e-shape

EuroGEOSS Showcases: Applications Powered by Europe

D5.21 – Final socio-economic value of EO in selected sectors report

The e-shape project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 820852

Document Type	Deliverable
Document Name:	e-shape-WP5-D5.21 – Final socio-economic value of EO in selected sectors report
Version:	V1.0
Date:	19/10/22
Status:	Final
Dissemination level:	Public

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Remarks / Improvements:				

Version History (preliminary)			
Version:	Date:	Comments, changes, Status:	Person(s) / Organisation Short Name:
v1.0	19/10/22	Draft	Daire Boyle (Evenflow)
vFinal	24/10/2022	vFinal	PMT

Version Numbering	
v0.1	Draft before peer-review approval
v1.0	After the first review
v2.0	After the second review
Vfinal	Deliverable ready to be submitted

Status / Dissemination Level			
Status		Dissemination Level	
S0	Approved/Released/Ready to be submitted	**PU**	Public
S1	Reviewed	**CO**	Confidential, restricted under conditions set out in the Grant Agreement
S2	Pending for review		
S3	Draft for comments	**CI**	Classified, information as referred to in Commission Decision 2001/844/EC.
S4	Under preparation		

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1 INTRODUCTION

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

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

Moreover, by extending the methodological framework developed within the Sentinel Benefits Study (SeBS), these reports provide a contribution to the body of knowledge of the European EO community when it comes to quantifying and presenting the benefits EO solutions enable. The SeBS cases are in-depth value chain analysis studies of well-established EO services which often have several paying customers. The use of concrete data points within these studies forms the basis of much of the extrapolation within this report. Specifics on our methodology are provided in the following chapter.

The expected output of this activity is three publications focussing on different sectors, delivered at M23, M32 and M40:

- The first publication focused on the agricultural sector. The report combined inputs from previous work with a fresh look into the value chains served by the different pilots under the e-shape agriculture showcase, so that the potential benefits they yield were highlighted.
- The second publication focused on public wellbeing, linking to pilots in various showcases within e-shape which provide services related to public health, safety, and quality of life.
- The final publication (this report) focuses on natural capital and the environment and draws from various showcases within e-shape to illustrate the plethora of associated benefits.

2 METHODOLOGY

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

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

Illustrated with lessons from diverse e-shape Pilots, the report extrapolates the concrete data points and deeply understood socio-economic benefits of EO from the SeBS studies to build a picture of the value of EO to different sectors.

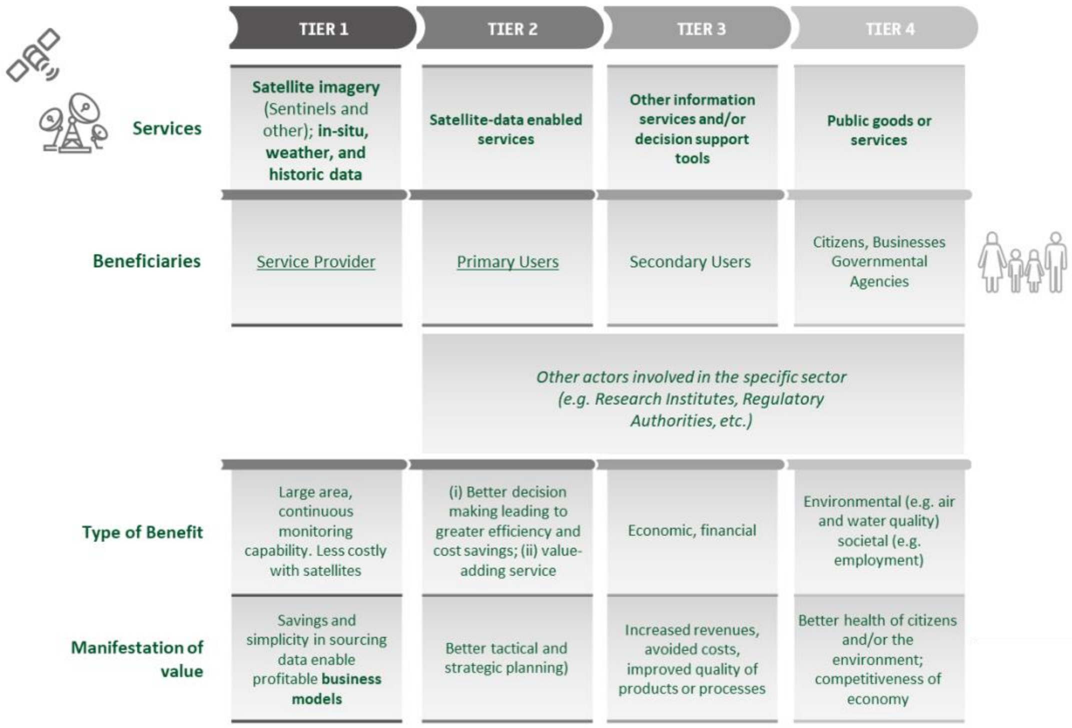


Figure 2-1: Visualisation of a "generic" value chain used to study the different cases

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

Typically, each value chain consists of 4 "tiers". Short descriptions of each tier are given below:

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

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

This report builds on the outputs of these efforts and attempts, for the first time, a consistent "upscaling" of the application of the value-chain approach. In this regard, **we shall draw from the very well understood value chains within the SeBS case studies to illustrate how value can be experienced**

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

across sectors, ideally in direct reference to the services produced by the e-shape pilots. The methodological framework developed in SeBS, and in particular the 6 dimensions of benefit (see 2.2 below) will form the basis for our analysis, which is extended through an extrapolation approach (see 2.3 below).

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

Across the value chain, the availability of EO-based data/products enables actors in each different Tier to access and act on different types of information, helping them to make informed decisions and proceed with targeted interventions. Whilst each case has its own characteristics, certain common benefits have been observed along 6 generic dimensions: **(i)** economic, **(ii)** environmental, **(iii)** societal, **(iv)** regulatory, **(v)** innovation and entrepreneurship-related, and finally **(vi)** science and technology-related. The definitions for each of these dimensions are provided below.

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

Table 2-1: Definitions of the benefit dimensions

In each of these dimensions, EO-based services can produce a significant impact. The benefits for some of these dimensions cannot always be quantified (let alone monetised). Yet, there is value to identify the specific contribution of EO. Therefore, in our effort to extrapolate the value generated by EO, we shall consider both the quantifiable and non-quantifiable aspects. The specific approach we introduce for e-shape is described below.

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

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

Here, we aim to build on the well-studied bottom-up cases and construct a broader, well-justified picture.

Please note: The extrapolation method described is primarily applied to economic benefits.

It starts with the assessment of specific value chains, which we then try to generalise and extrapolate so as to present benefits tracked back to EO-based services for whole sectors. A graphic representation of our approach is presented Figure 2-2. It distinguishes between a "bottom-up" type approach to estimating value and a "top-down" approach. A "bottom-up" approach gains a very good understanding of benefits and value manifested at the micro level i.e. in a single value chain with a relatively small number of stakeholders. This approach only gains a limited understanding of the overall value and benefits manifested at the macro level i.e. at a regional, national or supranational level. A "top-down" approach is the opposite, it gains a good understand of benefits and value manifested at a regional, national or supranational level, but only a limited understanding of the benefits and value manifested at the micro level. Our approach is somewhere in the middle, whereby we take well understood micro-level cases, link and group them by application and then build a picture of various market segments. Taking the market segments as "building blocks" of the overall market, we aim to illustrate the potential magnitude of the overall macro-level benefits.

