European Association of Remote Sensing Companies

Sentinels Benefits Study (SeBS)

SeBS Methodology

A Practical Guide for Practioners to evaluating the benefits derived from the use of Earth Observation data.

December 2020

SeBS Methodology: A Practical Guide for Practioners

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Client Representative: Alessandra TASSA

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Author(s): Geoff Sawyer (EARSC)

Dimitri Papadakis (EARSC & Evenflow Consulting)

Reviewer:

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1 Introduction

1.1 Documents scope and Objectives

This document describes the **SeBS methodology** which supports analyses to demonstrate the value of using Earth Observation data. It provides all the information necessary for practitioners to perform a "SeBS" case, benefits, assessment analysis. It will be updated with any future developments of the case methodology.

1.2 Context

SeBS – Sentinel Benefits Study – is a project carried out by EARSC and partners for the European Space Agency. This 4-year study, from March 207 to July 2021, is developing 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 Programme contributing to the Copernicus Services and serving as a crucial data source used by companies and public organisations to deliver products and services.

Why is this so important? Why are we concerned to measure the benefits derived from the use of Sentinel data or satellite Earth Observation data in general?

Earth observation data from satellites are used in many ways linked to our daily lives but in ways which are mostly invisible. Partly, this is because most of the uses are for business or governments so are not very well understood by, or even visible to, the average citizen. Whilst highly attractive imagery appeals to the media and may impress citizens, they do not convey the value of the information which is being generated. But it is also partly due to the wide range of applications and that none of these dominates to an extent that it becomes visible outside of specialist circles. Consequently, most **people are unaware of the value satellite Earth Observation is bringing to them in their daily lives**.

Governments are large users of data from EO satellites but even so, investments in new satellite systems are largely a question of faith or are considered for strategic purposes. The ever-increasing number of commercial investments points to a belief that a strong market will emerge but the return on these investments still seems some way off[1].

[1] EARSC Industry Survey; 2020 version at https://earsc.org/industry-facts-figures/

Yet, the value is there, even if it is not very visible. As a final complication, the value is dispersed over many applications and market sectors which makes it hard to quantify and even harder to monetize through revenues to commercial operators or in societal benefits for governments.

In this situation, **understanding the value becomes a key tool to explain to investors**, whether governments or private financiers, that their money is being well spent. For governments, the returns may be in meeting social goals, but in private businesses, hard revenues are what is looked for. As a result, EARSC is working with the European Space Agency (ESA) to understand this value and to expose it to stakeholders.

A methodology has been developed within the study (Sentinel Benefits Study), carried out by EARSC and our partners[2], to showcase the benefits of the use of Sentinel data. The methodology may be applied to similar analyses for any type of EO data and derived services.

The core of the analysis is to understand how a specific EO-derived service is being used by an organisation which is in turn, benefiting others and ultimately society and citizens at large. The approach is bottom-up **based on the evaluation of a value chain**. In this, it differs from many cost-benefit studies which work top-down at a macro-economic scale. As the study has progressed – 10 full cases have so far been published, the methodology developed during the first 3 cases studies[3][4][5][6] has been refined. This document describes the outcome of this work in the form of a guide for others.

1.3 Road-map to the Document

The report provides all the information necessary for someone to perform a "SeBS" case analysis although not all will wish to meet the same criteria as is required for SeBS.

Chapter 2 describes the SeBS methodology.

In chapter 2.2, the methodology is described. This starts with an overview before describing the process **to identify and select cases** and the criteria which should be met to maximise the possibility for a successful study.

In chapter 2.3, the core of the value chain methodology is described leading up to an **understanding of the value chain**, the beneficiaries and an understanding of the business sector and geographical context in which the case sits.

[2] Partners to the Study are The Greenland, IIASA, Evenflow.
[3] Winter Navigation in the Baltic; Sawyer & De Vries, September 2015.
[4] Forestry in Sweden; Sawyer & De Vries, January 2016.
[5] Pipeline Infrastructure Management in the Netherlands; Sawyer & De Vries, May 2016.
[6] Copernicus Sentinels' Economic Value Study: Final Report; July 2016

In chapter 2.4, the analytical approach which is taken to **assess the benefits** in 6 dimensions of value is described including the use of indicators and the guidelines which are used to assess the degree to which a case reflects the dimensions.

In chapter 2.5, various aspects which **extend the analysis** are discussed, notably the extrapolation of individual cases into a wider perspective.

In chapter 3, a brief description is given of the **storytelling aspect** which is the basis of communicating results.

In chapter 4, we include some final reflections on the application of the work.

1.4 Glossary and Definitions

Value chain: The value chain was first introduced by Michael Porter to help evaluate processes within a company. It has evolved to become a strategic analysis tool going beyond an individual firm to reflect the production of a good or service from raw material to finished article. In SeBS cases it is used as the succession of activities which arise through the use of an EO product or service. It starts with the EO data product or service supplied to the defined primary user organisation which defines the case. This is followed by organisations which are customers or beneficiaries of the service offered by the primary user through to society and individual citizens which ultimately benefit.

Benefits: The goal of the analysis is to identify and characterise the benefits which arise from the use of the EO data. We can also talk about value which is almost interchangeable with benefit.

SeBS: Sentinel Benefits Study is a 4-year project, from March 207 to July 2021) developng cases showing how EO-derived products or services based on data generated by one or more Sentinel satellites deliver value to society and citizens.

Benefits Dimension: In the context of this methodology, a dimension is the term used for one of the classes of benefits. Six dimensions or classes of benefit have been defined (see chapter 2.3.3).

Primary user: the primary user is the organisation to which the supplier is providing the EO service. The primary user may be a public or a commercial organisation and to have been selected, will have developed experience of using the EO service to support their core business practices.

Secondary user; the secondary user is a direct customer or beneficiary of the service being performed by the primary user. There may be many secondary users in a case which are generally considered together in tier 3 of the value chain.

Tier: is the name given to a part of the value chain. It will usually be characterised by different types of data passing between organisations and/or different business activities. See chapter 2.3.2.

Supplier: the supplier is the organisation which is providing the EO product or service considered at the heart of the case.

Value-added product: in our context is a product or service built upon EO satellite data. In other words, the EO data has been processed in order to provide some form of geospatial information which is used by the primary user.

InSAR: Interferometric Synthetic Aperture Radar, a technique used to measure very precisely, small vertical movements of the ground surface and hence where ground motion is occurring.

1.5 SeBS Reference Use Cases

Under the SeBS project, a growing collection of full (F) and short (S) cases have tested the SeBS methodology and led to its evolution. Reference is made to these cases throughout this document to give examples of certain aspects of the methodology. All the cases listed below can be accessed and downloaded from www.earsc.org/sebs.

Full Cases

F1. Winter Navigation in the Baltic, Sawyer and de Vries, September 2015

Sentinel 1 data is used by icebreakers to help ships navigate through the sea-ice and bring goods to ports in the Northern Baltic more efficiently.

F2. Forest Management in Sweden. Sawyer & de Vries. January 2016

Sentinel-2 data is used to help the forest agency detect where non-approved clearings have been made and to remind the 300,000 owners to meet their legal obligations.

F3. Pipeline Infrastructure Monitoring in the Netherlands, Sawyer & de Vries, May 2016

In the Netherlands, ground subsidence can cause gas and water pipelines to break where they enter houses. Sentinel-1 data is used to measure where the ground is moving and to identify the pipe connections at risk leading to their replacement.

F4 Farm Management Support in Denmark, Sawyer & de Vries, March 2018

Maps of the cereal crop fields across Denmark are generated through the growing season using Sentinel-2 data showing farmers where they have problems allowing them to be dealt with more quickly and efficiently so saving time, costs and reducing fertliser use.

F5 Flood Management in Ireland, Mamais & de Vries, December 2018.

Imagery from Sentinel-2 was processed by the Copernicus Emergency Management Service to show where land in Ireland was flooded. This was used by the emergency services to plan their relief operations more effectively so reducing risk to life and damage to property.

F6 Navigation through Sea-ice off Greenland, Sawyer & Oligschlager, February 2019

Ships navigating off the shores of Greenland, are provided regularly with maps showing the extent and evolution of the sea-ice. This allows safer operations and enables delivery of goods to remote villages along the coast of the island.

F7 Growing Potatoes in Belgium, Sawyer & Oligschlager, July 2019.

Farmers and frozen-food processors are provided with maps showing the evolution of the potato crop through the growing season. This allows the farmers to manage their crops more effectively and the food processors to plan their operations more efficiently.

F8 Farm Management Support in Poland, Mamais, Milosavljevic, & Khaborov, July 2019

Maps of the cereal crop fields across Poland are generated through the growing season using Sentinel-2 data showing farmers and agri-chemical companies the status of crops so saving time, costs and reducing fertliser use.

F9 Ground Motion Monitoring in Norway, Sawyer & Boyle, July 2020

A nationwide map, showing very small movements of the ground, is being produced across Norway enabling the roads management agency to avoid building in areas of risk as well as monitoring current road projects for early signs of ground movement.

F10 Aquifer Monitoring in Spain, Mamais & Oligschlager, October 2020

The water management authority in Murcia is using maps showing subsidence at the ground surface caused by water abstraction from deep-underground aquifers so reducing the risk of damage to property in the region.

Short Cases

S1 Peatland Management in the UK, EARSC, March 2018

Copernicus Sentinel data is being used by water utilities in the UK to improve the management of peatlands, leading to better water quality for local citizens, reduced costs of purification for the water companies and strong environmental benefits.

S2. Dredging in the Maldives, EARSC, February 2019

Copernicus Sentinel 2 data is being used in the Maldives to improve the efficiency of dredging for sand so saving ship time on site and reducing negative environmental impacts derived from damage to endangered coral reefs.

S3 Assessing Geese Damage in the Netherlands, EARSC, August 2019

Copernicus Sentinel data is being used by the Province of Fryslân in the Netherlands to improve the management of geese damage compensation through the Fauna Fund, leading to more efficient appraisals by saving time and cost.

S4. Illegal Wild Boar Activity in Lithuania, EARSC, December 2019

Copernicus Sentinel data is being used by the courts in Lithuania to help resolve legal disputes, leading to more efficient use of the judiciary's time, fairer judgements and swifter compensation payments for plaintiffs.

S5. Global Oil Industry Activity Monitoring, EARSC, February 2020

Copernicus Sentinel data is being used by energy companies, commodity traders and oil market speculators to better understand the markets they operate in, allowing them to optimise trades and make better informed business decisions.

S6. Golf Course Management in Italy, EARSC, April 2020

Copernicus Sentinel data is being used by Centrale Valutativa to monitor the health and status of the grass of the golf course as well as to give recommendations on the most efficient way to irrigate the grass helping to save water and energy.

1.6 Background Documents

Bernknopf, R., Brookshire, D., Kuwayama, Y., Macauley, M., Rodell, M., Thompson, A., Vail, P., Zaitchik, B. (2017). The Value of Remotely Sensed Information: The Case of a GRACE-Enhanced Drought Severity Index. Weather, Climate, and Society. 10. 10.1175/WCAS-D-16-0044.1.

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Macauley M.K., 2006. The value of information: Measuring the contribution of space-derived earth science data to resource management, Space Policy 22 (2006) pp. 274–282.

Olander, L., Johnston, R. J., Tallis, H., Kagan, J., Maguire, L., Polasky, S., Urban, D., Boyd, J., Wainger, L., and Palmer, M. 2018. Benefit relevant indicators: Ecosystem services measures that link ecological and social outcomes, Ecological Indicators, Volume 85, 2018, Pages 1262-272, ISSN 1470-160X, https://doi.org/10.1016/j.ecolind.2017.12.001.

Papadakis, Sawyer, Khabarov; 2020: Methodological Frameworks for EO Value Estimation.

Resolution adopted by the General Assembly of the United Nations on 6 July 2017, /RES/71/313, Annex: Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. URL: https://undocs.org/A/RES/71/313

2 Methodology

2.1 Overview

At the core of the analysis, **SeBS deploys a value chain approach** to study the **benefits brought about by the use of Copernicus Sentinel data**. This starts with the identification and selection of cases wherein Copernicus Sentinel are operationally used and contribute to better decisions or actions by different actors along the value chain. The benefits are assessed both quantitively and qualitatively against a set of well-defined dimensions. The results are presented via a storytelling approach, which includes short cases using a simplified (and less rigorous) methodology than the full reports.

There are three major steps required to conduct a successful and full analysis.

