belgium	€ 40.48	37.2	1934.4	€ 78,305	3	1.319	3	€ 234,915
Bulgaria	€ 5.99	40.5	2106	€ 12,615	3	2.894	4	€ 50,460
Croatia	€ 11.12	39.7	2064.4	€ 22,956	3	1.498	3	€ 68,868
Cyprus	€ 17.45	39.3	2043.6	€ 35,661	3	0.169	1	€ 35,661
Czechia	€ 13.54	40	2080	€ 28,163	3	2.439	4	€ 112,652
Denmark	€ 44.68	33.3	1731.6	€ 77,368	3	1.048	3	€ 232,104
Estonia	€ 13.36	38.1	1981.2	€ 26,469	3	1.000	3	€ 79,407
Finland	€ 34.04	36.6	1903.2	€ 64,785	3	2.060	4	€ 259,140
France	€ 36.61	37.4	1944.8	€ 71,199	3	20.332	10	€ 711,990
Germany	€ 35.63	34.8	1809.6	€ 64,476	3	10.884	7	€ 451,332
Greece	€ 16.39	41.7	2168.4	€ 35,540	3	3.549	4	€ 142,160
Hungary	€ 9.91	39.5	2054	€ 20,355	3	2.567	4	€ 81,420
Ireland	€ 33.20	36.5	1898	€ 63,014	3	5.513	5	€ 315,070
Italy	€ 28.76	37.1	1929.2	€ 55,484	3	9.068	6	€ 332,904
Latvia	€ 9.94	38.6	2007.2	€ 19,952	3	2.045	4	€ 79,808
Lithuania	€ 9.37	38.8	2017.6	€ 18,905	3	2.259	4	€ 75,620
Luxembourg	€ 41.62	37.9	1970.8	€ 82,025	3	0.104	1	€ 82,025
Malta	€ 15.00	39.4	2048.8	€ 30,732	3	0.010	1	€ 30,732
Netherlands	€ 36.42	30.4	1580.8	€ 57,573	3	1.904	4	€ 230,292
Poland	€ 10.67	40.3	2095.6	€ 22,360	3	9.838	6	€ 134,160
Portugal	€ 14.60	39.4	2048.8	€ 29,912	3	2.908	4	€ 119,648
Romania	€ 7.72	39.8	2069.6	€ 15,977	3	8.986	6	€ 95,862
Slovakia	€ 12.53	40.1	2085.2	€ 26,128	3	1.326	3	€ 78,384
Slovenia	€ 19.05	39.5	2054	€ 39,129	3	0.610	1	€ 39,129
Spain	€ 21.84	37.5	1950	€ 42,588	3	13.136	7	€ 298,116
Sweden	€ 36.29	36.4	1892.8	€ 68,690	3	3.369	4	€ 274,760
								€ 4,909,567

Table 6-1: Tier 1 economic benefits extrapolation

This extrapolation calculation provides us with an estimated aggregated annual economic value associated with the employment of full-time employees responsible for the delivery of KappaZeta-like services in each EU member state of **€4,909,567/year**.

To extrapolate the Tier 2 benefit, the following calculation has been undertaken:

As previously stated, ARIB monitor around 410,000 hectares in Estonia for grassland mowing subsidy direct payments. However, this does not account for all of the grassland in Estonia, as these 410,000 hectares are only the grasslands that are accessible, applicable and which farmers or landowners have registered to be monitored. Using the overall figures in the table below, 15.9% of Estonia's landcover is classed as grassland (of various types). This equates to around 721,000 hectares, meaning roughly 57% of this grassland is registered for CAP monitoring. Different regions in Europe have varying levels of grassland intensification and maintenance, with regions such as Ireland, northern and central France, Spain and The Netherlands boasting the highest intensity of grassland management activity.[59] Moreover, each member state will undoubtedly have varying percentages of their grassland registered to be monitored for CAP mowing subsidy payments. However, acquiring the granular data on the exact number of hectares subject to CAP mowing subsidy monitoring in each member state is beyond the scope of our work. Instead, we will base our estimations on the findings of a study entitled "*Combining satellite data and agricultural statistics to map grassland management intensity in Europe*" which has found that overall, around 64% of the entire EU's grasslands were mown at least once per year. Therefore, assuming each

59 Combining satellite data and agricultural statistics to map grassland management intensity in Europe: https://iopscience.iop.org/article/10.1088/1748-9326/aacc7a/pdf

member state has the same percentage of its total grassland registered and mowed as Estonia (i.e. 57%), is deemed a plausible average estimate for extrapolation purposes. We then linearly scale the €50,000/year saving across all other 26 member states based on relative grassland size to Estonia. **This provides us with an estimated figure of €5,685,532/year corresponding to savings from on-the-spot-checks across the entire EU.**