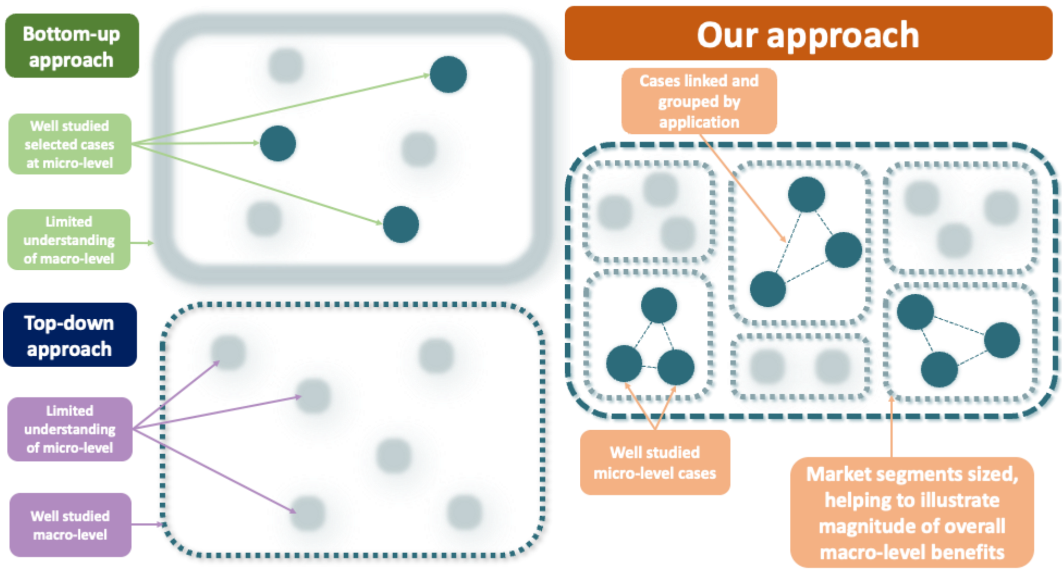


Figure 2-2: "Bottom-up", "top-down" and our approach to value estimation

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

[2] https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf

2.3.1 Geographic extension

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

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

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

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

2.3.2 Market Penetration

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

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

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

[3] See here: https://www.copernicus.eu/en/access-data/dias

2.4 Definition of "threads"

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

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

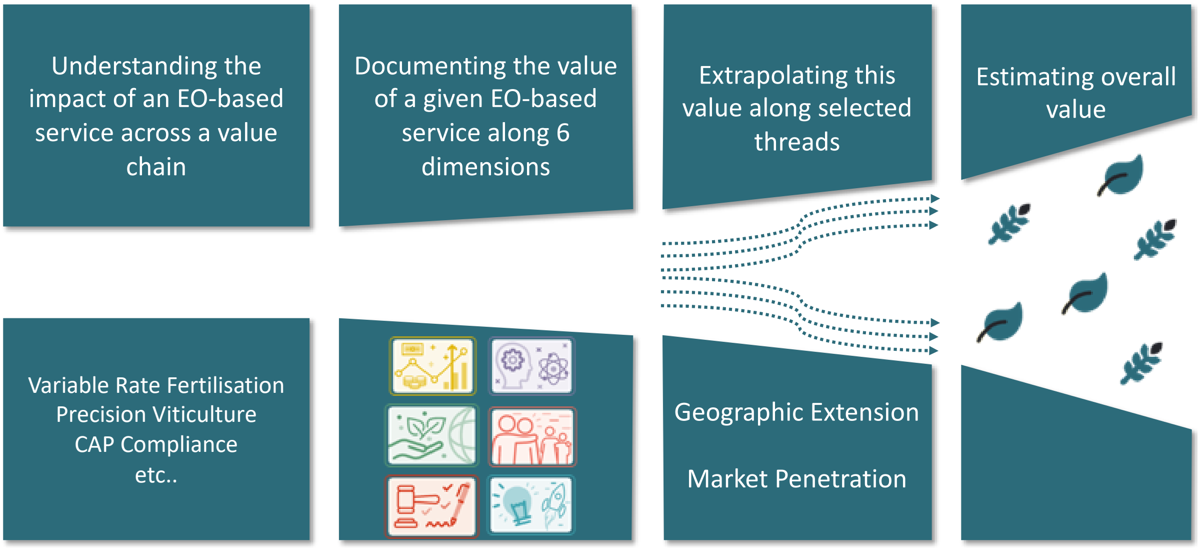


Figure 2-3: Graphical representation of the approach to evaluate socio-economic value in e-shape

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

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

2.5 Choice of sectors

The reasoning behind choosing broad “sectors” (i.e. public wellbeing or environmental monitoring) for each report is to link as many e-shape pilots back to the chosen sector as possible, thereby highlighting the work of all 37 e-shape pilots across the span of the three socio-economic reports. For each of the three reports we have chosen a “sector” or “theme” from which we can both extrapolate data from SeBS cases (to show the value EO has for the sector) and also weave in commentary which links back to each e-shape showcase/pilot. As can be seen in the table below, the plan is to cover each of the 7 e-shape showcases (and all pilots within) across all three reports.

Socio-economic report secotr or “theme”	SeBS case studies from which data will be extrapolated	Relevant e-shape showcases which can be linked throughout the report
1st report: “Agriculture”	MAKING WINE IN FRANCE GROWING POTATOES IN BELGIUM FARM MANAGEMENT SUPPORT IN POLAND FARM MANAGEMENT SUPPORT IN DENMARK GRASSLAND MONITORING IN ESTONIA	SC1 – Agriculture
2nd report: “Public wellbeing”	WATER QUALITY MANAGEMENT IN GERMANY GROUND MOTION MONITORING IN NORWAY FLOOD MANAGEMENT IN IRELAND AQUIFER MANAGEMENT IN SPAIN NAVIGATION THROUGH SEA-ICE OFF GREENLAND WINTER NAVIGATION IN THE BALTIC	SC2 – Health SC3 – Energy SC5 – Water SC6 – Disasters
3rd report: “Natural capital and the environment”	DEFORESTATION MONITORING FOR SUSTAINABLE PALM OIL PRODUCTION WATER QUALITY MANAGEMENT IN GERMANY GRASSLAND MONITORING IN ESTONIA AQUIFER MANAGEMENT IN SPAIN FORESTRY MANAGEMENT IN SWEDEN	SC4 – Ecosystem SC7 - Climate

Table 2-2: Choice of sectors across reports

As will be explained in the following section, the choice of “natural capital and the environment” also allows for strong parallels to be drawn between the aims of the e-shape pilots and the UN’s Sustainable Development Goals and Sendai Framework for Disaster Risk Reduction. The following section illustrates how EO can aid natural capital and the environment and describes some chosen threads of value across the already discussed 6 dimensions of benefit.

3 VALUE ADDED BY EO TO NATURAL CAPITAL AND THE ENVIRONMENT

3.1 How EO can aid Natural Capital and the Environment

Within e-shape, we hope to develop effective solutions which can sustain our natural capital and protect the environment. But what exactly are the types of environmental challenges that can be addressed by EO?

Ecosystem and biodiversity monitoring, greenhouse gas emission monitoring, extreme weather events and seasonal resource planning can all be informed by EO. In fact, EO can act as an important tool in our collective mission of achieving the UN's SDG13 – Climate Action, SDG14 – Life Below Water and SDG15 – Life on Land as well as the UN's Sendai Framework for Disaster Risk Reduction.

3.1.1 Ecosystem monitoring

Ecosystem destruction is one of the biggest threats facing plants and animal species around the world. When we clear forests or land for the likes of farming, mining, or urbanization, we are eliminating or altering the conditions necessary for animals and plants to survive, which in turn not only impacts individual species but also the health of the global ecosystem. The problem is also not unique to terrestrial ecosystems, as coastal areas, inland waters, and the ocean are also experiencing ecosystem destruction. Pollution and effluents from the land can travel easily through streams and rivers to the ocean, where they impact the health of fish, birds, and marine plants.

In the past, geographical coverage of data pertaining to ecosystem health was sparse and measurement methods differed around the world. Moreover, a lack of longer-term data made it difficult to track trends. However, thanks to Earth Observation we can now collect data regularly, at high resolution and across vast areas.