1. **Identifying use cases** requires a **careful selection of each case** to be analysed against a set of key criteria including the commitment of the persons involved. If several cases are being looked at, there may also be a filter on the types of case in order to meet a set of portfolio requirements.
2. **Developing the picture** takes the value chain analysis or core analysis which **sets out the value chain and examines how the EO service fits into the business process of the primary user.** It then describes the story of how the service is driving benefits in every tier of the value chain, reflecting the 6 dimensions of value.
3. **Analysing the Benefits** which analyses the **quantitative and qualitative benefits** for each of the stakeholders, in each of the tiers and against each of the value dimensions.

The terms and processes set out here will be explained in the relevant chapter of the report.

The goal is to develop a **deep understanding of how EO data is being used** which differs even between users in the same sector (see for example difference between the use of field statistics in Denmark (F4) and in Poland (F8)). This requires us to understand how the product is being used in the business operations of the primary user. To do this, a bottom-up approach is taken. **Cases are sought where a single product coming from satellite imagery is being used in an operational process**. This is then examined in detail to assess how the original product helps successive users along a value chain; starting from a primary user and reaching as far as the effects of the use of the product can be determined.

It should be recognised that we are only looking at the benefits and **ignore the cost side of the equation relating to the investment in the space infrastructure** although any relevant costs in the use of the EO data are accounted for. This is because of the difficulty to attribute a representative cost when the data is used for many different applications. Tying a fraction of this cost down to a single service was considered inappropriate and unnecessary. Instead, we **concentrate on estimating the benefits**.

For a deeper analysis of the methodology applied for SeBS, see Papadakis 2020.

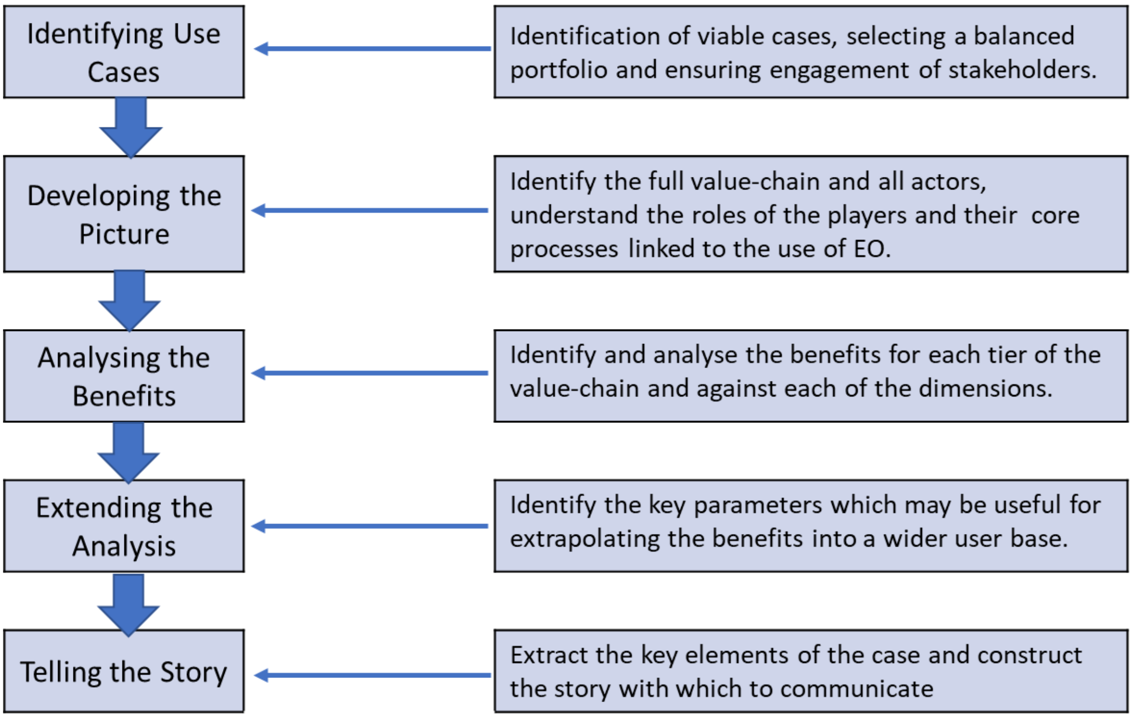


Figure 2-1: Overview of the SeBS case Methodology

2.2 Identifying Use Cases

2.2.1 Approach

In this chapter, we describe **the first step in the process to ensure that we have a case which is suitable for analysis**. This consists primarily of reviewing the case against a set of key criteria. Here, we describe those criteria used in the SeBS methodology, but other frameworks may demand that these criteria are adjusted to reflect the analysis requirements (e.g. Data from other satellites, specific market domain etc).

The use of data in the cases should be operational, i.e. part of an identified business process, so that there is a way to identify the key drivers of value. Sometimes, the concept of operational becomes stretched and we shall meet cases which are linked to one off events (F5 in Ireland), or to projects (F9 in Norway), but ideally the primary user has been using the EO data for some time to support their core operations.

Finally, cases are expected to form a portfolio, that is a balanced selection. This means that some cases, whilst suitable for analysis, are set aside in favour of others. Practically, we develop a long list of potential cases which then get examined in more detail according to either geographical or technical gaps in the portfolio. As cases mature, they may progress from the long list to a watch list and finally to be selected for analysis.

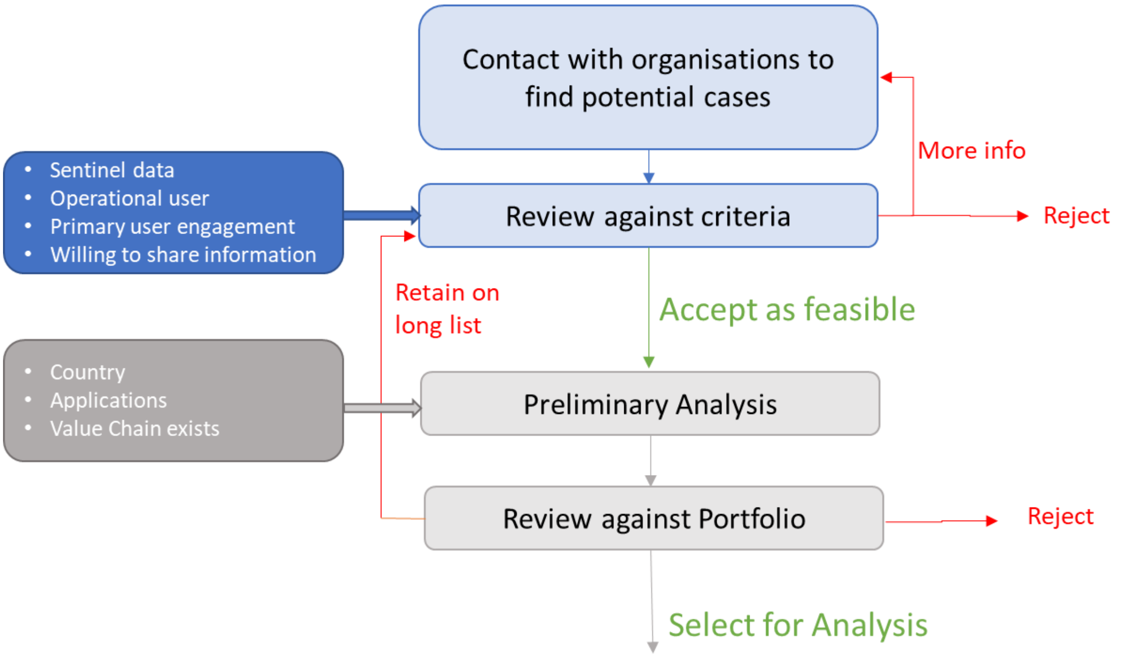


Figure 2-2: Steps to Identify & Select Use Cases

The steps to the process which is described in this chapter, are illustrated in Figure 2-2. It starts with finding candidate cases and then selects them according to criteria to make up a suitable portfolio.

2.2.2 Finding Feasible Cases

Generally, finding a case **starts from the perspective of an EO service**. Given the fairly strict criteria for selecting cases, a wide search is made, and the list of potential cases is constantly refreshed and reviewed to identify candidates. It involves scouring all possible sources, including social media, for news of services or service providers promoting new products. As these are found they **are reviewed against the first key criteria for feasibility**, which will involve making initial contact with one of the stakeholders in the case, most usually the service provider.

For SeBS, our goal is to study and promote the value coming from the use of Sentinel data, hence, a key-criterion is that some form of Sentinel data is being used to provide the service. However, other analyses may start from another perspective and the SeBS methodology could be applied to these other situations.

The key criteria which are first reviewed for SeBS are:

Sentinel data: this is a fundamental requirement. It does not mean that only Sentinel data is being used and indeed this would be unlikely, but there should be a certain dependence on the Sentinel data to be valid for our work. There may also be cases which are based on the prospective use of Sentinel data. In other words, a service has been built up using another data source which is or can be, replaced by data coming from one of the Sentinel satellites.

Operational use: So that there is an understanding of the value of the data, it is considered essential that the service in question has reached an operational status. The core of the need is that the business processes are understood sufficiently well that the value generated by using satellite data can be analysed. In reality, this means that the organisation which is the primary user has used the data enough to be able to describe the impact it is having. Note that as stated above, the meaning of operational may sometimes be stretched and includes event-based cases as well as project-oriented ones. However, where the use is part of a research project, it is considered too immature to be suitable for analysis.

Primary user engagement: this has been found to be an essential step to a case being feasible and so is introduced as a criterion at the very beginning of the selection process. It is difficult to overestimate how important it is that the primary user is fully engaged, and not just the contact but their management hierarchy as well. It is extremely disruptive if the primary user moves to a different job or work on the case is suspended by management. Ideally, an initial conversation is held with the primary user but most usually, the supplier is asked to validate this point.

Willingness to share information: for a full case, the supplier and the primary user must be willing to be open with what may be quite sensitive information. Cases are of value to both of these stakeholders as marketing tools either for commercial sales or to demonstrate the value of work that is being done. The level of information to be shared is a key determinant between full and short cases. These points will all be discussed with the service provider who must be fully committed for the case to proceed.

Practical tips to assess if a case is viable for a "SeBS" analysis:

- What is the satellite-derived product or service which will form the case and which organisation is producing and supplying it?
- Is the supplier of the service committed and engaged in supporting the analysis?
- What is the primary user of this service? Is he/she willing to support the analysis? Does the contact in the primary user have the authorisation and support of their management?
- Has the primary user been using the service as part of their core business operations? Do they have a preliminary idea of how the EO service is generating value in their organisation?
- For which business operations is the primary user using the EO service? How is the EO service being used and what decisions are being taken as a result?
- How do these specific business operations fit within a business sector (which may be commercial or within a public agency) in the defined geographical context?
- Are the supplier and the user willing to share information, especially to discuss openly their business processes?

2.2.3 Building a Portfolio

In the SeBS project, the objective is to analyze many different use cases that use the Copernicus Sentinels' data and **ultimately to form a portfolio of suitable cases**. If a case is considered feasible, it will then be evaluated against several additional criteria which reflect it's fit into a portfolio of cases. This does mean that some good or even excellent cases get set aside as they do not fit the portfolio needs.

The portfolio of cases all together provide an excellent opportunity to extract more knowledge concerning applications and the value chain. We address the practical implications of this in chapter 2.5. For our work on SeBS, the key criteria are:

- **Location of use**: most of the SeBS cases are analysed in relation to a single country. The exceptions are those cases which have a global dimension. The country is important reflecting the political nature of the Copernicus Programme and its Sentinel satellites. At least one of the key players in the case should be from a country participating to the Copernicus programme and a balance of countries should be reflected in the final portfolio of cases – as it builds up in time.
- **Applications**: the thematic application of the cases should be balanced whilst at the same time multiple examples of similar cases will also be attractive to develop cross-cutting lessons. Hence, this is not a straight-forward criterion to evaluate and relies a lot on judgement.

- **The Value chain**: for the SeBS methodology to work, a value chain must be described such that further stakeholders may be identified. This may be developed at this point in the study but will mostly be during the initial steps of the next phase.

At the end of this stage of the process, it should be clear whether the case is to be analysed and if so, whether it will be done as a full case or a short case.

2.3 Developing the Picture

2.3.1 Approach

In this chapter, we are looking at the first step in the analysis of case, which is to develop our **understanding of the value chain**. Once a case has been selected for analysis, the next step is to build the picture and relationships of the actors within value chain. This involves identifying the key stakeholders relevant for the case and understanding the role which they are playing, including the ways in which they are benefiting from the use of the EO data.

The analysis process is shown in Figure 2-3, covering the two steps for developing the picture and analysing the benefits. We break it into these two steps as they largely reflect the difference between a short and full case.

