European Commission

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There is value in Earth observations: can you measure it?

Proceedings from the workshop

Advancing the understanding and measurement of the societal benefits of Earth Observations

1–3 July 2019 | ESA-ESRIN | Frascati (Rome), Italy

EXECUTIVE SUMMARY

The goal of this workshop was to advance valuation of the benefits from Earth Observation (EO) through case studies and through cross-fertilization with researchers, practitioners and managers from different disciplines. It brought together around 60 economists, engineers, scientists, policy makers and key personnel from space agencies and international organisations to discuss the motivations, the approaches and the challenges for valuing EO. During a dense three days programme, the participants shared ideas about areas for improvement and elaborated concrete recommendations to support the advancement of EO valuation practices. The working sessions, addressing separately different types of benefits (i.e. socio-economic, socio- environmental, regulatory, on innovation and entrepreneurship and on scientific research), stimulated the participants to discuss the challenges intrinsic to the measurement of the different impacts. The splinter sessions allowed concrete and interactive discussions among small groups, whose conclusions were brought together during a final session. The workshop summary findings and the recommendations are documented in these proceedings.

The workshop agenda and the presentations are openly available at
http://earsc.org/Sebs/workshop-2019

"As a space agency and a provider of Earth Observation satellite data, ESA takes a direct interest in understanding the value that users derive from the use of EO data. From various interactions and studies we know that this value is substantial, but it is important to be able to assess it and to communicate about it in a trustable way. It was thus a pleasure to host this workshop and to meet the international community that is undertaking similar efforts."

Alessandra Tassa | ESA

"Understanding and quantifying the societal benefits from EO is critically important in prioritizing, using, and enhancing the value of EO in decision making. The workshop provided an important opportunity for the international community to share advances and challenges in methods and practice for assessing the value of EO."

Carl Shapiro | USGS

DAY 1 - SETTING THE FRAME

MOTIVATIONS AND CHALLENGES OF VALUING EO

Government geospatial environmental information brings tremendous benefits to the economy, the environment and society. Understanding and quantifying these benefits is critical to programme planning, prioritization and product development but rigorous, quantitative assessments can be extremely challenging. This is certainly the case for satellite-based, Earth Observation (EO) data made available freely and openly in support to environmental monitoring and disaster management such as those from the European Copernicus Sentinels and the US Landsat missions.

With the goal to advance the measurements of the societal benefits brought by the use of EO data, the European Space Agency (ESA), the United States Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), the European Commission (EC), the European Association of Remote Sensing Companies (EARSC) and FourBridges organized a Workshop which brought together an international, interdisciplinary group of economists, scientists, and engineers. The workshop leveraged on **an existing international community, GEOvalue, which focuses on the value and socioeconomic impacts of geospatial information for decision-making (see www.geovalue.org)**. It built upon a previous workshop held on the occasion of the GEO Plenary in Washington in October 2017 (see the WS Proceedings here).

The workshop was opened by ESA's Director of Earth Observation Programmes and Head of ESRIN Josef Aschbacher. In his keynote speech, he recalled the outcomes from different independent studies about the economic benefits associated both to the EO upstream and downstream sectors. He considered that EO valuations should not neglect non-monetary societal values: advances in the understanding of Earth system sciences represent a key benefit for humanity which is recognized also by the public (e.g. a recent survey showed that "*in the eyes of Europeans, the primary area of progression for space activities would be to foster a better understanding of what is happening on Earth, particularly regarding the climate*"). **Research and development activities should also be better valued as precursors and enablers of operational services that bring outstanding economic benefits, such as from meteorological and Copernicus observations**. Aschbacher concluded by mentioning the need to invest in R&D: according to a recent study performed for ESA, for each Euro invested, 4 Euros

Economists, engineers and key personnel from space agencies and international organisations discussed the motivations, approaches, and practice for valuing EO in a comprehensive manner.

are returned on the European economy (Link). The second keynote speech was delivered by Cynthia Lodge, acting Deputy Director of the United States Geological Survey, who described a vision for 21st Century EO to become so well integrated that EO can support a real-time digital model of the Earth benefiting partners and decision-makers at many levels. This integration is an important direction for the USGS as it develops new ways of more effectively using EO for the monitoring, analysis, and projections required to inform decision-making. She highlighted the importance of building international partnerships for a sustained and interconnected system-of-systems observing network. (Link). The European Commission's Kamil Kiljanski (DG-GROW, Head of the Unit Space Data for Societal Challenges and Growth) proposed to the audience to reflect upon the nature of **EO as a public good**. In this respect, he proposed a parallel with the music market, recalling similarities such as e.g. the non-rivalrous nature, the distribution industry and the pricing policies. So far, the parallel is not fitting because the EO market is not fully structured but changes in technology and the increased uptake of the data might reshape the associated policies and market-type pricing valuations might then become more appropriate and change the regulator's role. Market-type valuations can then become increasingly complementary to the currently adopted ones, even though the public and strategic nature of a programme such as Copernicus will always remain prominent. The subsequent debate focused **on the potential of EO to develop into a mature market and about the role of the private sector**. In this respect, Kamil Kiljianski reinforced the concept of EO as a public good and of the regulator maintaining a key role; Josef Aschbacher highlighted that Copernicus definitely paved the way to the commercial exploitation of the data and even to open up new markets, thanks to its open and free data policy and especially thanks to its long-term reliable commitments. Cynthia Lodge highlighted the importance of transforming EO into actionable intelligence both in the public sector response to issues of public interest such as natural disasters and in the private sector. The efforts made by agencies and institutions to make data more available to the users were also mentioned, intended to advance data exploitation and to fully unlock the huge potential that ex-ante studies have consistently been predicting over the years.