Within e-shape, several pilots are developing solutions directly addressing, or partially addressing this dimension. Under the **Showcase 4 – Ecosystem**, these include:

- Pilot 4.1 – mySPACE
- Pilot 4.2 – mySITE
- Pilot 4.3 – myVARIABLE

3.1.2 Climate and atmospheric monitoring

We can monitor and predict changes in the Earth's climate based, in part, on atmospheric conditions. By understanding the composition of greenhouse gases in our atmosphere we can effectively plan and respond to climate variations and extreme weather events. Earth Observation can provide us with continuous and widespread data on changes to atmospheric composition and help track pollutants, which in turn allows us to inform governments and businesses on the impacts of atmospheric pollution on public health, the environment, and the economy.

Super resolution air quality monitoring service

Within e-shape, several pilots are developing solutions directly addressing, or partially addressing this dimension. Under **Showcase 7 - Climate**, these include:

- Pilot 7.1 – Global Carbon and Greenhouse Gas Emissions
- Pilot 7.2 - Urban resilience to extreme weather - Climate Service
- Pilot 7.6 - Super resolution air quality monitoring service

3.1.3 Seasonal preparedness

Information is a critical resource in planning for seasonal weather conditions. Data regarding the timing and extent of low temperatures in winter or high temperatures in summer can help regional governments in planning for resource allocation. This information can also be used by private actors to efficiently plan and prepare for potential disruptions to business operations. Earth Observation can help by contributing to accurate forecasting of climactic conditions over vast areas, ensuring stakeholders are best informed for potential issues.

Within e-shape, several pilots are developing solutions directly addressing this dimension. Under **Showcase 7 - Climate**, these include:

- Pilot 7.2 - Urban resilience to extreme weather - climate service
- Pilot 7.3 - Forestry conditions - climate service
- Pilot 7.4 - Hydropower in snow reservoir – climate service
- Pilot 7.5 - Seasonal preparedness

3.2 Economic threads

When it comes to the impact of EO in natural capital and the environment, there is a plethora of varying case studies, impact assessments and scientific research regarding how EO data and EO based technologies can add value. As a result, conducting an all-encompassing, meta-analysis of the true value EO brings to our ecosystems and environment is a very complex if at all attainable endeavour, and therefore goes beyond the scope of this publication. We can however try to shed light on some very important aspects of our natural environment that are aided through the use of EO, thus capturing a proportion of the overall value that EO can deliver. To that end, we will take the approach of using the previously discussed "threads" of value to extrapolate some already well understood, real-world economic benefits from various SeBS case studies.

3.2.1 Understanding the impact of EO services across value chains

The table below is a summary of the SeBS cases which involve a strong natural capital or environmental protection dimension. "Extrapolatable"[4] benefits from each case are listed and aggregated (where applicable) to provide data points regarding total value per year stemming from the case specific application of EO data in its respective region. Given that most cases have many situational nuances and uncertainties, both low and high value estimates are provided.

Case study	Natural Capital/Environmental dimension	Specific benefit within the case	Lower findings of value	Upper findings of value
DEFORESTATION MONITORING FOR SUSTAINABLE PALM OIL PRODUCTION[5]	**Ecosystem monitoring & protection**	Monitoring and protection of forests	€19 million/year	€33.6 million/year
WATER QUALITY MANAGEMENT IN GERMANY[6]	**Water resource monitoring & protection**	Better water quality in lakes	€4 million/year	€7.8 million/year
GRASSLAND MONITORING IN ESTONIA[7]	**Ecosystem monitoring & protection**	Maintenance and protection of grasslands for biodiversity	€103,000/year	€1.1 million/year
AQUIFER MANAGEMENT IN SPAIN[8]	**Water resource monitoring & protection**	Monitoring and protection of aquifers	€31.7 million/year	€71.8 million/year
FORESTRY MANAGEMENT IN SWEDEN[9]	**Ecosystem monitoring & protection**	Monitoring and protection of forests	€16 million/year	€21.5 million/year

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

[4] By "extrapolatable" we mean that the benefit found in the particular case is generic enough as to allow one to reasonably assume that when applied in a different geographic location, a similar benefit would be achieved.

[5] https://earsc.org/sebs/deforestation-monitoring-for-sustainable-palm-oil-production/

[6] https://earsc.org/sebs/all-cases/water-quality-management-in-germany/

[7] https://earsc.org/sebs/grassland-monitoring-in-estonia/

[8] https://earsc.org/sebs/aquifer-management-in-spain/

[9] https://earsc.org/sebs/forestry-management-in-sweden/

3.2.2 Extrapolating the data

The next step is to set our extrapolation parameters, based on geographic extension. Clearly EO is almost uniquely positioned in its applicability to huge geographic extension, however, for the purposes of this document, geographic extrapolation is limited to the EU-27.

The value calculated at the national level of each of the selected SeBS cases will be extrapolated to other countries, based on relative magnitudes (see bullet points below). For example, to geographically extrapolate the benefits associated with grassland monitoring in Estonia, grassland cover data sets across Europe have been consulted. Moreover, when it comes to extrapolating benefits relating to forestry management in Sweden, forest cover data sets across Europe have to be used.

- **Water Quality Management in Germany:** Lake surface area per country (km^2)
- **Grassland Monitoring in Estonia:** Grassland surface area per country (km^2)
- **Aquifer Management in Spain:** Fresh groundwater abstraction per country (million m^3)
- **Forestry Management in Sweden:** Forest surface area per country (km^2)

Note: For the **Deforestation Monitoring for Sustainable Palm Oil Production** case, the figures will remain as is and not extrapolated as this case concerns a commodity not cultivated in the EU (i.e., palm oil) and the case is based in Malaysia and Indonesia, therefore extrapolation across the EU27 is not relevant.

The following table shows the extrapolation data used in our calculations. **Please note:** Not all fresh groundwater data was available.

Country	Lake surface area (km^2)[10]	Forest cover (km^2)[11]	Grassland cover (km^2)[12]	Fresh groundwater (million m^3)[13]
Belgium	340	8113	8,633	-
Bulgaria	1271	48915	16,352	561.73
Czechia	978	30234	15,879	359.3
Denmark	596	8587	8,446	707.82
Germany	6140	123766	74,218	-
Estonia	2185	26277	7,339	229.09
Ireland	1480	9882	40,334	-
Greece	1731	53005	18,224	6228.35
Spain	5209	175161	64,021	-
France	6835	181930	135,161	-
Croatia	470	27226	9,834	425.3
Italy	5382	106337	49,568	-
Cyprus	33	2224	1,012	135
Latvia	1960	35326	13,489	87.28
Lithuania	1657	25504	14,329	162.74
Luxembourg	15	904	853	22.99

[10] https://ec.europa.eu/eurostat/databrowser/view/LAN_LCV_OVW__custom_2182909/default/table?lang=en

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

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

[13] https://ec.europa.eu/eurostat/databrowser/view/ten00002/default/table?lang=en

Hungary	1767	24848	16,279	606.88
Malta	4	12	59	37.94
Netherlands	3758	5637	13,031	-
Austria	1505	36301	20,266	-
Poland	5561	114590	64,510	2550.3
Portugal	1626	34496	14,092	-
Romania	3735	81339	54,598	705
Slovenia	108	12708	3,601	187.73
Slovakia	481	22437	8,634	338.7
Finland	36323	220637	19,552	-
Sweden	39798	279329	24,821	-

Table 3-2: Extrapolation parameters

Taking all data points and extrapolation parameters into account, the following table displays the results of our calculations for potential added value of EO in selected natural capital and environmental monitoring/protection applications across the EU. It must be noted that due to the generalisations and assumptions made, the range of value is relatively large. However, due to the fact that all estimates of potential value are regarded as conservative, the values in the following table help to convey (by orders of magnitude) just how impactful EO could be for protection of Europe's environment and natural capital. The figures below can be thought of lower and upper estimates of the "Total Addressable Market" (TAM) for the earth observation applications in natural capital and environmental monitoring.