The value chain is a useful tool for discussing with the supplier and the primary user as it helps create a common understanding of the analysis. It supports the process to identify the key beneficiaries along the value chain and to define the scope of the sector which needs to be understood.

At the end of this work, we should have a **well-defined value chain with identified beneficiaries in each tier** and a well-developed **description of the sector in the geographical context** relevant for the case. These may not be the final versions and may become modified by information gathered later in the analysis, but the understanding is good enough to be able to hold an intelligent conversation with the actors which will be part of analysing the benefits.

An initial idea of the nature of the benefits should also be developed. The different ways in which benefits may be achieved should be considered within the framework which comprises **6 dimensions of value.** The major benefits should be identified within the dimensions according to the stakeholders. This provides all the information required to prepare a short case and is the foundation for a full case analysis.

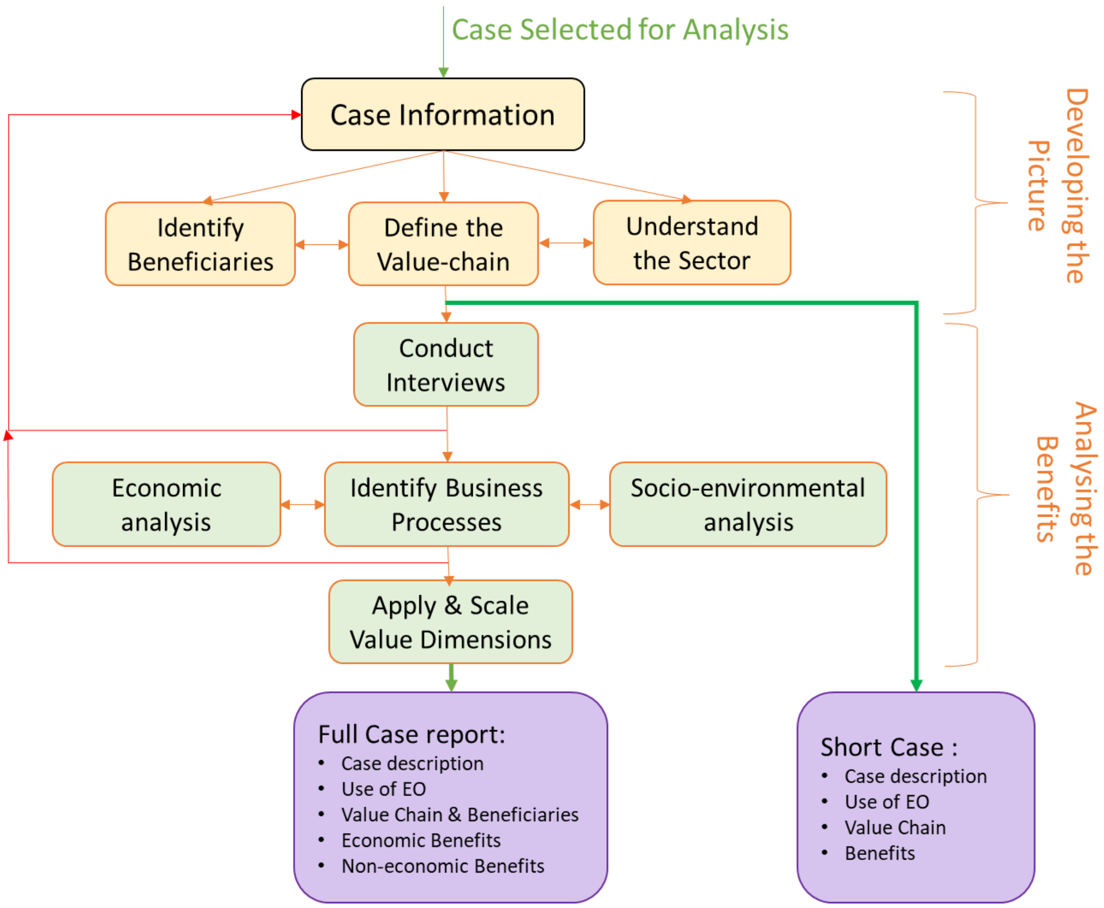


Figure 2-3: Process for SeBS Case Analysis.

2.3.2 Understanding the Value chain

At the **heart of the SeBS methodology is the value chain approach**. Before starting to explain the steps taken to analyse cases, it is first important to explain what this means.

The principle for the case analysis is that a single product derived from earth Observation data is used by a user organisation. This organisation is referred to as the **primary user** and is placed at **tier 2** in the value chain: see Figure 2-4.

We define the value chain as having 4 "tiers". Early cases had more than 4 tiers in the value chain but, as the work has progressed, we have moved to restrict it to 4. In each case, tier 1 is the "**supplier"** of the EO service, tier 2 is the "**primary user"**. Tier 3 are the "**secondary users"** i.e. all the specific users of the service provided by the primary user and tier 4 is the wider "**citizens and society"**. Note that the tier 3 users are those directly linked to the function which the primary user is providing. For an agriculture case, it may be food processors or chemical suppliers, for a roads case, it may be engineering companies. There may be tertiary beneficiaries which sit alongside the main value chain, which may be government bodies or other institutions with a direct responsibility or interest in the sector. For example the Ministry of Agriculture and the Minitry of Environment would be relevant for an agriculture case.

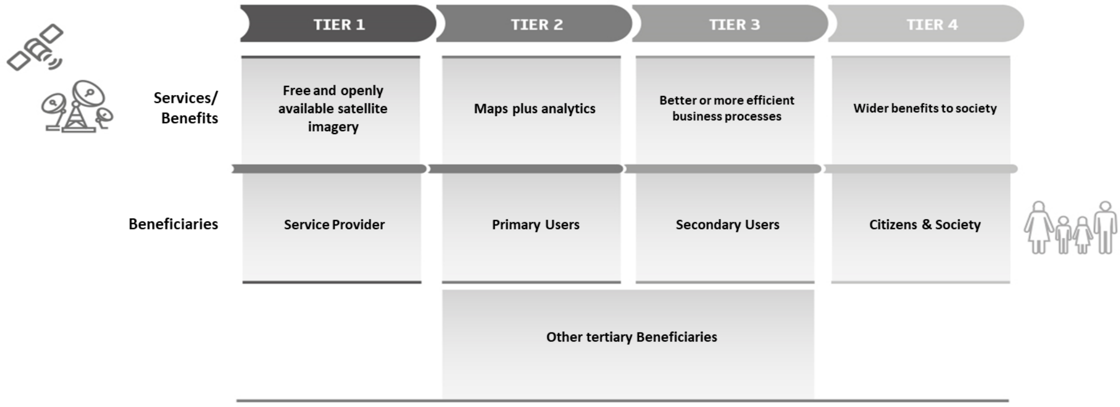


Figure 2-4: Illustration of the Value chain.

Another way of considering the value chain is through the inputs and outputs at each tier. In our representation, the input for the supplier is satellite data and their output are maps or analyses in the form of geospatial information. These latter form the input to tier 2 whilst the output from the primary user depends strongly on their business processes which is also the case for tier 3. Finally, the social benefits come in many forms which cannot easily be characterised. **For each case, this value chain should be drawn up with case specific data introduced into the visual representation**. A blank value chain chart is included in the annex.

In tier 1, the **service provider** is using the satellite data along with any other data and transforming it into maps or other information for the use of the primary user. At this point, the nature of the service is rather clear.

In tier 2, the **primary user is transforming the value through their business process**. In selecting the case, it has been determined that the EO service has become integral to their business process. Hence the business process needs to be understood to be able to estimate the values associated with its use.

In tier 3, the visible effect of the service has become strongly diluted and the service is most likely completely invisible to a tier 3 stakeholder. They are **benefiting from the process within the activities of the primary user** and hence are largely unaware that satellite data is being used. For example, a roads agency may use satellite data to identify the risk of the ground movement, but the engineers or construction workers are only concerned with the defined works and not how the route was chosen. Similarly, a farmer may be using data concerning his fields to manage his crops, but his customers are only interested in the quantity and quality of the crops. Again, the business process must be evaluated to determine the benefit which is being generated. As we move down the value chain, the question of attribution becomes harder –see chapter 2.5.

In tier 4, the benefits of the satellite data have become very diffuse and the general population, citizens and society, will even be unaware of that there are any links with satellites! They may suffer fewer delays on the roads, but have no idea of the process going on to achieve this or that satellite data has been used to determine a route which will hopefully avoid remedial works in the future. In many ways, this emphasises one of the objectives of the SeBS studies; to make the citizens and their representatives aware of the true value being created.

In some cases and at the preference of the analyst, additional layers may be expressed through the value chain as shown in Figure 2-5. As well as the beneficiaries and the services, this representation includes the type of benefit which is manifest as well as how it is manifest. These can be expressed for each tier although since many types of benefit may be present, the figure will show the dominant ones.

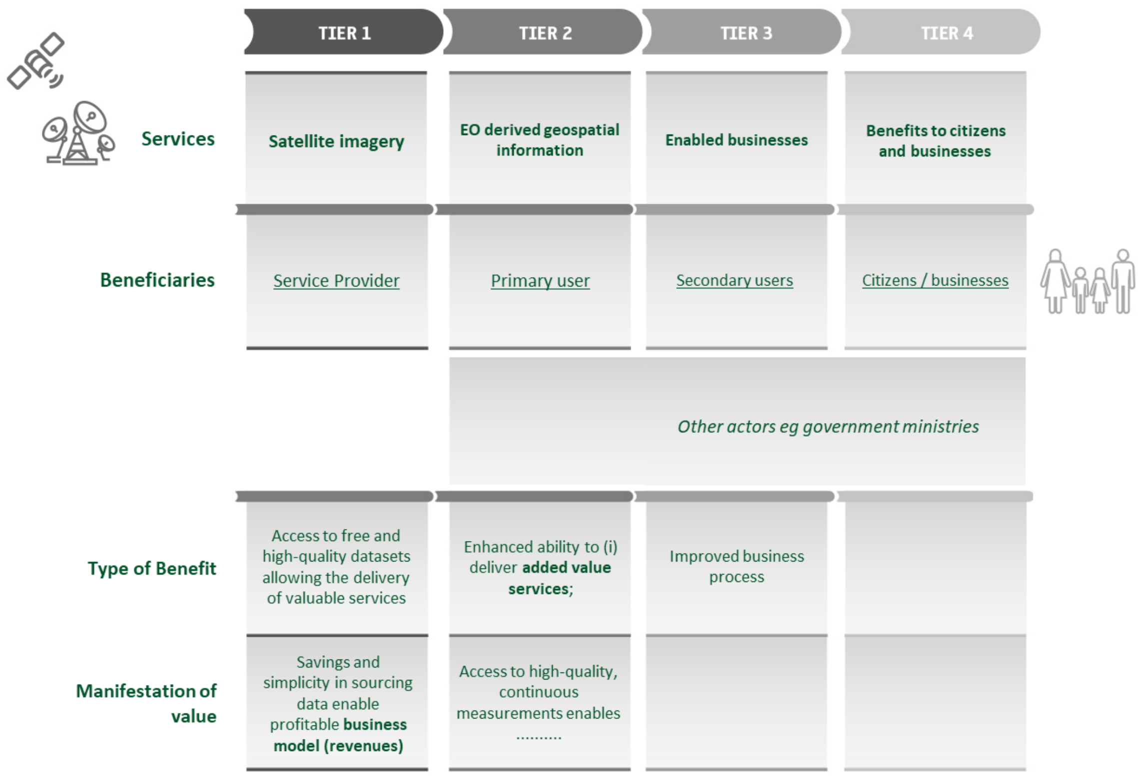


Figure 2-5: Enhanced value chain representation with additional layers of information.

2.3.3 Six Dimensions of Value

As each tier of the value chain is looked at, so consideration is given to the benefits arising for the beneficiaries. These include economic and non-economic as well as monetized and non-monetized benefits[7]. To focus and structure the further analysis, a set of dimensions of value

[7] There is discussion around the use of the term economic benefits. We have generally used it to mean benefits in the value chain which can be monetised. In other words, we can place a financial value on the

have been introduced which may be monetized or not i.e. may be assessed quantitatively in financial terms or qualitatively or quantitively in non-financial terms as shown in Figure 2-6.