Opening session: motivations, approaches, and practice for valuing EO

To start the opening session, Claire Jolly (OECD) provided perspectives about evaluation and impact assessments across different countries. She highlighted that **the demand for evaluation as a tool for priority setting and decision-making is generally increasing, although capabilities remain fragmented and practices diverse**. She indicated that there are many methods and they are not always interoperable. We need more uniformity and acceptance of "best practice" models. She urged the workshop participants to maintain the effort in building an international knowledge base to provide know-how and valid experiences to practitioners as well as solid evidence-based information to decision-makers and citizens on benefits (when they exist) (Link).

Steven Ramage, the Head of External Relations for the GEO secretariat, highlighted **the attention that GEO is putting on the societal benefits derived from EO and especially about the crucial importance of communicating them** (Link). USGS perspectives were presented by Carl Shapiro, who stressed that understanding the value of EO is more than an issue of budget evaluation -- the results are important to increasing the use and value of EO! Studies on societal benefits are a bridge between USGS "reliable scientific information" and the societal outcomes explicitly identified in its mission (Link). Mary Ann Kutny from NOAA stressed **the importance of understanding the value of Earth observations to inform investment decisions, support resource requests, and increase cost efficiency and enhance impact**. She noted NOAA's strategy is to focus on identifying and understanding the users of NOAA's EO data, including developing a NOAA-wide mechanism to collect socioeconomic data from end users, and undertake priority analyses. (Link).

Charlotte Mathieu from the ESA reported about **the Agency's increasing attention to the space economy across all its directorates** (including e.g. launchers, telecommunications and navigation) while her colleague Mark Doherty reported about a recent study for ESA which focused on the **ESA's Future EO programme as an enabler of operational programmes** which can be expected to bring substantial benefits (Link).

> *"It remains key to maintain efforts in building an international **knowledge base** to provide know-how and valid experiences to practitioners, as well as **evidence-based** information on benefits to **decision-makers and citizens"***
>
> **Claire Jolly** | *OECD*

Round table: measuring impacts: experience from different domains

Michael Obersteiner from IIASA reflected on **the environmental benefits of Earth Observations through examples from the GEOBENE project** and shared with the audience some lessons learnt from the institute's experience. Yakob Seid from the United Nations Food and Agriculture Organisation talked about **the use of EO data within FAO activities and how the integration of EO with statistical and other geospatial information can help improve the monitoring of national and global development outcomes**. FAO has documented its own experience and the impact of use of remote sensing data in a set of handbooks on remote sensing for agricultural statistics (2017) and crop yield forecasting (2016 and 2018). Furthermore, when it comes to the UN Sustainable Development Goals, Yakob highlighted the fundamental role of EO data as compared to the practical infeasibility of counterfactuals (Link).

The last presentation of the day provided an example of impact assessment activities performed by the Canadian Space Agency, which has been structured and consolidated over the last 23 years. David Haight, chief economist at CSA, related the results from the **2018 State of the Canadian Space Sector Report**, which relies on 25 quantitative and 15 qualitative indicators from 6 domain areas (3 of which related to EO) (Link).

Questions and answers, moderated by Rudy Aernaudt

(Senior Economist at the EC) and Jay Pearlman (FourBridges) started gently but soon developed into a dynamic discussion, much part of which was dedicated on the appropriateness of traditional economic approaches to EO valuation. **The audience challenge the possibility of getting trustworthy counterfactuals that can be used in the analyses**. However, techniques such as randomized trial experiments can hardly be leveraged, especially when public safety is at stake.

The difficulty to value EO through a factual understanding of the data use was also mentioned, together with the need of bottom up analyses to provide this information. Another important aspect that was pointed out was the **need to always clarify the boundaries of application of any impact assessment** not only in terms of beneficiaries and objectives but also in terms of the time perspectives, given that societal benefits tend to materialize much later following the availability of mature data and information.

DAY 2 - INTO THE FIELD

EXAMPLES OF IMPACTS MEASUREMENTS THROUGH SHOWCASES FROM THE SENTINELS BENEFITS STUDY AND OTHERS PROGRAMMES

The use of EO data can bring different types of benefits, from economic to environmental to scientific ones. Knowledge about these categories is not equal, with some areas being underestimated where monetary evidence and quantitative assessments are difficult to tackle. In order to reflect on all these aspects and to allow appropriate and focused discussions on the different types of impacts, five distinct panels were organized on Day 2 of the workshop which would separately address socio-economic, socio-environmental, regulatory, innovation and scientific aspects of EO value impact analyses.