Dimension	Lower estimate of value	Upper estimate of value
Water resource protection (Extrapolated from Germany and Spain cases)	€ 229,452,493/year	€ 492,686,642/year
Terrestrial ecosystem protection (Extrapolated from: Forests - Palm oil & Swedish cases, Grasslands - Estonian case)	€ 126,196,050/year	€ 271,607,429/year
Totals	**€ 355,648,542/year**	**€ 764,294,072/year**

Table 3-3: Potentials for threads of EO added value in natural capital and environmental protection applications

It is clear from the values presented above that EO holds huge promise in protecting our natural resources, ecosystems, and the environment. Even the conservative lower estimate of €356 million per year is a significant benefit to the citizens and society of the EU. Within the context of this study, the €356 million per year added value is considered an absolute minimum, with real added value certainly higher in practice. As can be seen, the upper estimate of value is over €764 million/year. This figure is quite staggering and stands as a testament to the efficacy and potential for EO in delivering both economic value and protecting our environment.

Again, the figures above represent only some "threads" of economic value that can be realised through the implementation of EO in environmental protection applications. These threads represent only a portion of how EO can add value, with there being many other parallel threads whose economic value are not captured within this report. **For example, we have not included the economic benefits associated with the likes of improved air quality, reduced greenhouse gas emissions, or protection of aquatic ecosystems etc. Rather than attempting to truly quantify the impact of EO in the domains**

of environmental and natural capital protection, by simply taking a small number of robust data points from well-established real-world applications, the narrative above gives an idea of just some of the efficacy and possibilities with regards to EO as well as conveying just how pervasive and impactful it can be.

3.3 Environmental threads

The following sections provide a detailed view on the various environmental benefits in the SeBS cases and how these intersect with environmental benefits of e-shape pilots.

3.3.1 Ecosystem monitoring

Traditionally, data on parameters related to ecosystem and biodiversity health was collected almost exclusively through on-site observations. However, with EO, both public and private entities are now developing extremely innovative applications thank to its ability to assess quantifiable parameters on land and in water, and to detect when an imbalance in these parameters can inflict damage on the local flora and fauna. Notable examples of such applications are the UN Biodiversity Lab which provides EO data to put nature at the centre of sustainable development, the EU Soil Observatory, aiming to develop a soil health database, and the Natura 2000 Land Cover product, meant to help assess the effectiveness of measures taken to protect specific grassland-rich sites.

Satellite observations support the efforts of maintaining natural habitats and biodiversity through detection of environmental issues on land such as deforestation, grassland destruction or peatland destruction and the likes of harmful algae blooms in water bodies. EO based monitoring guides the likes of governments and responsible stakeholders in detecting ecosystem damage or destruction and putting in place measures to fight against it.

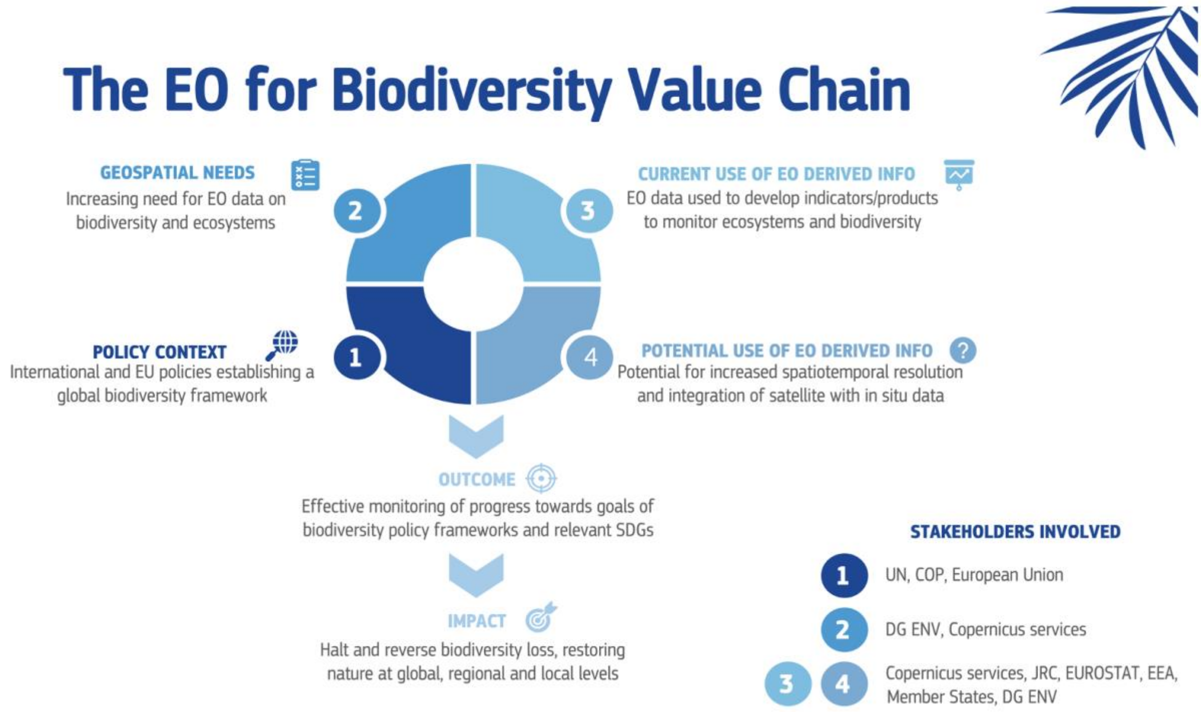


Figure 3-1: The EO for biodiversity value chain[14]

[14] https://knowledge4policy.ec.europa.eu/earth-observation/earth-observations-biodiversity_en

Many of our natural ecosystems also need to be protected through government action. As discussed in the analyses of the relevant SeBS cases (i.e. Deforestation Monitoring for Sustainable Palm Oil Production, Grassland Monitoring in Estonia, Lake Water Quality Management in Germany and Forestry Management in Sweden), EO helps to improve the monitoring of biologically diverse habitats and ecosystems, ultimately aiding in their protection.

Pilot 4.1 – mySPACE, Pilot 4.2 – mySITE and Pilot 4.3 – myVARIABLE are working both separately and together to develop ecosystem monitoring products. These include remote sensing-based information for the management of selected Protected Areas and environmental assessment in benchmark ecosystems and a common registry will be in form of a web-based platform which will integrate over 1000 site-based in-situ measurements that will be the basis for any long-term and large-scale ecosystem assessment.

3.3.2 Climate and atmospheric monitoring

When it comes to climate and atmospheric monitoring, there actually have not been any SeBS cases completed yet, however, there is an upcoming case on Air Quality Monitoring in Latvia, due to be published soon. The e-shape pilots, on the other hand, have a plethora of climate and atmospheric monitoring applications.

For instance, Pilot 7.6 - super resolution air quality monitoring service aims to improve air quality monitoring at large. Pilot 7.1 - Global Carbon and Greenhouse Gas Emissions is developing products to support the Global Carbon Project which studies the integrated picture of the carbon cycle and other interacting biogeochemical cycles, including biophysical and human dimensions and their interactions and feedbacks. It contributes to the endeavours of UNFCCC, IPCC, GCOS, GEO by annual publication of the Global Carbon Budget (GCB) which has been established as one of the most prominent services to climate policy.