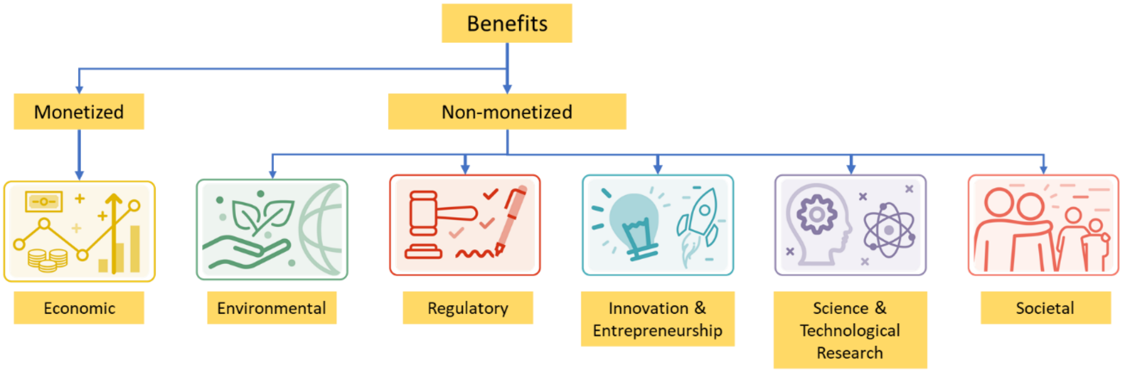


Figure 2-6: Hierarchical relationships of benefits

As studies have progressed, it became increasingly clear that many of the benefits of using the satellite data were not economic or linked to a monetised quantity. Indeed, for some stakeholders, the non-economic benefits may be more important than economic ones; for instance, around environmental issues. As for the economic benefits, these non-economic benefits are assessed at each tier of the value chain. A framework for assessing the benefits will be described in chapter 2.4, but here we can introduce the 6 dimensions as they are already used in short cases. The 6 dimensions, and a definition of each, are shown in Table 2-1.

In order to help evaluate each of these dimensions, a set of indicators has been developed as a guide. These will also be discussed in chapter 2.4.

It should be added that, in principle, all the benefits could be monetized, i.e. have a value placed upon them in monetary terms. Using a variety of analytical techniques, it would be possible to estimate the monetary value to society coming from better regulation, from a better quality of life or of geostrategic benefits. However, many of these analyses would be complex and demand a high degree of effort to achieve and some of the benefits may be more readily recognised in non-monetary terms i.e. number of species saved, number of human lives saved etc.

Hence, our approach is to monetize the benefits where it is reasonable to do so in relation to the time and resources available to complete the analysis.

The goal at this point is to be sufficiently informed to either write up the short case or to be able to conduct a detailed, informed interview with the primary user so as to develop the understanding of the economic benefits.

benefit. Hence the term as it is used is essentially interchangeable with financial benefits – although this is also open to different interpretations.

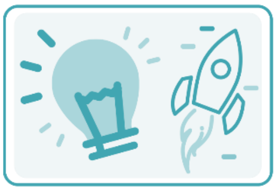
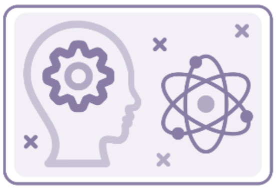
Dimension		Definition
	**ECONOMIC**	Impacts related to the production of goods or services, or impacts on monetary flow or volume, such as revenue, profit, capital and (indirectly, through turnover generation) employment.
	**ENVIRONMENTAL**	Impacts related to the state and health of the environment, particularly as regards the ecosystem services on which human societies depend.
	**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 and/or business processes.
	**SCIENCE-TECHNOLOGY**	Impacts linked to academic, scientific or technological research and development, the advancement of the state of knowledge in a particular domain.
	**SOCIETAL**	Impacts related to broader societal aspects, such as public health, citizen security and welfare.

Table 2-1: SEBS benefit dimensions

2.3.4 Indicators and a Scale of Benefits

The value of the data or rather the benefits of its use will be analysed along the value chain and in each dimension. To assist and guide the evaluation and to improve consistency between analyses, a set of indicators has been introduced for each of the dimensions along with a scale on which they can be represented.

It must be highlighted that these dimensions are to be considered as different "lenses" through which we are observing the same phenomenon (i.e. the impact of using satellite data). The derived indicators are not mutually exclusive and may in fact be overlapping e.g. economic benefits are likely entailing improved living conditions and welfare, but both dimensions are worth to be considered. For example, when we identify “quality of life from increased leisure activities” as a benefit for Swedish forest owners in case F2, it is a benefit in the societal dimension which is also given an economic representation through the perceived value of the leisure utility.

The indicators identify parameters by which the benefits can be identified and subsequently evaluated. A “set” is given for each dimension, oriented towards the impact which the EO data has along the case value chain. They are not rigid, neither are they complete, and further work will improve both their definitions and their application.

The indicators are introduced in each of the dimension sub-chapters in chapter 2.4.

An assessment is made against each dimension and for each tier of the value chain. The economic indicators, are all quantitative and expressed in monetary terms i.e. Euro. Some of the other indicators may also be quantified but not monetised i.e. number of research papers, numbers of employees, but the majority are qualitative. Hence, to provide a visual representation of the importance of the indicator and by extension, the dimension, a grading system or scale from 0 to 5 has been introduced as shown in Figure 2-7. The scale is applied also to the economic dimension.

At present the scale is applied to the whole dimension which leads to difficulty in its definition. This arises as indicators of differing factors are being combined and hence all are taken into account in assigning the subjective value. This is an area for improvement in the future but for now, relies on the judgement of the analyst on whether the importance is small, large, or significant. Only for the economic dimension have we tried to introduce some specific values but even this is difficult to apply when comparing the benefits today with those potentially available in the future. What relative weight do we give to the future benefits compared to those of the present?

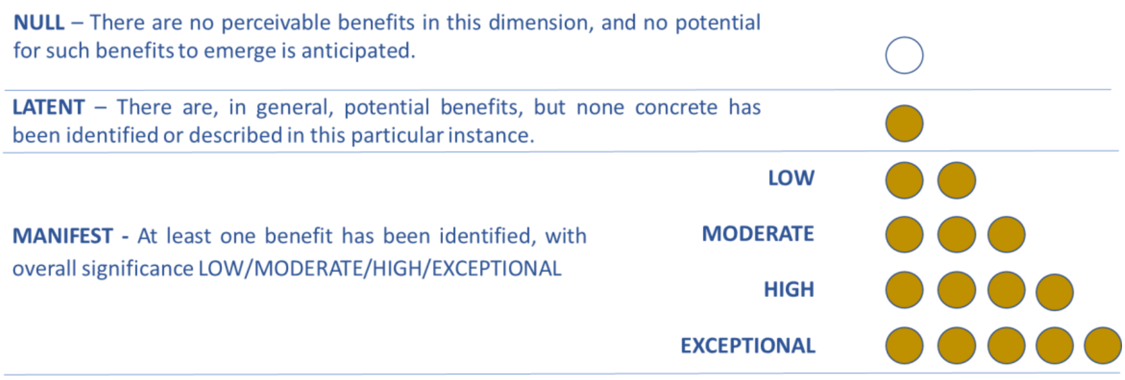


Figure 2-7: Scaling of benefits

For the moment, for expediency, the scale is generally applied for each dimension. With a growing number of cases across different geographic and application areas, a benchmarking exercise can be attempted which could help to refine the reference scales and enlarge their representativeness at the same time as making them easier to apply. A guide is given as to the weight to apply.

In the meantime, we point to the existing case studies (see chapter 1.5) and the examples they provide as a reference for judging new cases.

Practical tips to develop the case:

- Which other stakeholders are relevant as beneficiaries of the business operations of the primary user? Are there other players which feature in the value chain? Are there any links to academia or to government departments?
- What does the full value chain look like from the supplier of the EO service, through the primary user and secondary users to citizens and society? At this point we should draw the value chain.
- What decisions are being taken by the stakeholders? What information is being used to make those decisions?
- Which are the major benefits experienced by each of the identified stakeholders?
- Getting the support of the supplier and the primary user is essential which is sometimes difficult. Everyone is busy and these two key stakeholders may not immediately see the benefit of the case to them. One approach which can help (it helps us as well) is to write up a short version of the case story. This helps the dialogue with the stakeholders – as well as helping to get the story clear for us.

2.4 Identifying and Analysing the Benefits

2.4.1 Approach

Up to this point, the analysis has focused on understanding and setting out the perimeter of the case analysis. The next stage is to develop the detail by identifying all the benefits and analysing them where possible.

The starting point of each case study is the value chain. For each tier, we shall seek to identify the *benefits* brought about by the availability of the data. This means analysing the increase in efficiency and effectiveness of operations as a result of better decision-making due to the availability of enhanced information.

Achieving this means a close understanding of the case – "**getting under the skin of a case**" – and the first step in this phase of the work will be interviews with the primary user and some representative tier 3 beneficiaries. These may be conducted by phone, but face-to-face meetings, especially with the primary user, are much to be preferred.

The next step is to assess the degree or scale of the benefit in such a way that cases may be quickly understood and compared if a number of similar cases exist. In the longer run, this will allow comparisons of cases in the same country or for the same application area (i.e. agriculture) or using the same technology (i.e. Ground motion maps).

The final step is to extend the analysis, if necessary, to the required boundary. Most usually, for SeBS, this will be a national one and impacts most especially the benefits in the economic dimension. For example, in case F10, the analysis has been conducted for the Murcia region and then extended to the whole of Spain based on other regions of Spain which are extracting water from aquifers.

Now we shall discuss the different ways and some of the tools to analyse cases in each of the 6 dimensions.

2.4.2 Economic Benefits

We talk about "getting under the skin of a case" which is our way of saying that **we need o understand the decisions which are being taken by the various actors concerned**. The decisions are having an impact and the use of EO data is changing that impact – we hope for the better. How to evaluate this impact in financial terms lies at the heart of the analysis in the economic dimension.

The economic benefits are those related to the economic performance of the actors at each tier of the value chain. By definition, the benefits can be monetised although this may not always be easy. This is the hardest part of analysing the benefits and consumes the most time and effort. It requires the development of models representing the way in which the business process is generating value. Often, direct figures are not available from the primary user or other stakeholders and we must rely on many assumptions which are each clearly stated.

The indicators which have been used in cases to estimate economic benefits are shown in Table 2-2.

Impact along the value chain

In the first tier – where the service provider integrates the satellite data into its services – **the data form an essential part of the service**. Where this is supplied to the primary user if on a commercial basis, there will be revenues associated with the service. This revenue is a cost to the primary user and so must be tracked to avoid double counting. However, leverage due to the service being used may mean additional revenues and associated employment, which would be a benefit in the first and maybe second tier.

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.**
Capital expenditure reduction or avoidance	Aversion/reduction of capital expenditure which would or could otherwise have been incurred
Cost savings	Aversion/reduction of operating expenditure which would or could otherwise have been incurred
Increased revenues	Income through the commercial exploitation of EO-enabled value-added services
Efficiency gains	Time or material saved through the use of services.
Reduction of risk	Reduction of risk and consequential costs
Employment	Increased employment in the service provider (which is not a cost in the value-chain)

Table 2-2: Indicators of Economic Benefits

The economic benefit is relatively easy to identify in tier 1 as it relates directly to the EO service concerned. In tier 2, the EO service is used by the primary user to improve some parts of their business process, their operations. Hence the types of benefits are much broader as reflected by the full set of indicators. The benefit has been transformed.

Calculation of the value is most easily performed when it is known what was done before the EO service was available. This leads to a counterfactual which may be translated into a reduced cost, a gain in efficiency, a reduction of capital expenditure or a reduction of risk. These benefits come on top of any increased revenues or employment.

In tier 3 and 4, not only is the transformation much greater, but the impact of the EO service is becoming much more diluted and spread over a wider range of operations. As a result, it becomes hard to identify the role and added value of EO data in these next tiers: they seem to vanish. Furthermore, as there are no data costs, the associated cost component does not need to be passed on to the next tiers in the value chain (which is the case in 'normal' value chains) and so it is hard to identify a correlation between the use of the data and economic performance.

Even if the impact of the use of the data explodes, the value manifests more and more in the form of non-monetary benefits. So, this sets the challenging task to identify and assess the benefits, even if they become (almost) invisible and the proportion that can be allocated to the availability of Copernicus data, becomes really small. Put differently, as you move down the value chain, the volume of impact becomes much larger even as the percentage due to the use of EO data becomes increasingly insignificant.

This also has important implications for the actual measurement of this incremental value. Where in the first tiers we can still measure the value based on 'solid' economic figures (like decrease in costs, increase in output), as we move down the value chain that incremental value is watered down. What you see is not the value itself, but rather indicators or proxies of that value.

Introducing Models

Our approach to the analysis is based on estimating the **value of information (VOI)** which places information (not intervention) at the heart of our investigation. Several analytical techniques have been deployed in the case analyses mostly based upon an economic estimation of factors along the value chain.