	Total area (km^2)	Share of total area by type and land cover (%)				
		Woodland and shrubland	Cropland	Grassland	Water areas and wetland; bareland	Artificial
EU-28	4 369 364	44.8	22.2	20.7	8.0	4.2
Belgium	30 668	26.3	28.5	31.0	2.8	11.4
Bulgaria	110 995	46.6	29.2	18.8	3.5	1.8
Czech Republic	78 874	38.5	32.0	22.3	2.6	4.6
Denmark	43 162	20.4	50.6	17.5	4.7	6.9
Germany	358 327	34.9	32.3	21.9	3.6	7.4
Estonia	45 347	58.6	13.5	15.9	10.1	2.0
Ireland	70 601	25.3	5.8	56.3	8.8	3.8
Greece	131 912	56.7	15.3	19.4	5.1	3.4
Spain	498 504	45.7	21.3	19.0	10.6	3.4
France	549 060	33.8	28.9	26.7	5.2	5.4
Croatia	56 539	58.0	16.7	19.1	2.6	3.7
Italy	301 291	39.5	25.1	21.7	6.8	6.9
Cyprus	9 249	45.3	19.4	13.2	16.8	5.4
Latvia	65 519	55.8	14.3	22.5	5.8	1.6
Lithuania	65 412	38.7	29.4	24.9	4.2	2.8
Luxembourg	2 595	37.2	23.3	28.9	0.7	9.8
Hungary	93 013	26.0	43.7	19.9	6.4	4.1
Malta	315	19.1	26.3	23.4	7.6	23.7
Netherlands	37 824	15.0	24.2	36.3	12.4	12.1
Austria	83 944	48.3	15.3	24.7	7.4	4.3
Poland	313 851	36.7	33.2	22.6	4.1	3.5
Portugal	88 847	52.8	11.7	23.6	6.6	5.3
Romania	239 068	34.7	32.2	27.1	3.9	2.2
Slovenia	20 277	63.7	9.5	21.7	1.9	3.3
Slovakia	49 026	48.9	26.6	19.5	2.1	3.0
Finland	337 547	72.3	5.9	4.4	15.9	1.6
Sweden	449 896	69.8	4.2	5.4	19.0	1.6
United Kingdom	247 763	30.9	19.7	36.2	6.4	6.5

Source: Eurostat (online data code: lan_lcv_ovw)

Table 6-2: EU member state land cover by type[60]

All in all, the total extrapolated value across the entire EU amounts to **€10,595,099/year.**

- **Increased Market Penetration**

Whilst the potential for wider geographical coverage is undeniable, the question of increased market penetration is a prevalent one. KappaZeta already boast a strong presence in the Estonian remote sensing technology and innovation sector. Through their relationship with ARIB they already have a foothold with an EU paying agency, and through this are gaining valuable experience in serving public sector clients. At the supranational level, KappaZeta are building an ever-expanding network of key contacts through their involvement in the various ESA and EU funded projects already discussed. These levels of recognition at both national and international levels, along with KappaZeta's proven operational competence could, over time, lead to many opportunities in other international markets.

The beauty of satellite data is that in theory, KappaZeta can conduct all of their work from Estonia, reducing market entry costs such as the requirement of a physical presence in a country in which

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

you wish to conduct business. Moreover, thanks to the EU single market, the barriers to trade for selling their products or services within any of the 26 other EU member states are significantly low. All of this considered, market penetration and expansion is something that is most certainly within KappaZeta's competency and on their horizon.

- **Improved Technological Maturity**

Technological maturity should be understood here as (i) the capacity of the users to make optimal use of a given service (even when this service remains unchanged over time), (ii) the ability of the providers to improve their value proposition using the feedback (and data analytics) from their customers.

In the case it seems that the user, ARIB, are already in a very good position to make the most of what is provided. If we extend beyond Estonia, it is safe to assume that new users will require some effort to integrate the software into their operational workflows. However, due to its user-friendly nature, the adoption of this software is not seen as a major barrier for any future user to overcome.

With regards to the value proposition provided by KappaZeta, there is no doubt that the service is at the forefront of innovation as it is one of the first operational services of its kind. This alone obviously serves as one of the most powerful value propositions a company can offer. Despite this, there is of course room to improve the service and KappaZeta have the appetite and capabilities to do so. As already discussed, KappaZeta are developing a number of additional services alongside the University of Tartu, Tallinn University of Technology, the Estonian University of Life Sciences and Gisat. These include a crop classification tool, a harvest prediction tool and grazing detection service. Integration of the mowing service with the grazing detection system is also currently being developed. More overarching market trends such as advances in Artificial Intelligence, machine learning, and Big Data handling may also result in better processing techniques which KappaZeta can use to further enhance their offerings in the future.

6.4 Final Thoughts

The value of Sentinel data in enabling accurate and efficient verification of CAP initiatives, supporting environmental sustainability and, consequently, generating significant benefits along the value chain has been clearly showcased. Whilst this case has primarily focussed on Grassland Monitoring in Estonia, its narrative and conclusions are valid not only for similar cases all across the EU and possibly even beyond, but also for other agricultural contexts. In that regard, this case forms part of a family of cases analysed under the *Sentinels Benefits Study*.