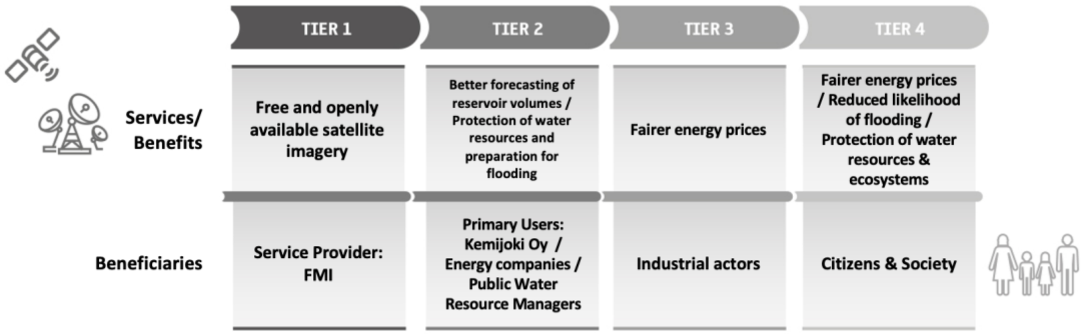
Similarly, when it comes to atmospheric monitoring, the Copernicus Atmosphere Monitoring Service and commercial platforms such as AirQast are some examples of innovative ways in which we can monitor how our atmosphere is changing.

Throughout the development of this report we have taken time to interview several pilots to produce short case studies on the overall benefits associated with their activities. See case study relating to Pilot 7.4 - Hydropower in snow reservoir – climate service in the box below. Through its optimisation of hydroelectric power planning, one of the many benefits associated with this pilot is its contribution to the reduction of greenhouse gas emissions associated with other forms of energy production.

Case Study – **Pilot 7.4 - Hydropower in Snow Reservoir – Climate Service**

In most basins in Scandinavia and Finland, more than 50% of the annual precipitation falls as snow. Errors in snowmelt timing and melt rate simulations are one of the largest sources of stream flow prediction errors in snowmelt-dominated watersheds. Thus, snow storage and melting periods have a significant impact on hydropower production reservoirs. Forecasts of reservoir inflow and energy prices are used to schedule the quantity and timing of releases for daily, weekly, and seasonal operations.

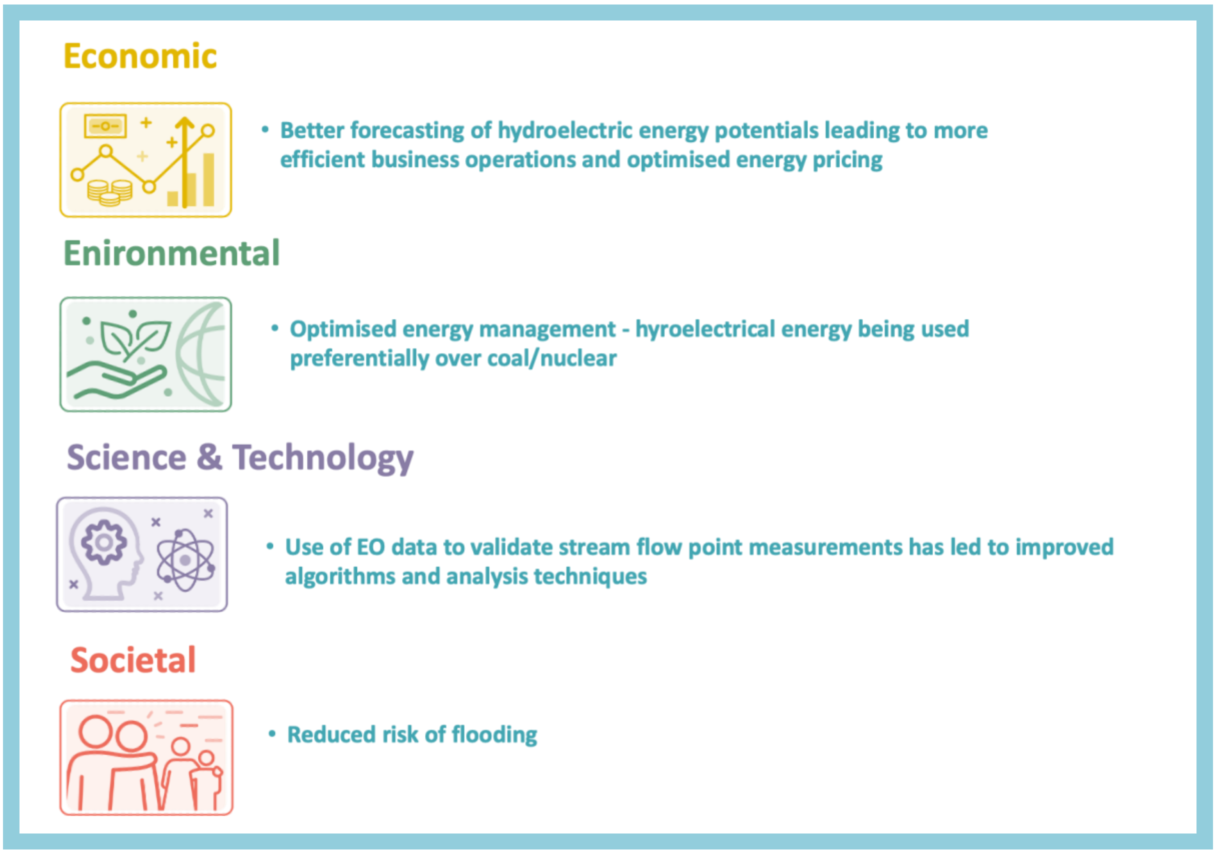
This pilot service focuses on producing hydrological forecasts for a hydropower company (Kemijoki Oy) operating in Northern Finland. A particular focus is placed on snow reservoir energy potential forecasting. The key diagnostics are reservoir inflow and snow reservoir energy potential, which together with other factors is a measure of stored hydropower potential. Reduction of spring snowmelt driven flood risks through more reliable hydrological nowcasts and forecasts and increasing the end-user's situational awareness and understanding of uncertainties and consequently providing a basis for optimization of hydropower operations. The outcome aims to bridge the gap between forecast providers and forecast end users by seeking solutions to remove barriers for information dissemination, application, and utilisation.



Currently modelling and forecasting of snowmelt timing and melt rate uncertainties stem from uncertainties in model forcing data. The lack of widely available and reliable forcing data restricts widespread application of more complex models, particularly in operational stream flow prediction systems. EO based snow state ingestion and communication with end users will be used to address these limitations. Ingestion of Earth Observation based snow observations into hydrological models will significantly reduce hydrological model snowpack simulation uncertainties. The use of EO based snow observations offer two main types of advantages:

- EO based snow observations are independent from point scale observations (usually used to drive hydrological models) and can be used to validate each other.
- They provide basin wide information and data on the state of the snowpack as opposed to point scale observations.

This pilot aims to decrease the vulnerability of energy companies to variations in meteorological and hydrological conditions through improved seasonal forecast products. Descriptions of the primary dimensions of benefit are given below.