Extracting the information requires us to understand how decisions being taken by the actors are having an impact. Often, these actors are not aware themselves of the full range of impacts these decisions are having and several rounds of discussions are necessary which converge on a position.

In practise this means that a first discussion is interpreted by us to lead to a first calculation of the benefits. This is shared with the key actors who, with the picture laid out before them, are able to provide improved information around the assumptions which have been used. This leads **to a revision of the analysis and the assumptions** and to a revised picture which will again be tested with the key actors.

Estimating the benefits requires the use of models; sometimes these can be simple, but they may also become quite complex. There may be one embracing model or several reflecting different decisions or business processes relevant to the case. These may vary according to the tier of the value chain. In case F1, a statistical model was used to represent the uncertainty in arrival time of ships arriving at ice-bound ports and the economic impact of reducing it. In case F3, a business model was used to calculate the impact on the users' balance sheet through better use of investment capital. Other types of models have been used based on financial or economic parameters.

Models are essentially used in two ways depending on the nature of the benefit. The information coming from the use of EO may be better or it may be cheaper. If it is cheaper, then the cost of acquiring the data by alternative means will be the rationale for calculating the benefits. In this instance, the model may well be used to calculate the cost of the alternative means to gather the needed data. Note that this may not have been the case, and the alternative could have been seen as too expensive for example in F5 (Ireland) or in F2 (Sweden).

However, in most situations the data comning from the use of satellite data is better than the alternatives and here the model must attempt to rationalise how the betterness is feeding into the business decisions and leading to better outcomes. This is the case with the ground motion mapping in F9 (Norway) and for aquifer monitoring in F10 (Spain).

In other situations, the data may be both cheaper and better; for example, in the Baltic (F1) or Norway (F9). Here both types of model should be sued to valuate the benefits.

Whatever the model used, some of the values of the physical, technical or economic parameters driving the model will likely be unknown. **This leads us to make assumptions which are clearly**

stated and open to be challenged. Uncertainties in the assumption may lead to considering a range of values. These are injected into the model to calculate the benefits.

If more than one of the parameters is given a range of values, combining them follows a pragmatic approach. If say three parameters are to be used in a model, we should not use a maximum value for all three which risks to lead to an extreme result.. Neither will we calculate all the possible outcomes as our goal will be to find a minimum and maximum for the variable in question (ie. reduction in fertiliser use). In the extreme, a monte-carlo analysis could be used to arrive at a realistic outcome.

Where the use of the EO service replaces earlier methods, ie removing helicopters from icebreakers in case F1, or in-well strain gauges in case F 10, **the counterfactual cost of the previous service ie helicopters, can be used to calculate the efficiency savings**. However, where the EO service is enabling new processes i.e measuring where ground motion is taking place in case F9, or avoiding farmers walking their fields as in case F4, then we need to generate a model of the processes.

In some situations, values become very imprecise to the extent that modelling them becomes impossible. Two approaches are being used to overcome this. Mostly this arises where there is a public amenity as in the value to the local population of increasing incomes, of keeping transport infrastructure open (case F9) or of increased leisure activities (case F2). In this case we **generally use a willingness-to-pay (WTP) approach**. In our studies, we do not have resources to conduct a full survey, so we tend to ask several of the actors we are interviewing to gather their views. Afterwards, we are estimating the population which reap the benefits and assigning a range of values to the amount each would be prepared to pay.

In some situations, even the WTP becomes problematic (!) and we are left to find other proxies to support our estimates. This was especially difficult when we came to estimating the strategic value of Greenland (case F6).

Projects vs services

We have found two basic types of use of the EO services within primary user organisations. Our core requirement is that the use is operationalised, meaning that it is used in regular business processes. But **sometimes these processes are projects** which is especially the case for roads management, or events (case F5). Here, the EO service may only have been used a few times since roads construction projects take many years to reach completion.

In this situation we are looking for several examples where the service has been used in order to build the picture of how the benefits are arising. The way in which the service is being applied may vary between projects but generally, we have been able to extract the core of the process in order to place some values upon its benefits.

Summing up

More than one indicator may be relevant to each tier, so each should be calculated to give a total value of the benefit. It is often useful to bracket the assumptions used to give ranges of outcomes (see economic benefit in Figure 3-2). As stated earlier, a visual scale has been introduced (mainly for the non-economic benefits) but can be applied to both benefit types. In a guide is given which may be used to allocate a rating to the economic benefits for the case and to provide some consistency across cases. This is quite subjective and whilst the guide is available, some flexibility may be assumed in its use.

	Scale for Economic Benefits	Comments
0	No quantifiable economic benefits are identified today or in the future	Many moderating parameters are possible which would reflect the size relative to population, size of economy, size of country etc. These could be considered in a future revision but for now, an absolute scale is preferred for clarity.
1	No quantifiable economic benefits are identified today but potential exists for the future	
2	Economic benefits are moderate today (€0-€5m) and in the future (€0-€10m)	
3	Economic benefits are moderate today (€5m-€10m) but significant in the future (€5m-€20m)	
4	Economic benefits are significant today (10-50m) and in the future (€20m – €50m)	
5	Economic benefits are large today and/or in the future (>€50m)	

Table 2-3: Scale for Economic Benefits

Practical tips to elaborate the economic benefits:

- Has the development of the EO service by the supplier led to increased business with the primary user or new customers, or shows potential to do so?
- Has the use of the EO service by the primary user led to any efficiency or cost savings through for example the replacement of alternative measurement means? Has it led to increased business or budget or to increased employment?
- Has the use of the EO service by the primary user led to, or shows potential for, changes to business practices which either improve operational efficiency, reduce risk of additional spending needs, reduced the need for capital investments or manpower?
- Has the use of the EO service by the primary user had an impact on the service which they deliver to their stakeholders?
- Has the service offered by the primary user changed in such as way as to improve performance, reduce risks or to reduce costs for other stakeholders in the sector or for society at large?
- An iteration of the analysis is usually necessary with the supplier and primary user.

2.4.3 Environmental Benefits

The focus for SEBS is on **indicators describing *environmental benefits* stemming from the *use* of satellite data**, not on indicators describing the precise *state* of the environment or evaluation of benefits stemming from such a state. Therefore, the focus of the research is shifted from a static estimate to a dynamic context – describing a change induced by the *use* of satellite data.

The effects of such dynamic change could be reported after monitoring (observing) over certain period of time. This rather “direct” approach, however, could require substantial time (e.g. few years in case of agricultural applications where statistics on annual crop yields has to be collected). The long time-span and dynamic nature both call for alternative methods for assessments of the value of satellite data (e.g. scenario- and expert-based estimates).

The analysis of the environmental aspects requires us to understand the impact of EO data on the user business process in environmental terms. Care should be taken to make the distinction between the impact of the underlying sector and the impact of the EO service. For example, the EO service InSAR is seen to have a very strong potential to help with management of roads infrastructure – and roads and their use has a huge environmental footprint. However, the impact of the use of InSAR is not perceived to have an impact on the environment and hence the grading for these cases is low.

As with most non-market driven indicators, putting an economic value on the environmental impact is complex. Various contingent valuation techniques may be used and especially using a WTP process. However, our goal is not so much to put an economic value on these factors but to highlight them as significant within the confines of the case. To evaluate the environmental impact, we are generally relying on specific experts. If environmental factors lie at the core of the case, the primary user will likely have sufficient knowledge. If not, we generally seek contact with a leading expert in a university or research institute who can advise us.

Often there will be a direct regulatory link since much environmental regulation exists. But this does not mean that the EO service impact is greater. Others might be better seen as elements related to societal benefit, such as matters linked to public health (societal dimension). The fundamental test is if environmental parameters are affected directly, which is reflected in the set of indicators shown in Table 2-4.

Environmental	**Impacts related to the state and health of the environment, particularly as regards the ecosystem services on which human societies depend.**
Reduced pollution	Reduction of unwanted material in the environment (water, air, marine etc)
Reduced impact on biodiversity	Denotes whether an intervention has an impact (positive or negative) on the local ecosystems or on the biodiversity of its fauna/flora
Reduced natural resource depletion	Reduced destruction or consumption of natural resources

Table 2-4: Indicators of Environmental Benefits

The set of indicators for the environmental dimension are focused on environmental or climatic changes which may be impacted (it is assumed reduced) through the use of the EO service. The three indicators which have been identified so far all relate to the reduction of pollution, biodiversity or on natural resource depletion.

The scale of environmental benefits is shown in Table 2-5. These are moderated in terms of their impact depending on the degree of severity and/or the geographical extent of the parameter. For example, if the impact is on a local woodland, this is less impactful compared to all woodland in a region or country. Similarly, the impact of a pollution event may be considered mild or severe depending on the effect it has on local populations.

	Scale for Environmental Benefits	Comments
0	No environmental benefits, linked to the use of the product or service are identified today or in the future.	The scale of environmental impact must be assessed today. The geographical extent of the benefit should be taken into account and or the degree in which it will impact on human activity or biodiversity. The product or service should be supporting measures to mitigate the impact of the environmental factors.
1	Some potential environmental benefits have been identified linked to the use of the product or service but nothing is effective at the time of the study.	
2	Limited environmental benefits (either in impact or in geographical extent) have been identified, linked directly to the use of the product or service.	
3	Significant environmental benefits (either in impact or in geographical extent) have been identified linked directly to the use of the product or service.	
4	Very significant environmental benefits (either in impact or in geographical extent) have been identified, linked directly to the use of the product or service.	
5	A major contribution to environmental benefits (either in impact or in geographical extent) has been identified linked directly to the use of the product or service today.	

Table 2-5: Scale of Environmental Benefits

Practical tips to dig out the environmental benefits:

- Did the use of the EO-based service or of any derived information help to reduce the use of any substance which is potentially damaging the environment (e.g. fertilizers, chemicals…), or does it show the potential to do so?
- Can the use of the EO-based service be linked to any (mis)use of natural resources. Can this effect be measured directly through changes in the affected geophysical parameters (e.g. reduction in water waste, reduction in soil consumption)? Or is there any proxy that could be related to this impact?
- Did it help to preserve the natural environment by preventing or reducing environment-adverse practices such as e.g. deforestation?
- Is any governmental or non-governmental entity concerned with environmental preservation potentially relevant for this value chain? Can they be interviewed? Have they expressed any opinion on the use of the service?

2.4.4 Regulatory Benefits

The regulatory benefits are those where the capability which the **EO service provides has a direct impact on the regulatory environment**.

This may be achieved by regulators being able to **draft better policies knowing that the EO data is available or that the implementation of the regulation can be more effective using EO data**. As an example of the former, the use of precise ground-movement measurements can help water management authorities understand when risk arises from water abstraction from underground aquifers (case F10). Knowing the movement can be measured more precisely allows regulators to put tighter limits on the permitted movement before it causes problems for houses in the neighbourhood.

An example of the latter, improved monitoring, can be present when such measurements provide a better knowledge of <u>when</u> movement of the ground took place as well as <u>where</u>, and hence can support resolution of or even avoid claims for damages due to engineering works (case F9).

It is not always about stronger regulation but better regulation. Another example of the latter occurred in Sweden (case F2), where a light regulatory approach was adopted to give incentives to the forestry industry, but which was also applicable to the 300,000 individual, family forest owners. The use of EO-based services enabled the authority to guide these family owners to take the right measures for national benefit.

Hence, we have two indicators of value; the ability to draft better regulations or the ability to measure compliance with regulations more accurately or more efficiently. These are shown in Table 2-6 and the scale to assess this dimension is shown in Table 2-7.

Regulatory	**Impacts linked to the development, enactment or enforcement of regulations, directives and other legal instruments by policymakers.**
Better regulations	Improvements in the policymaking process and the resultant policy as a result of knowing that EO data is available to support.
Improved monitoring	An improved ability to monitoring compliance or implementation with respect to regulations (e.g. more efficient monitoring of CAP compliance)

Table 2-6: Indicators of Regulatory Benefits

	Scale for Regulatory Benefits	Comments
0	No explicit reference to use of the EO-based solution in the legislation or for its monitoring has been found, and no potential has been identified in this respect.	The scale of regulatory benefits is based upon the use of the EO-based product or service to monitor regulations or to improve the efficiency or effectiveness of monitoring. The scale goes from *no links to legislation exist or are anticipated*, through to the situation where the solution is recognised in existing legislation.
1	No explicit reference to use of the EO-based solution in the legislation nor for its monitoring has been found, but a potential has been identified during the study.	
2	The relevance of the EO-based solution to support legislation and/or its monitoring is recognised by specialists in the sector and specific pieces of legislation identified.	
3	The relevance of the EO-based solution with respect to legislation is recognized. Specific pieces of legislation have been identified and amendments are being discussed by relevant stakeholders and/or results of monitoring have been demonstrated as applicable.	
4	Legislation including the EO-based solution is being brought forward by relevant law makers and/or monitoring is already taking place against existing legislation,	
5	The EO-based solution is explicitly enshrined in the legislation as well as having demonstrated the capability to monitor its implementation in an efficient and effective manner.	