Individually, but also collectively, such cases underpin how public investment in a cutting-edge technological asset (i.e. the Copernicus Sentinels) returns significant benefits to businesses, governmental authorities, international organisations, research institutes and the public at large. Moreover, the service generated using Sentinel-1 and Sentinel-2 data in this case supports processes that are directly tied to European legislation which promotes the wellbeing of our environment and our society. In that regard, such cases act as a "lighthouse" illuminating how different actors can cooperate along the value chain and produce a wide array of benefits, economic, environmental, societal, regulatory, innovation- and science-related.

Although outside the scope of this study, understanding the detailed mass balance of carbon emissions versus carbon sequestration at the macro level in the context of CAP grass mowing requirements is deemed an important piece of future work. It could help to shed light on the overall environmental benefits associated with the grassland mowing requirements.

In light of all the above, we hope that the analysis presented herein will spark further uptake of the solutions discussed here – by authorities dealing with similar issues. We also hope that researchers will be inspired to carry out complementary analyses, in relation, for instance, (i) developing even smarter CAP regulation monitoring applications, and (ii) assessing how remote sensing can further help design CAP regulation itself.

Annex 1: References and Sources

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Annex 2: General Approach and Methodology

This case has been analysed as a part of the Sentinel Benefits Study (SeBS), which looks at the value being created by the use of Sentinel data. It follows a methodology[61], established during a previous study, looking at a value chain for the use of a single EO service.

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.

The value-chain is divided into a number of tiers where the supplier is Tier 1, and the primary user is Tier 2. The last Tier is always "Citizens and Society". The number may vary according to the complexity of the value-chain. The benefits are then analysed against each of these tiers.

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 a common understanding. Note that we are not asking these experts to endorse our findings but to indicate any gross errors or sensitivities which may have been introduced. At the end of this process, the report is made public.

As work has proceeded and more cases analysed, some modifications have been made to the SeBS methodology. The first of these has been to expand from the two dimensions used earlier, namely economic and environmental benefits, to add those connected to societal, regulatory, innovation and entrepreneurship and scientific and technological. These six dimensions are described in the table A2-1 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 A2-1: Definitions for the benefit dimensions

61 SeBS Methodology; June 2017.

For each of these, a ranking has been introduced to give an immediate, visual impression of the scale of the benefits under each dimension. To aid in the quantification of these, a guide has been introduced which is shown in Table A2-2.

Rank	Benefit status	Criteria
0	**Null**	The case presents no perceivable benefits in this dimension, and no potential for such benefits to emerge is anticipated.
1	**Latent**	The value chain described in the case may, in general, present potential benefits in this dimension, but none have been identified or described in this particular instance.
2	**Manifest**: At least one benefit in this dimension has been identified through the value chain within the case. Its significance in the context of the case overall is judged to be:	**Low**
3		**Moderate**
4		**High**
5		**Exceptional**

Table A2-2: The ranking of the benefits.

In order to introduce further basis for comparison, a systematic approach has been developed for the analysis of the benefits. A series of indicators have been defined for each of the benefit dimensions against which each case can be considered.

The indicators used in the case are listed in section **5.3**, and a full list of all indicators considered is provided in Table A2-3.

Dimension	Indicator	What it can mean.
Economic	Avoided costs (AV)	Alternative means to gather data
	Increased Revenues (IR)	Increased production/sales
	Reduced Inputs (RI)	Less time spent or material saved
	Improved Efficiency (IE)	Better use of resources
Environmental	Reduced pollution (RP)	Reduced amounts of pollutants in key resources e.g. water, air
	Reduced impact on natural resources (RR)	Reduced environmental impact e.g erosion, habitats/biodiversity.
Societal	Improved public health (IPH)	Less toxicological risk
	Common Understanding (CU)	Better control and communication of remedial efforts i.e through common maps.
	Increased trust and better transparency (ITT)	Improved preparedness / response
	Strategic Value (SV)	Common societal value to a country or region.
Regulatory	Improved policy / regulation design/drafting	Better information (scale, accuracy) leading to better regulation
	Improved efficiency in policy/regulation monitoring	Better information available to monitor adherence to regulations.
Innovation & Entrepreneurship	Innovative products	Sentinel data leads to creation of new products / services
	New Business models	New ways to generate income.
	New markets	Global nature of sentinel data enables international business development
	New businesses	Creation of new companies; start-ups
Science & technology	Academic output	
	Research exploitation	Applied science to operational services
	Research contribution	New product enabling scientific research

Table A2-3: Complete list of indicators considered within SeBS analyses.

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.[62] 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.[63]

How technological progress and innovation are related to employment has been an area of fierce debate for centuries. From fairly recent studies appear that product innovation spark new economic activities, creating new sectors, more jobs, whereas process innovation[64] 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.[65]

> 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).[66] 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.[67] 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.[68]

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.

Annex 4: About the Authors

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