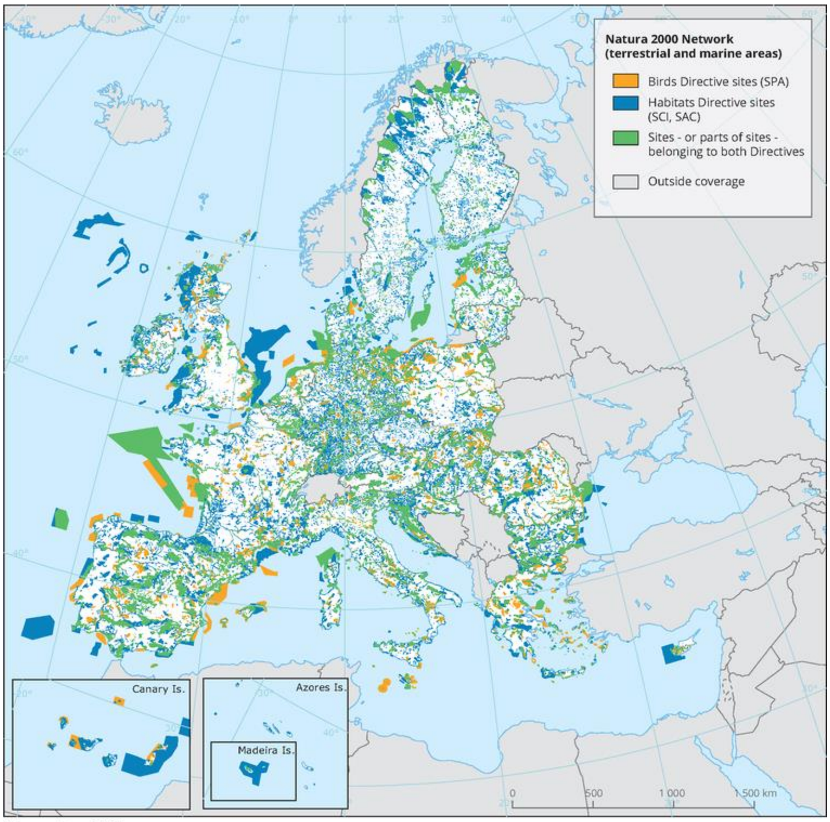


3.4 Regulatory threads

3.4.1 Ecosystem monitoring

The European Union has put forward its ambitious Biodiversity Strategy for 2030 which is an ambitious plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on a path to recovery by 2030 by promoting the adoption of a global post-2020 biodiversity framework under the Convention on Biological Diversity. The Biodiversity Strategy is seen as core part of the European Green Deal.

In the context of the Biodiversity Strategy for 2030, the EU aims to establish protected areas under the Natura 2000 initiative for at least 30% of land and sea in Europe. Natura 2000 is the largest coordinated network of protected areas in the world. It offers a haven to Europe's most valuable and threatened species and habitats. EO can play a huge role in contributing to this, for example products and tools such as the Copernicus Land Monitoring Service (CLMS), the Climate Change Service (C3S) and the Marine Service (CMEMS) all contribute to monitoring changes in ecosystems and biodiversity loss. As already mentioned, under the CLMS has developed a dedicated Natura2000 product to help monitor protected areas by mapping land cover and use in the selected sites and producing comparative analyses of the time series of the product that show the effectiveness of Natura 2000 as a legal protection. Moreover, the EU Biodiversity Strategy calls for the establishment of an international natural capital accounting initiative, which the EU is developing through the Knowledge Innovation Project on Integrated Natural Capital Accounting (KIP INCA), making use of data on ecosystems services and conditions derived also from remote-sensing information.



Reference data: ©ESRI

Figure 3-2: Natura 2000 sites[15]

The Group on Earth Observations Biodiversity Observation Network (GEOBON) developed "satellite remote sensing essential biodiversity variables" (SRS-EBVs for short), in an effort to support a global biodiversity monitoring strategy under the Convention on Biological Diversity. Several indices can be derived from remotely sensed data to monitor SRS-EBVs related to the likes of forest cover, land cover, leaf area index, vegetation phenology and soil moisture etc.

There are a number of objectives in protecting the aquatic ecosystems and water quality[16,17]. The key ones at European level are general protection of the aquatic ecology and specific protection of unique and valuable habitats. The EU Water Framework Directive has given a push to European countries to streamline their monitoring activities, improve their water quality and protect their aquatic biodiversity. This has led to increased environmental awareness and increasing demands to counteract the accelerating pollution of European lakes described above. CMEMS ocean variables and monitoring indicators provide quality data on temperature, sea level, acidity and other phenomena that can be used to monitor marine ecosystems and to protect Marine Protected Areas (MPAs). Under C3S, the Sectoral Information System (SIS) in support of biodiversity derives climate-related information targeted at the biodiversity sector to understand climate change impact on biodiversity.

[15] https://www.eea.europa.eu/data-and-maps/figures/natura-2000-network-terrestrail-and

[16] https://ec.europa.eu/environment/water/water-framework/info/intro_en.htm

[17] "A set of procedures for identifying that point for a given body of water and establishing chemical or hydro-morphological standards to achieve it, is provided, together with a system for ensuring that each Member State interprets the procedure in a consistent way (to ensure comparability). The system is somewhat complicated, but this is inevitable given the extent of ecological variability, and the large number of parameters, which must be dealt with." EU WFD

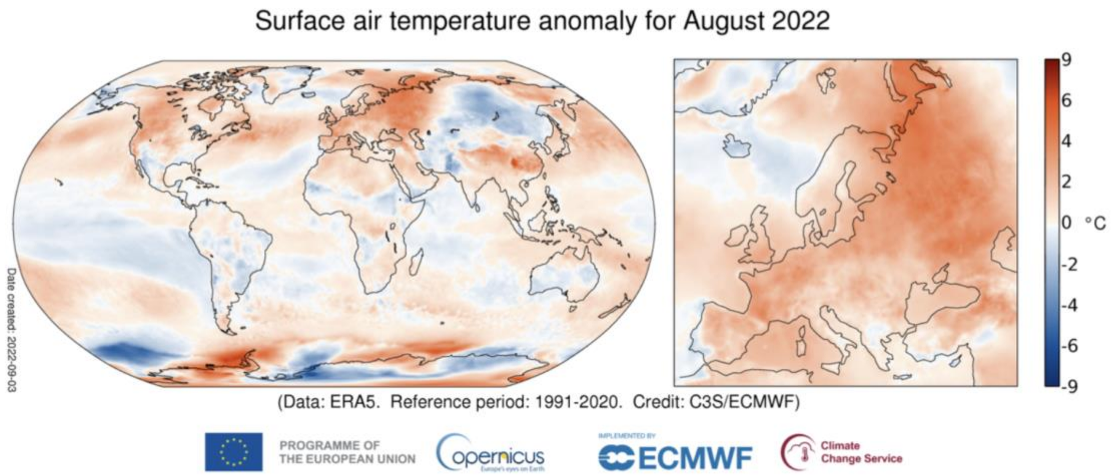
In addition to Pilot 4.1 – mySPACE, Pilot 4.2 – mySITE and Pilot 4.3 – myVARIABLE who are developing ecological monitoring products, Pilot 5.6 - EO based phytoplankton biomass for WFD is providing WFD ecological status products of phytoplankton biomass for management of selected water bodies, based on Chlorophyll-a concentrations derived from EO data.

3.4.2 Climate and atmospheric monitoring

The European Climate Law sets a legally binding target of net zero greenhouse gas emissions by 2050. The EU Institutions and the Member States are bound to take the necessary measures at EU and national level to meet the target, considering the importance of promoting fairness and solidarity among Member States. The law aims to ensure that all EU policies contribute to this goal and that all sectors of the economy and society play their part.

With ambitious climate policy efforts undertaken at European level, the European Union provided a substantial contribution to the international climate negotiations for the post-2020 period, following the signature of the Paris Agreement in 2015.

In Europe, the Ambient Air Quality and Cleaner Air for Europe (AAQ)[18] Directive is the primary regulation associated with air quality. The AAQ aims to protect the environment from the harmful effects of air pollution and sets clear and binding objectives and defines specific responsibilities for EU Member States to monitor, report on and manage air quality. As a result, EU Member States are required to ensure that up-to-date information on ambient concentrations of the different pollutants is routinely made available to the public as well as to other organisations.



Surface air temperature anomaly for August 2022 relative to the August average for the period 1991-2020. Data source: ERA5. Credit: Copernicus Climate Change Service/ECMWF.

Figure 3-3: Summer 2022 Europe's hottest on record[19]

The Copernicus Atmosphere Monitoring Service (CAMS) provides consistent EO-derived information related to global air pollution and greenhouse gases. With its European-scale infrastructure of air quality models, CAMS supports policy makers on national, regional, and local levels with a set of tools and reports that describe air quality in Europe and its evolution over the years. The so-called "Assessment Reports" are produced each year and provide an overview of the quality of the air in Europe for the previous year. The policy tools are interactive web applications based on the CAMS air

[18] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008L0050-20150918&from=EN

[19] https://climate.copernicus.eu/copernicus-summer-2022-europes-hottest-record

quality models and provide information about the effect of emission reductions on the European air quality or information about where pollution is coming from during pollution episodes.