Table 2-7: Scale of Regulatory Benefits

Practical tips to dig out the regulatory benefits:

- Is the service or the technology explicitly mentioned in any policy or regulation?
- Is the EO-based service actually used by any public administration to inform the design of policies or to monitor and enforce them? What are the related policies?
- To what degree is the public administration using the service? For instance: has the service been incorporated within the regular processes of the administration or has it just been used in a trial?
- Has this use lead to a more effective application of the policy from the side of the public administration? Has it improved its capability to implement the policy? Is there any plan to improve the integration of the service?
- Is the industrial sector which is using the EO service or its derived information, subject to specific regulations which may be adapted or monitored through spatial measurements?

2.4.5 Innovation & Entrepreneurship Benefits

In this dimension, we are looking at the capability brought by the **EO service to help stimulate innovation and new businesses**.

We have identified two indicators for this dimension, although others such as revenues and employment are covered in the economic dimension.

EO is not yet a generally or widely applied technology, so the introduction of the service may itself be innovative and/or be a source of further innovation within the supplier and/or the primary user. This can often bring a strong benefit and high value through new employment and research projects (which links to the *science and technology research* dimension). In many instances, the EO service is developed within a new company (a start-up) or by a new business line within an existing company. Either or both can lead to new jobs which will be contained within the economic dimension. The strong political interest in start-ups and SME's led to the identification of this as a distinct dimension.

The service may also have been offered outside the supplier's home market as an export business. This is taken into account in this dimension as a change of business process within the supplier. However, any associated revenues or increased employment would be considered under the economic dimension.

The introduction of the use of EO services into organisations (i.e. the primary user) can drive new business processes. If the information is directly replacing data obtained from other sources e.g. satellite images replacing helicopters as in the case in the Baltic, then the innovative coefficient is low. However, more usually, the introduction drives new processes and hence innovation is high.

Some importance may also be placed upon the nature of the service itself; its origins and whether it has been patented. The latter would be an indicator itself of the service, but absence of patents should not be considered in any way as a detracting factor.

In both these indicators, as shown in Table 2-8, the degree of importance of the satellite data should be assessed. In other words, would the new company exist if the satellite data was not available, or has the satellite data "only" been a factor contributing to a more successful start-up?

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

Table 2-8: Indicators of Innovation or Entrepreneurial Benefits

The scale factors used to assess the importance of this dimension are shown in **Error! Reference source not found.**. The scale is subjective relating to the degree to which business practices in the supplier or primary user have been driven by the uptake of the EO service. The extreme is where a new company has been created as a start-up or maybe a spin-out. More subjectively, the degree of change to the business process is left to the experience and judgement of the practitioner.

	Scale for Innovation & Entrepreneurship Benefits	Comments
0	The introduction of the service shows no evidence of starting a new business nor to have led to changes in business processes in the value-chain.	The scale of benefits depends on the impact the service has made through innovation. Which may be in the service itself or in the business processes which it is feeding. Alternatively, or additionally, the service may have stimulated a start-up or a new area of business in an existing organisation – which may not be commercial.
1	The introduction of the service shows potential for starting a new business or to lead to changes in business processes in the value-chain.	
2	The introduction of the service has led to a new business (start-up) and has demonstrated a change to business processes in the value-chain.	
3	The introduction of the service has led to a new business (start-up) and has become operational with a moderate change of business processes in the value-chain.	
4	The introduction of the service has led to a new business (start-up) and has become operational with a significant change of business processes in the value-chain.	
5	The introduction of the service has led to a new business (start-up) and has become operational with a fundamental change of business processes in the value-chain.	

Table 2-9: Scale of Innovation or Entrepreneurial Benefits

Practical tips to dig out innovation and entrepreneurship benefits:

- Is the service or the technology particularly innovative in its own i.e. bringing forward a completely new solution which was not existing before in this manner and shape?
- Is the service covered by any patent?
- Is the service not innovative per-se but is it bringing some innovation as per its application in a new context?
- Has the service led to a new way of doing business? For instance, has it helped to set-up a new business process? To what extent was the new process changed with respect to business-as-usual?
- Has this change had any major impact (e.g. on other benefits dimensions)?

2.4.6 Science and Technological Research Benefits

How much has the EO service contributed to improving the understanding about the Earth system or to advance any frontier technological know-how ?

In judging the importance of the research dimension, we are considering **how much the EO service can contribute to science and technological goals**. Hence, it is less a question of the background of the service but more about the future evolution of it as a contribution to R&D goals.

One of the clearest indicators of research interest is the presence of an academic institution within the value chain. We have found this several times in F4, in F9 and indeed even in F1 and

F2. Indeed, this is an indication of links to research activities but not of the importance of the service to further research activities.

Indicators have been identified linked to the **number of academic publications, numbers of research staff and the budgets which are assigned to the topic**. Although a rare occurrence we also recognise that there is the possibility of spin-offs from the academic institution which would be considered as a start-up recognised under innovation & entrepreneurship. The list of indicators is shown in Table 2-10 and the guidance for the scale in Table 2-11.

Science	Impacts linked to academic, scientific or technological research and development, the advancement of the state of knowledge in a particular domain.
Academic publications	Publications, relevant to the service, linked directly to the actors or the EO service.
Research Staff	Working on topics directly linked to the EO service or application
Research budgets	Increasing level of budgets dedicated to research linked to the EO service and/or its application.

Table 2-10: Indicators of Science and Technological Research Benefits

	Scale for Science & Technology Benefits	Comments
0	The service shows no evidence of contributing to scientific research or technological developments.	The degree to which the service is contributing to research activities which may be through an extension of or further benefits to the service itself or a contribution to research in different academic areas where the service has an impact.
1	The service shows evidence of the potential to contribute to scientific research or technological developments.	
2	The service shows evidence of limited contribution to scientific research or technological developments.	
3	The service shows evidence of moderate contribution to scientific research or technological developments.	
4	The service shows evidence of significant contribution to scientific research or technological developments.	
5	The service shows evidence of strong contribution to scientific research or technological developments.	

Table 2-11: Scale of Science and Technological Research Benefits

Practical tips to dig out benefits related to advancements in science and technology:

- Has the service or the technology helped to understand better any process or natural phenomenon (either global or local)?
- Have these findings been captured in any academic publication?
- Has the service been used in any scientific context (e.g. research centre or university) to help advance any research activity?
- How many researchers are involved in this use?
- Has the solution or any related application received any public fund for research?
- Has there been any company created as a result of this research?

2.4.7 Societal Benefits

Generally, these are recognised at tier 4 of the value chain, but not exclusively so. These are **benefits which are attributed to society at large including industrial or governmental players which are not closely associated with tiers 2 or 3**. It is also true that benefits which are recognised in the case but which are not attributed to any specific actor may be considered here. The societal benefits may manifest at a local or a national level.

Improvements to public health may arise due to the use of the service to reduce pollution of some form or to reduce human exposure to pollution, for example by predicting peaks of air pollution and enabling citizens to avoid it. Examples could be found through the reduced use of fertilisers or chemicals in farming so improving water quality. These would essentially be linked to increased opportunity for leisure activities ie swimming in non-polluted lakes.

The citizens' sense of security can be improved by enabling a better response to a dangerous situation e.g. a flood as in case F5. The use of the EO service supports emergency response and reduces risks to both individuals and property.

The geostrategic value can be affected by the quality of life for the local population as is the case in ice-bound territories where ice breakers keep local communities served with essential goods through the winter. In the extreme, the community would not exist without a shipping service and whilst the EO data is not fundamental to the service it does greatly improve efficiency and save costs. Hence the strong link between economic benefits and societal ones.

The use of EO services can help raise local public awareness of a risk or danger by increasing transparency of operations of public services which can also improve public utility of an asset such as a lake affected by a harmful algal bloom.

The quality of life in the community can be increased by a general raising of wealth by increased revenues within the value chain. It may also be improved through better access to infrastructure by reducing times when ie roads are closed for remedial works.

Finally, the EO service can help improve oversight by promoting a common operating picture amongst stakeholders, for example, the emergency services, and so improve co-ordination of actions. The use of EO data as a “neutral” source which is open to all players to use can give confidence to citizens that their interests are being respected. In case F7, the availability of a common map helps bring together actors from many different backgrounds with the common goal to increase revenues and livelihoods of the communities concerned.

The indicators which have been identified are shown in Table 2-12.

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

Table 2-12: Indicators of Societal Benefits

The scale of benefits for the societal dimension is shown in Error! Reference source not found.**.**

Table 2-13: Scale of Societal Benefits

Practical tips to dig out the societal benefits:

- Can the service or any of its derived information be linked to any perceivable benefits regarding the sense of community at the level of the involved users e.g. shared information leading to improved coordination and sense of identity for different users and organisations.
- Has the service or any of its derived information been used to improve public awareness and provide better information for the general public? (e.g. was the information used in any press event to help the population understand a specific topic e.g. in case of an emergency?)
- Can the service or any of its derived information be linked to any perceivable benefit on the general population in terms of public health and wellness e.g. access to cleaner air and to greener areas…?
- Does the service bring any sort of strategic advantage e.g. improve the standing of a community or of any of its public authorities? Does it improve its independence or self-reliance (e.g. less need for third party technology, less need for third party data…)?
- Can the service or any of its derived information be associated to an increased, fairer or wider access to public utilities?
- Can the service or any of its derived information be associated to an increased sense of European (or national, or regional) identity?

2.5 Extending the Analysis

The processes described in the previous chapters allow a case to be analysed within certain defined boundaries, which may be political e.g. a country, or thematic e.g. roads management or indeed both. However, for many cases, we wish to extend the analysis to **allow cases to be analysed against a wider perspective.** This gives rise to a number of further challenges.

2.5.1 Attribution

The tricky challenge of **attribution** concerns the question of, **how important the EO data is to the realization of benefits**? Whilst the EO data is an essential part of the service, it is seldom the case that Sentinel data is the only source of information for a value-added output; there are often other inputs: from in situ sources, other satellites, or socio-economic datasets. Disentangling the contribution made by the Sentinel data to the final product is the challenge faced here.

Our challenge is to assess **how much of the benefit should be attributed to the use of the EO (or Sentinel) data**. This question becomes even greater as we progress along the value chain and, as we have seen, the link between the service and the benefit becomes harder to detect and to analyse. Ideally, a with and without comparison of performance would be investigated but rarely are the processing chains sufficiently robust and the inputs decorrelated for this to be possible. Other approaches are needed.

Of course, **some products could not be produced at all without the satellite data input** (e.g. flood extent maps as in the Irish case). In such instances, there is 100% attribution, since the satellite data is a *necessary* condition of – to develop the example – map production (although notably, not *sufficient*, on its own, to be of much use, without the corresponding reference data on transport networks, hydrology, elevation etc.).

But for other situations, for instance in the case of pipeline monitoring in the Netherlands, where Sentinel-1 data acts as a trigger to investigate with higher resolution, commercial data, we **need to disentangle the contribution of each source**.

This is generally tackled in two steps. In Tier 1 and to an extent in tier 2, we are concentrating on the relative importance of the source data. **A percentage will be assumed as to the relative contribution** (which can be 100%). A range of values may be used and any argument to back up the estimation is declared. The values used will normally be validated with the supplier and, if appropriate, the primary user.

For tiers 3 and 4, where the link is much harder to detect, the challenge is to **assign a level of contribution of the service to the changes in business processes**. Once this is managed, the same percentage of relevance of the source data will be assumed as is the case for tier 1 and 2.

The percentage attributed may change with time. The Sentinels are a relatively new data source, and services being built upon them are often not fully mature. Further, for some cases, the build-up of data over time to create a history can itself add more value. Both the absolute benefit figure and the attributed value could increase.

2.5.2 Extrapolation

The second challenge is **to extrapolate the analysis** beyond the defined boundaries of the case. This extension may be geographical, technological or market based.

Each case is based upon the operational, business use of an EO service within a defined, geographical extent depending on the primary user and their boundaries, whether they are local, regional, national or global. Where the use is at local or regional level, most **SeBS cases are extrapolated to a national level**. This has both practical and political consequences.

<u>Politically</u>, as this has the most recognition amongst the stakeholders of ESA and the EU. <u>Practically</u>, as the **national boundary will normally constrain both market and regulatory conditions**. In other words, assumptions that are made will usually hold up to the national level but not necessarily beyond. Indeed, even technical conditions may limit the scope as was a

factor in case F3 where the geological conditions which determined if ground subsidence is an issue, only exist in parts of the Netherlands.