Again, Pilot 7.1 - Global Carbon and Greenhouse Gas Emissions aims to support Copernicus and its DIAS platform by making use of the key atmospheric measurement datasets available there.

The box below provides a short case study on the overall benefits associated with the activities of Pilot 7.5 - Seasonal preparedness. This service helps tyre companies and citizens prepare for winter tyre season in Finland.

Case Study – **Pilot 7.5 – Seasonal Preparedness**

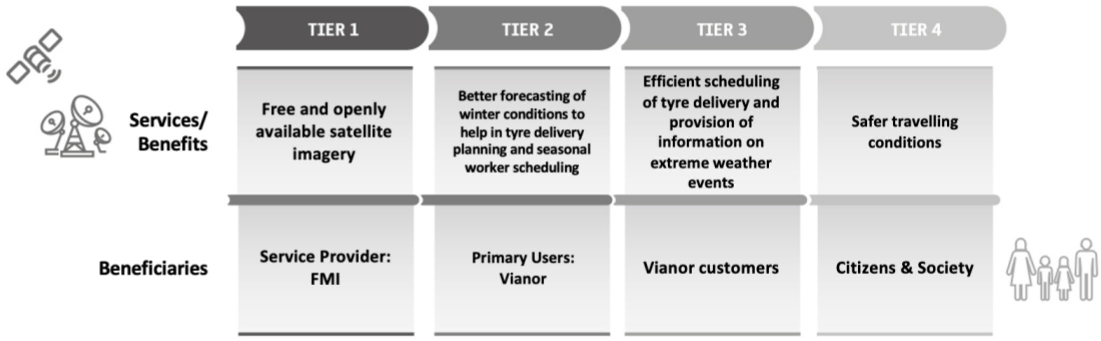
The pilot aims to increase preparedness and resilience of transportation and tourism sectors to inter-annual climate variability through user-oriented climate services that provide tailored forecast products for various timescales. Two services were developed within the pilot: the sub-seasonal and seasonal prediction service for tyre companies in Finland developed by FMI and the CRITERIN service for tourism sector developed by AA. **For this case study, we will focus on the tyre service in Finland.**

This service provides tailored sub-seasonal and seasonal climate outlooks for winter tyre season and safety driving conditions. These outlooks are:

- Winter tyre season: slippery road conditions for the beginning of the season and non-slippery road conditions for the end of the season
- Probability of snow cover
- Snow depth
- Probability of freezing temperature

The following seasonal climate outlooks are included into the service:

- Probability of snow cover
- Probability of freezing temperature



The service developed helps tyre manufacturers plan for the winter season by optimising their winter tyre delivery planning and their seasonal worker scheduling. This helps the tyre manufacturers remain competitive and delivers economic benefits. In addition, the service helps to increase the safety of all road users through the delivery of timely information on winter weather and road conditions.

Descriptions of the primary dimensions of benefit are given below.

Economic

- **Better forecasting of winter conditions to help in tyre delivery planning and seasonal worker scheduling leading to economic benefits**

Societal

- **Safer driving conditions**

3.5 Innovation and Entrepreneurship threads

EO-based services and data can help to stimulate the creation of new businesses. There is a lot of potential and room for innovative services based on EO data to make processes for stakeholders involved in the monitoring or provision of natural capital or environmental monitoring services to be more efficient and effective. In particular, there are three distinct indicators that stand out in representing the potential for innovation and entrepreneurship of EO in these applications; changed business practices, the creation and sustainability of start-ups and the tracking of patents[20]. The following elaborates on these three indicators and how they were present (or not) in the SeBS cases.

Moreover, a current initiative by the EU known as "Europe's Digital Decade"[21] is driving the digitalisation of our economies and ways of life. The digital decade will run up until 2030 and as part of this initiative focus will be placed on start-ups and scale-ups to further adopt the use of digital technologies. The following sections exemplify just how the adoption of EO in natural capital or environmental monitoring applications contributes to the goals of the digital decade.

3.5.1 Changed Business Practice

When adopted, EO can revolutionise working practices for the better. In several SeBS cases, we have seen that this often implies strong benefits for both the supplier of the service in terms of new employment and for the primary user, in terms of more efficient business practices.

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

In the Deforestation Monitoring for Sustainable Palm Oil Production, we saw how Bunge, a huge food processing company, adopted new EO-powered methods of ensuring the palm oil they sourced came from reputable sources and did not contribute to the destruction of natural habitats in Southeast Asia. In the Grassland Monitoring in Estonia case, we saw how ARIB, the Estonian paying agency responsible for distributing grassland maintenance subsidies adopted new EO-powered capabilities to continually monitor grassland maintenance activities across the entire country. This is in stark contrast to how they previously monitored these activities, which involved in-person checks on only 5% of registered

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

[21] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

grasslands. In the Water Quality Management in Germany case, the primary user, LUBW, could introduce new, EO-powered processes into a public agency. In the Aquifer Management in Spain case, CHS introduced innovative EO-powered technologies into its workflow with the help of another public institution (IGME). Forestry Management in Sweden also exemplified a new change in business practices with the Swedish Forest Agency adopting Sentinel-enabled forest monitoring services.

3.5.2 Creation of Start-Ups

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

Thanks to the availability of EO data, start-ups are empowered like never before. Given its free and open data policy, Copernicus Sentinel data in particular really lends itself to the formation and sustainable growth of EO-powered start-ups as large data costs can be saved right off the bat. Throughout the course of the Sentinel Benefits Study, several new companies active in the various domains of natural capital and environmental monitoring have been created such as Satelligence, DARES and KappaZeta that would not exist without the Copernicus programme and its Sentinel fleet. It is the availability of free Sentinel data that makes these young EO companies and their business models viable as the programme ensures continuity including sufficient frequency of fresh data, adequate spatial resolution, and accuracy as well as zero-marginal cost per hectare for automated solutions. Other companies such as EOMAP, who existed before the use of Sentinel data, later took advantage of its free and open data to help lower costs and expand their business.

3.5.3 Patents

The registration of patents is hard to monitor, particularly in the EO sector. However, given its innovative and entrepreneurial nature and ability to offer wholly new services that were not possible before, it is almost certain that EO companies focused on the various dimensions of natural capital and environmental monitoring discussed within this report will patent their innovative products and services based on EO with a national authority or the European Patent Office. With a quick research and as a rough indicator, the EPA's database finds around 15,000 registered patents related to Earth Observation and environmental monitoring, atmospheric monitoring and greenhouse gas emission.[22] Some of those are certainly related to equipment or devices, but it shows that patents are used to protect innovations from environmental-related EO services, an indicator of the positive socio-economic impact since patents and employment are often correlated in high-tech sectors.

3.6 Science threads

3.6.1 Better science and more high-quality data

EO can unlock several new approaches to science in the domain of environmental monitoring. Thanks in large part to its spatial and temporal coverage of our earth, it provides new and unique sources of data to provide invaluable insights which can contribute to furthering scientific understanding.

In the Deforestation Monitoring for Sustainable Palm Oil Production, we saw how Satelligence contribute to the scientific landscape with their participation in the RADD initiative. This publicly available system, developed alongside Wageningen University went live through the Global Forest Watch and provides insights on deforestation using Sentinel-1 data. Through the development of the

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

system, new remote sensing detection methods[23] have been contributed to the scientific and technological landscape.

In the Grassland Monitoring in Estonia case, KappaZeta have had a number of scientific research papers published throughout the development of their grassland monitoring services which interpret several vegetation parameters derived from Sentinel-1 SAR data and Sentinel-2 optical data.

The abundance of EO data showed its efficacy in the Water Quality Management in Germany case. While the knowledge on how to abstract information on water quality parameters from satellite images is quite well-developed, the regular and frequent availability of images from the likes of EO data is unprecedented and can help to understand the ecosystem at local, regional, and global levels. The data derived from satellites is unique and is not obtainable through other tools – at least not at an affordable price. Multiple measurements per week, of key water parameters, over the whole country – indeed the whole surface of the Earth – is impossible without satellites.

The box below provides a short case study on the overall benefits associated with the activities of Pilot 7.2 - Urban resilience to extreme weather - climate service. This service helps urban planning authorities better plan cities in order to avoid the likes of heat islands through the use of EO data.

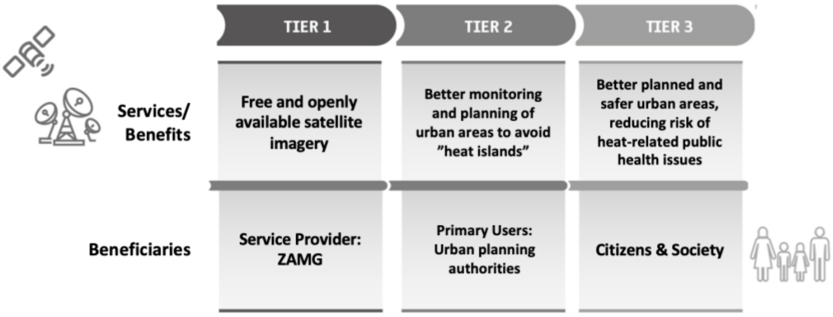
Case Study – **Pilot 7.2 – Urban Resilience to Extreme Weather - Climate Service**

This pilot has three subcases. All with the goal of strengthening urban resilience to extreme weather in the summer and winter seasons using various timescales (sub-seasonal and seasonal forecasts, as well as climate projections).

For the purposes of this study, we will focus on the following subcase:

- **Climate projection products for various Austrian cities with a focus on summer heat load for urban planning, risk management and environmental protection.**

Within this subcase, ZAMG, a Governmental Research Institute by the Austrian Federal Ministry of Research and Education (BMBWF) are developing climate projection services on heat load to help urban planning authorities in creating climate resilient cities focusing on climate adaptation and risk assessment.



Thanks to the use of satellite data, urban heat islands can be better monitored. Moreover, planning authorities can avoid potential hotspots when designing built-up areas or plant trees and shrubbery in areas of concern to help regulate their temperature. This ensures that certain

[23] https://iopscience.iop.org/article/10.1088/1748-9326/abd0a8/pdf

vulnerable buildings, such as schools, hospitals and senior housing can avoid extreme heat events which could put public health at risk.

Descriptions of the primary dimensions of benefit are given below.

Societal

- **Avoidance of extreme heat in urban areas ensures vulnerable members of society do not suffer from heat-related health issues**

Enironmental

- **Planting of trees and shrubbery in areas of concern to promote urban temperature regulation**

3.7 Societal threads

As this report focusses largely on environmental benefits, these are intricately linked with societal benefits. When we use EO to preserve natural habitats or fight against climate change, we are gaining benefits for society as it contributes to protecting the world for citizens to enjoy and helps to ensure life is sustained for generations to come.

3.7.1 Public Health

Within e-shape, there is already a dedicated showcase on health. **D5.16 – Second socioeconomic value of EO in selected sectors** has already covered the links between the e-shape pilot activity and public health. D5.16 also details how various pilots are exploring the likes of EO-powered air quality monitoring, pollution monitoring and disease monitoring, with a view to improving the health of citizens and society.

Within the context of this report, Pilot 7.2 - Urban resilience to extreme weather - climate service is also several services pertaining to seasonal preparedness in urban areas. One sub-service within this pilot is monitoring for "urban heat islands". This EO-based service aims to increase the preparedness of city authorities and decrease the vulnerability of urban populations to extreme heat events in built-up areas caused by climate variability and climate change

3.7.2 Public utilities

Ensuring citizens have access to high-quality and essential amenities is at the forefront of most public utility providers. Pilot 7.4 - Hydropower in snow reservoir – climate service is developing an EO-based web-service that provides detailed hydrometeorological information to support more efficient hydropower production operations in Northern Finland. This service aims to reduce uncertainties in spring, snowmelt driven, runoff forecasts. The idea is to decrease the vulnerability of energy companies to variations in meteorological and hydrological conditions through improved seasonal forecast products is the primary focus of the project.

Within the various SeBS cases we have seen how EO is ensuring critical supply chains and transport links remain operational for people in vulnerable areas (again, see Navigation through Sea-Ice off Greenland and Winter Navigation in the Baltic). We also see in the Ground Movement Monitoring in

Norway case how EO is ensuring public roads are safe while also helping in the pre-emptive detection of landslides.

3.7.3 Civil Security / Seasonal Preparedness

The e-shape climate showcase has several pilots who are developing services which aim to improve citizen safety and preparedness for extreme climactic and weather events. Again, Pilot 7.2 - Urban resilience to extreme weather - climate service is developing beneficial and user-friendly sub-seasonal and seasonal climate forecasts, as well as climate projection products and indicators for city authorities to prepare in advance for extreme events. Moreover, it aims to raise awareness among stakeholders in European cities regarding the consequences of climate variability and climate change and include the services as part of their decision chains.

Pilot 7.3 - Forestry conditions - climate service aims to develop EO-products which can help forestry managers in predicting and preparing for seasonal forestry conditions which could affect road trafficability and pose a big risk to both workers and forestry operations.

Finally, Pilot 7.5 - Seasonal preparedness is developing tailored sub-seasonal and seasonal forecast products for winter tire season and driving conditions in Finland. Timely installation of winter tires is essential when temperatures drop, and roads become covered by ice and snow. However, the time of winter tire installation and thus their distribution to the customers varies from year to year depending on weather conditions. The tailored sub-seasonal and seasonal forecast products for winter tire season and safety driving conditions will allow tire companies to plan the distribution of right tire types, ensuring the citizens of Finland are prepared, have access to winter tires when needed and can navigate low-temperature conditions safely.

4 FUTURE CHALLENGES

This report primarily addresses the socioeconomic benefits associated with the use of EO in natural capital and environmental monitoring. However, several challenges were identified within the various dimensions discussed, including the following:

- Meeting biodiversity, environmental and climate-related commitments, including the reduction of greenhouse gas emissions and pollution reduction targets;
- Reducing both terrestrial and aquatic habitat loss;
- Improving the accuracy and coverage of ecosystem, atmosphere and climate monitoring services;
- Ensuring citizens and society are better prepared and less affected by extreme seasonal weather events;

All of these challenges require concerted efforts from many stakeholders, from high-level decision makers and international organisations to technological innovators, research scientists and even members of the general public. There can be no doubt that e-shape and its pilots are contributing to the fight against the negative outcomes of many of these challenges, with the likes of to Pilot 4.1 – mySPACE, Pilot 4.2 – mySITE, Pilot 4.3 – myVARIABLE, Pilot 7.1 - Global Carbon and Greenhouse Gas Emissions and Pilot 7.5 - Seasonal preparedness all aiming to directly address these daunting but extremely important issues. EO will undoubtedly continue to be adopted in ever more innovative ways to ensure our precious ecosystems are protected and our climate change commitments are adhered to.

5 CONCLUSION

From the various applications and innovations discussed within this report, it is clear that the use of EO in natural capital and environmental monitoring applications holds huge promise and will undoubtedly add to the protection of our natural capital and help turn the tide against climate change. It is also clear that in adopting EO in such applications, several positive economic and societal impacts are being felt by stakeholders involved in the utilisation of the data and technology.

Building upon the various well-understood benefits of EO added value exemplified within the SeBS cases, this document illustrates just some of the possibilities of EO in natural capital and environmental monitoring applications. The pilots within e-shape will undoubtedly impact the various sectors discussed within this report in their own way, contributing the continued success of this extremely exciting innovation ecosystem. This document marks the final of the three socio-economic value analysis reports within e-shape.