Nevertheless, the **geographic extent is normally a choice and for SeBS the report format has always been referred to a specific country** (e.g. in the form Aquifer Monitoring in Spain, or Potato Growing in Belgium) except when the market is global (see case S5). Future analysis may be developed to extend over even larger geographical areas i.e. the EU, where a common regulatory regime and the single market can support the analysis. This will demand the development of further tools to support the extended analysis.

The case analysis is may be carried out across the whole country, but it is often the case that it relates to a region (e.g. case F10 considers Murcia in Spain, case F3 considers an area around Rotterdam in the Netherlands). **Extrapolation to the rest of the country requires that similar conditions exist elsewhere** ie areas of water abstraction from aquifers in Spain, or areas where the geological conditions are similar in the Netherlands. The extrapolation is normally limited to the economic or environmental dimensions since the others are either unique (limited to the supplier or primary user organisation) or applicable to the whole country (ie regulatory).

In respect of the technological developments, this has been touched upon earlier in this chapter. Operational use of the service can lead to a better understanding of how the service works which can, in turn, **lead to a build-up of knowledge which improves the service**. As such, the value generated can be increased. Sometimes this can be recognised and incorporated into the analysis, for instance by projecting increases in indicators; other times this will only be recognised after the event, in which case it can be useful to revisit the case analysis.

Finally, many of the cases, especially those dealing with agriculture, have **only penetrated a certain part of the potential market**. For example, in Denmark, only around 3% of the farms were using the precision farming application from Fieldsense. This **market penetration is expected to increase** and especially as the value which it can drive is demonstrated. Hence, the cases may project into the future towards greater market penetration.

This raises an issue on whether we consider the explicit service on which the case is based or whether we consider that the farmers will be served by multiple services. Since we are looking at the benefits of the use of Sentinel data, we are in effect indifferent if a part of the market need is met by another or multiple service providers. Either approach is valid, and both have been used.

Finally, **several of these extrapolation vectors may be applicable to the same case**. Most obviously the question of market penetration and increased technical performance go hand in hand for agriculture cases. In this case, we produce a small 2 axis chart to reflect this potential increase in value.

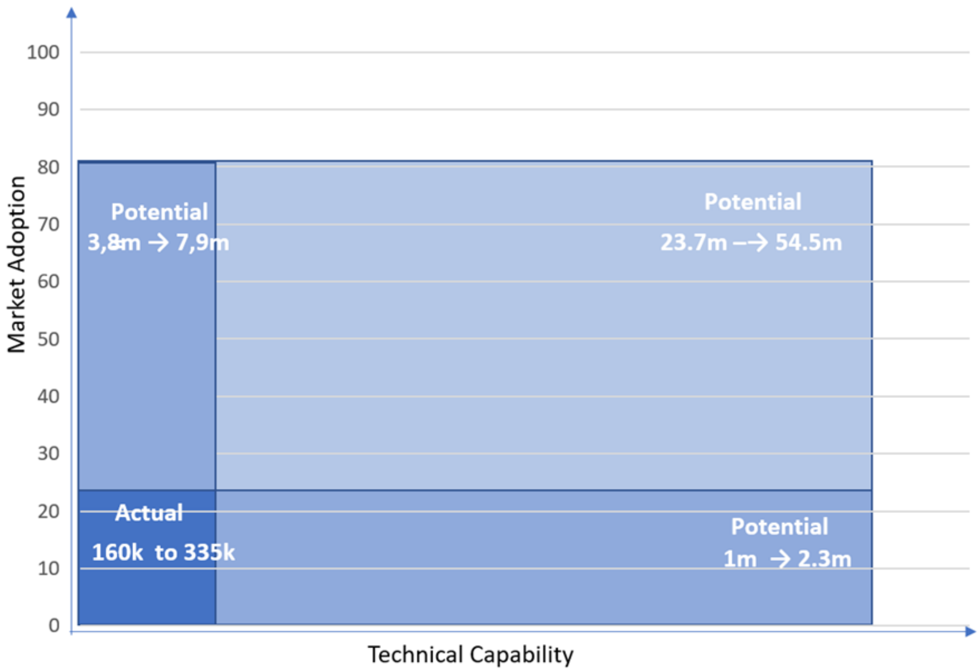


Figure 2-8: Extrapolation of benefits in 2 directions (taken from Farm Management support in Denmark)

2.5.3 Results Interpretation and Confidence Levels

A third challenge lies in the accuracy and/or confidence in the results. We explained earlier how assumptions play a large role in the analysis, plus we often bracket these by defining a range (upper and lower limit) on their values. In doing so, we hope to give greater confidence in the results without going to the extent of evaluating each parameter to give it a confidence level.

The assumptions are always tested with those interviewed in the case. We do not ask them to validate each assumption, but they should inform us if we are significantly wrong in the models and values that we are using. Each case is very different not just in its nature but also in the level of knowledge of those interviewed which is also a factor in developing models.

The model will also depend on the knowledge of the counterfactual. If this is coming as a result of a direct replacement of an alternative source of data, it may be straightforward. But more usually, the benefit is coming from better data and here the level of accuracy of the benefit calculation relies on knowledge of the benefits of separate business decisions.

Our goal in developing the SeBS cases, is not academic, but some practitioners may have this objective. In this case, attention should be given to the confidence levels with which each economic benefit is calculated. Doing this will require a much deeper level of understanding surrounding the values used in the analysis. Even as assumptions, error bars should be assigned which necessitate a degree of application which we are unable to devote to cases.

It also has implications for the way the necessary models are constructed and operated. All-in-all, this goes beyond the level of analysis which we are able to provide.

2.5.4 Comparison

With a growing number of cases across different geographic and application areas, we are able increasingly to make comparisons between the cases which allows us to refine the analysis as well as driving additional findings through case-comparisons. The more cases which are available the richer such comparisons can become.

Comparison across cases has led to the refinement and homogeneization of the levels of benefits dimensions attributable to the single cases and an improvement in the interpretation of the cases themselves as well as their specificities and boundaries of application. A benchmarking exercise can also be attempted which could help to refine the reference scales and enlarge their representativeness.

At the time of writing, we have completed 12 full cases (10 have been published) and 6 short cases where the detail is less. This allows us to embark upon two forms of comparison which are currently identified for similar market sectors i.e. agriculture, or similar technologies i.e. InSAR. The agriculture sector has many different crop types and we can already make a comparison between cereals and potatoes. Cases in preparation will allow this to go further and if other practitioners are able to develop cases using this methodology, then we shall hope to go even further.

Type	Characteristic	Thematic	Cases
Market	Agriculture	Cereals	Denmark (F4), Poland (F8)
		Potatoes	Belgium (F7)
		Grapevines	To be published
	Sea-ice	Icebreakers	Baltic (F1)
		Shipping	Greenland (F6)
Technological	Ground Movement (InSAR)	Pipeline infrastructure	Netherlands (F3)
		Roads	Norway (F9)
		Aquifers	Spain (F10)

Table 2-14: Potential case comparisons.

In the **agriculture cases, we find that although the service may be quite similar, the business models of the suppliers and primary users differ** (see Farm Management in Denmark and in Poland, both concerning cereal farming) leading to different results. Further, different value chains lead to different results also. Comparing either of the two cereal cases with that for potatoes in Belgium immediately shows a difference, as the business case for potatoes rests on the frozen food processors, whilst for cereals, the volume and range of uses are so great that the benefits are negligible in tier 3 of the value chain. Even greater differences can be seen in a case to be published linked to grape growing and winemaking where the nature of the business models change dramatically the way benefits are manifest.

Comparing cases using the same, or very similar, technology is equally illustrative. The use of InSAR to measure ground motion has been at the heart of 3 cases. Each one has its particularities and, even if the source service is very similar, the benefits are very different for pipeline monitoring in the Netherlands, Ground Motion in Norway and Aquifer Monitoring in Spain.

Looking at the comparisons allows us to gain a better understanding of the value chains. Different business models bring in different actors and deepens our understanding of the sector and especially the way in which the EO service is used.

Hence, each case has its own characteristics, and it is difficult to present any methodology for comparison yet can acknowledge that **rich results can be possible through the comparison of cases**. For others who apply the SeBS methodology or variants thereof, we shall be eager to draw lessons through examining and contrasting cases where similarities can be exposed.

2.5.5 Non-Economic Benefits

Extending the analysis beyond purely economics has led to the framework of **dimensions**, with **indicators** and a **scale of importance** to set aside the financial or economic benefits. The characterisation of this scale is not so well defined and the definition of the scale for the dimensions needs to be improved through more benchmarking based on analysis which are conducted. This will demand a greater portfolio of cases to enable clearer definitions compared to the minor, significant, major impacts currently used for most dimensions.

Introducing scales for each indicator will allow more precision but at the expense of a more comprehensive and detailed analysis which takes longer. Just as there is a trade-off between converting non-economic benefits into monetized ones at the expense of (possibly considerable) additional analysis, the same trade-off exists for the scales of non-economic benefits if they are to be analysed at the indicator level. As always, there is a trade-off between precision and investment.

Some practical tips for extending the analysis:

- What is the perimeter of the case from which each of the beneficiaries in each tier benefit financially from the primary user use of the EO service and what are the values of these benefits?
- What are the benefits for each stakeholder in each of the 5 non-economic dimensions?
- How will these benefits increase if the scope of the analysis is extended to account for future evolution of the service, future technology and/or market improvements and changes to the geographical extent?
- Does the case have any similarities with previous cases studied? Are there any findings which can read across from earlier cases? Does this allow any comparisons to be made?

3 Telling the Story

The goal of the work is to communicate effectively concerning the benefits of using Earth Observations. Whilst not strictly a part of the methodology, communicating the results is what makes the studies valuable and so a brief description of this activity is given here. As a result, 3 forms of output have been used.

1. A full report is a document of 50 or 60 pages which explains the analysis performed in detail. It provides extensive information regarding the key actors and how they work together in the business. It provides a quantitative assessment of the benefits as well as constructing a sound qualitative view along the 6 dimensions of value (see chapter 4).
2. A short case is a 6-page document which summarises the case. It does not contain detailed assessments of the benefits but does identify the main indicators which can lead to those benefits.
3. A flyer is a 2-page summary of either a full case or a short case and which describes the full contours of the case. This is intended for the casual reader whilst the full and short case reports provide greater detail.
4. Setting the scene. Each of the full cases has a short text which imagines a story connected with the case. This is entirely fictional but is designed to help readers understand quickly the essence of each case. Examples are at the beginning of each of the full cases.

Some tools have been introduced to help communicate the results and proved very effective.

- The value chain representation: this is usually very effective to help tell the story because it provides an overarching view of all the actors involved and of the core relationships. A representation of the value chain together with a pictogram summarising the results is used in each full report and its associated flyer. The value chain is also included in short cases. Whenever possible, a quantitative measure of the benefits is also accompanying the graphical representation. An example of the value chain representation taken from the case on Ground Motion Monitoring in Norway is shown in Figure 3-1.
- The qualitative indication of the different types of benefits over a standardized scale. This usually helps to highlight where the focus of the case is and greatly facilitate the inter-comparison of different cases. The estimated importance of the benefits within each dimension is finally represented in the reports and flyers in the form of a pictogram form. An example from a recent case is shown in Figure 3-2.

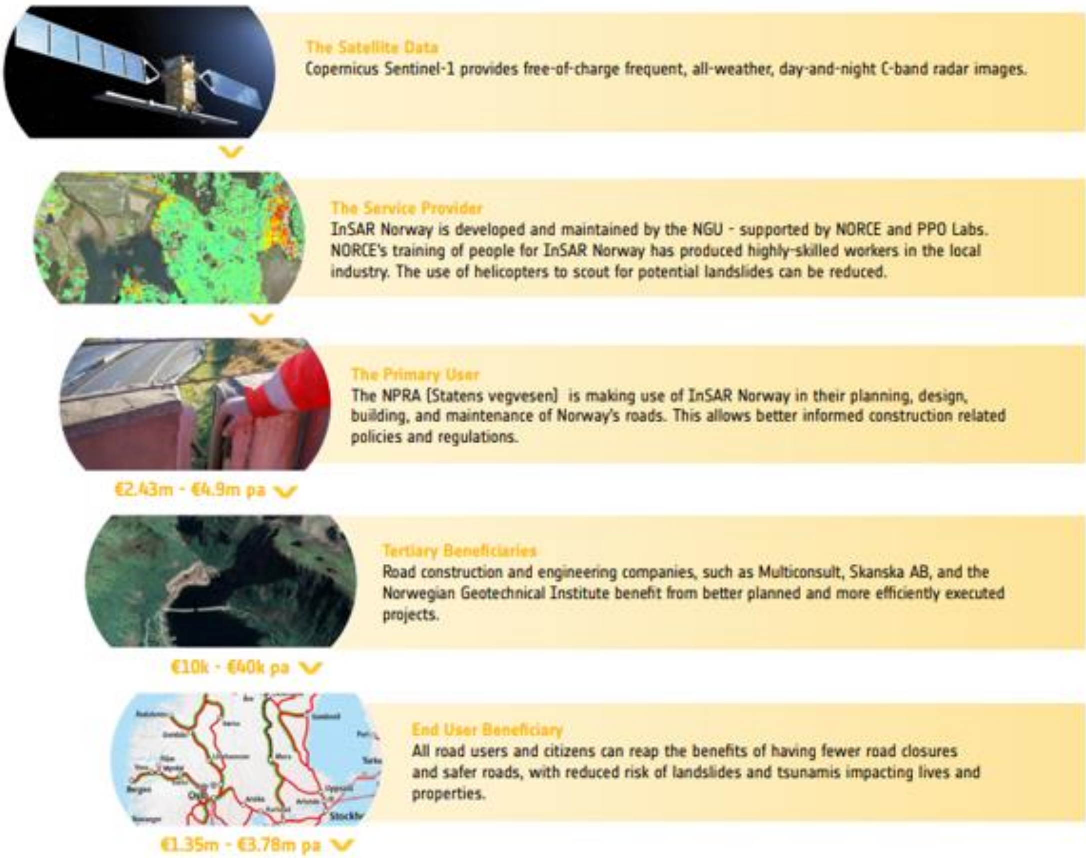


Figure 3-1: Example Value chain representation used for Communication purposes.

Figure 3-2: Pictogram of benefits using the SeBS Dimensions.

4 Final Considerations

With this document, we **aim to give other analysts a guide** on how to determine and represent the value that comes from using EO data. Whilst each case analysed is a valid goal in its own right and should stand alone as an example of value, building a collection of such analyses will enable a fuller picture to be developed. In the 10 full cases so far completed, we can see benefits which alone justify the investments made in the Sentinel missions – and we know that this is only scratching the surface. In addition, comparisons made will provide extremely useful insights into how **EO data is used and transformed into value for society at large**.

The basis of our approach is to **analyse use-cases of Sentinel data in an operational context**. This enables created value to be assessed along a value chain of users and beneficiaries. As more cases have been analysed, the framework for the work has become more clearly defined and allows us to share our thoughts and experiences with others. The SeBS methodology is applied to the use of Sentinel data but could similarly be applied to other data types and sources.

Even if well-developed, the **methodology always has room for improvement**. The factors discussed under the section about extending the analysis, give direction on where we can strengthen the analysis even further. **Better tools for understanding the attribution** can be developed and comparisons between different cases promises to expose some rich value understanding. The definition of the scale for the dimensions needs to be improved through more benchmarking based on analysis which are conducted.

A key lesson, but not evident, has been the **importance of ensuring that not only is the primary user fully committed** to supporting the case analysis but that **their hierarchy also supports this**. Several times we have come up against barriers when halfway through a case, due to our key contacts changing job or coming under a new management structure. We believe that it is important to make the users a key part of the story and to ensure that the report meets their internal needs as well as being a public document.

Storytelling has become a very important part of the work. A set of products have been defined through which to communicate the results. Not all cases are suited to being fully analysed. The most common reason for this is either that the EO service use is not fully operational or that the key stakeholders are unable or unwilling to share key business information. It is understandable since we need to get a good understanding of what the primary user organisation is doing and some of the business details are quite sensitive but is a complete block to undertaking the analysis.

Where details or the depth of understanding is limited, this can lead to a **short case where we provide the essence of the story** including details of benefits in several dimensions, but we cannot go as far to make an economic analysis. Short cases are still highly effective for communication purposes and have the benefit of being much shorter and easier to read!

We hope that this guide may be useful to others. We plan to continue working on these and similar topics and we shall always be happy to discuss any developments to the methodology and/or adaptations to different circumstances. A community, called GeoValue[8] is being constructed with this goal in mind; come and join us!

Please feel free to contact us with any questions about the work described here or any suggestions concerning how it may be improved or adapted to new situations. Our email addresses are given in our profiles or you can write to info@earsc.org.

[8] https://geovalue.org/

Annex A: About the Authors

We wish to acknowledge the work and support of the rest of the team shown in Annex B as well as Alessandra Tassa of ESA (the European Space Agency) who has reviewed and contributed greatly to ensuring the completeness of the report.

Geoff Sawyer, BSc (Electronics), MBA

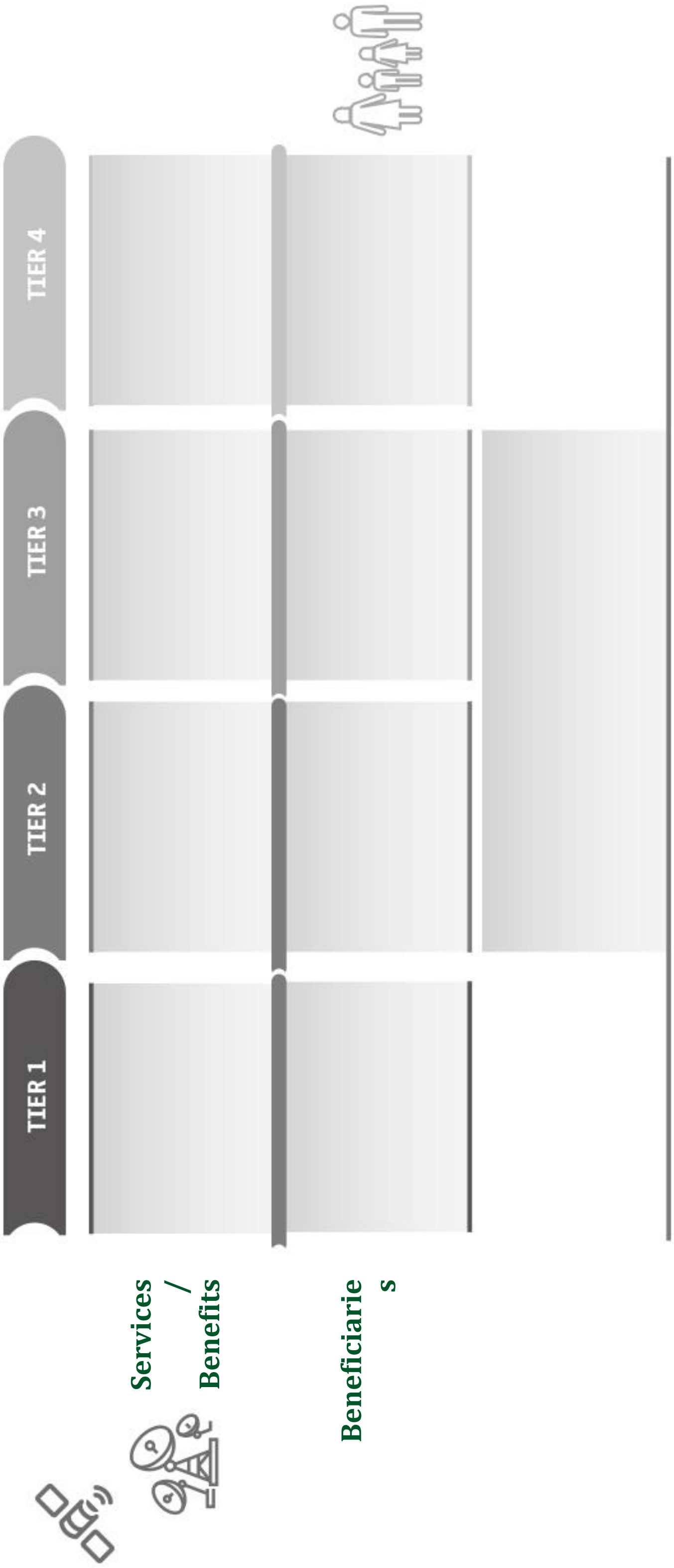
Geoff is Secretary General of EARSC having held senior management positions in the space industry and numerous representative positions in the UK and Europe. Geoff was the radar systems engineer responsible for the ERS-1 synthetic aperture radar and after many steps was, until 2011, EADS Vice President Corporate Strategist for Space. In addition to his extensive industrial experience, Geoff spent three years working for the European Commission where he was responsible for supporting the creation of the GMES initiative (now Copernicus). geoff.sawyer@earsc.org.

Dimitrios Papadakis, M.Sc. Research Methods

Dimitrios is a strategy consultant and communication/dissemination expert with over ten years of experience in the commercialisation, uptake and exploitation of space-based data and applications, primarily as concerns the Copernicus programme and its services. He has provided expertise on a range of major market, cost-benefit and user uptake studies in the EO domain, for clients including the EC, ESA, EEA and the SatCen.

dimitri.papadakis@earsc.org and dimitri@evenflowconsulting.eu

Annex B: Blank Value Chain Figure



Annex C: The SeBS Study Team

The SeBS study is conducted by a team of experts under the direction of ESA (the European Space Agency) and led by EARSC (the European Association of Remote Sensing Companies. The team is of a variable geometry and different experts work together on the different cases. The full team and the organisations for whom they work, is shown below.

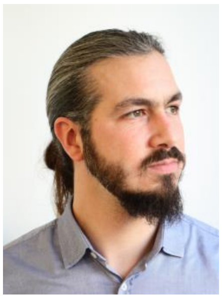
Geoff Sawyer, BSc (Electronics), MBA

Geoff is Secretary General of EARSC having held senior management positions in the space industry and numerous representative positions in the UK and Europe. Geoff was the radar systems engineer responsible for the ERS-1 synthetic aperture radar and after many steps was, until 2011, EADS Vice President Corporate Strategist for Space. In addition to his extensive industrial experience, Geoff spent three years working for the European Commission where he was responsible for supporting the creation of the GMES initiative (now Copernicus). geoff.sawyer@earsc.org.

Lefteris Mamais, MSc in Theoretical Physics

Lefteris is a strategy consultant with solid knowledge of programmatic, strategic and business aspects of EU Space Programmes (Copernicus and Galileo). In the past 10 years, Lefteris has been extensively involved in various studies and projects related to the development, market uptake and exploitation of EO downstream applications. He has been advising clients and partners across the full spectrum of the EO value chain, including EU institutions (EC, EEA, SatCen, ESA), universities and private companies.

lef@earsc.org and lefteris@evenflowconsulting.eu



Dimitrios Papadakis, M.Sc. Research Methods

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dimitri.papadakis@earsc.org and dimitri@evenflowconsulting.eu

Marc de Vries, BSc EC, LLM

Marc has professional degrees in both law and economics (Utrecht 1991). He has been active in the field of Open Data re-use for more than 18 years, both at the national and European levels. Through his company The Green Land he serves clients in the public and private sectors in the Netherlands and beyond (EC institutions in particular). He is a frequent speaker and moderator on Open Data conferences and events. Also he has published various books and articles on PSI, highlighting the legal, economic and policy perspectives. marc@thegreenland.eu.

Nikolay Khabarov, PhD

His expertise is mathematical modelling and optimization under uncertainty. Dr. Khabarov joined IIASA to strengthen the team in charge of quantifying benefits of improved Earth observations. Since then he has been a principal investigator and contributor to a range of research projects focusing on economics of adaptation, estimation of the value of information, disasters modelling, reduction of risks through innovative financial tools. khabarov@iiasa.ac.at

Christopher Oligschläger,

Christopher is an analyst with EARSC. He holds a Bachelor degree in European Studies from Maastricht University and a Double Master's degree in Governance and International Politics from Aston University, UK and Otto-Friedrich-University Bamberg. He gained first work experience (2017) at the Institute for European Politics in Berlin and the OSCE's Conflict Prevention Centre in Vienna before focusing on European space policy and concrete space applications through earth observation. christopher.oligschlaeger@earsc.org.

Dáire Boyle, BEng (Electrical Engineering), MSc Business & Economics

Dáire is a consultant with the Brussels-based consultancy Evenflow, who work in collaboration with EARSC on the Sentinel Benefits Study (SeBS). Dáire worked as an engineer for a large upstream oil & gas company in Aberdeen, Scotland for 4 years before moving to Belgium to complete a masters in International Business Economics & Management. Daire has extensive root cause analysis and statistical analysis skills developed through both his professional and academic career. He currently acts as exploitation manager for the H2020 CYBELE project. Email: daire@evenflowconsulting.eu