The organisers invited the audience to look for common practices and challenges across the different studies and use cases with focus on each of the topic areas. In order to help frame the five aspects, findings from the Sentinels Benefits Study (SeBS) were presented at the beginning of every session. This is an on-going project that takes a bottom-up perspective to develop detailed value chain analyses for selected case studies (Link): the project team made an effort to retrospectively look at the 10+ case studies of its portfolio and to present the corresponding findings from the five different viewpoints to provide structured inputs to each one of the round tables.

MEASURING THE SOCIO-ECONOMIC IMPACTS

A large number of studies exist that document the socio- economic impacts of the use of EO data. Over time, practices have been developed and techniques have been consolidated so a reliable body of knowledge exists that can be leveraged[1]. As the first presentation of the day, Geoff Sawyer from EARSC presented the SebS findings in terms of the main sources of economic value that were consistently identified across the analysed use cases (e.g. avoided costs, increased revenues, reduced inputs, improved efficiency and strategic value) and the indicators and the economic models that have been used to measure them. The extension of the analysis to more cases throughout the project duration is expected to improve the definition of the utilised models and to reduce the uncertainty in the extrapolation to wider contexts in Europe. As a main lesson learned, Geoff stressed the **importance to get "under the skin" of a case** in order to understand what is going on and to build credible economic estimates and effective narratives (Link).

The need for micro-economic data as well as long term data to inform macro economic analyses was highlighted by Martina Sindelar (EC DG-GROW) in presenting the approach followed for assessing the impacts of using data and information from the Copernicus Programme. The European Commission undertakes activities both to stimulate the uptake of the data as well as to monitor the impacts of the Programme. The Copernicus Market Reports that have been elaborated in 2018 and 2019 present a rich source of information across different major market sectors. However, Martina highlighted that comparisons across sectors and countries, that are important for the policy makers, are hard to untangle and that lower economic impacts related to e.g. start-ups, are not sufficiently well captured (Link). DG GROW is looking for more analytical approaches, and for more concrete and comparable results. From a different perspective, Alan Smart from Australia (Acil Allen Consulting), highlighted how most valuation studies tend to neglect non-use value, which should be taken into the picture. Alan listed a number of issues to be addressed such as who is the audience, what are the nature of the products and services, how to capture and share data/ methods, and accommodate uncertainties. **He stressed the need for a body of work that would facilitate cross-checking and helping countries work up their own assessments** (Link). The recent formation of the Australian Space Agency has also acted as a pull with a set of parameters identified for analysis to show the impact of the new space policy in the country.

Evidence about the **challenges of attributing value to the information, but also about its very dynamic nature, was effectively provided through the account of the recent Landsat user survey performed by the USGS**. Using contingent valuation methodologies to assess the users' willingness to pay for Landsat images, the survey presented by Crista Straub from USGS, concluded that charging for improved imagery would result in a substantial reduction in use (even at the lowest cost per scene) (Link). Crista's highlight about the very dynamic evolution of the value of information prompted reflections about the need to repeat investigations along time. The idea of sharing the different assessments worldwide was also highlighted at the end of the presentations.

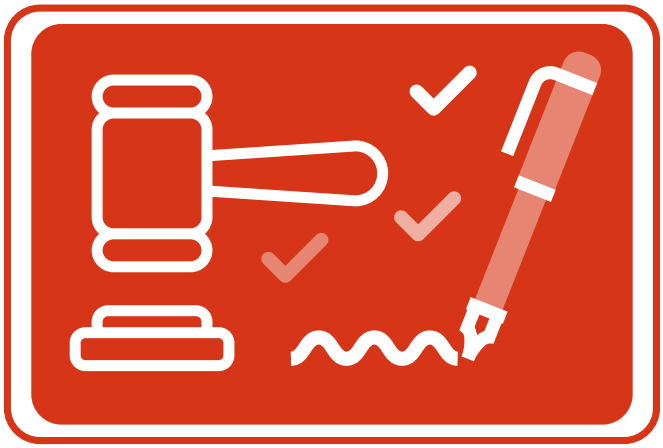
1. See a recent review in e.g. Kruse, J., Crompvoets, J., and Pearlman, F., 2018, "GEOValue, The socioeconomic Value of Geospatial Infortmation".

MEASURING THE SOCIO-ENVIRONMENTAL IMPACTS

The SeBS study has so far marginally dealt with environmental aspects, mostly focusing on e.g. pollution reduction (reduction in use of nitrates and pesticides and reductions on fuel consumption). A lively account was provided by Steven Krekels from VITO, who offered new perspectives to the audience about potatoes by introducing a platform that brings together farmers, agronomists and the powerful potato processing industry in Belgium. According to the study, the improved focus of spraying and the consequent reduction in chemicals consumption that is allowed by the use of the platform can partially be attributed to the regular synoptic views provided by Sentinels data. In presenting the study results, Lef Mamais highlighted the **difficulties encountered to establish a measurable correlation, let alone causation, between socio-environmental benefits at the end of the value chain and the availability of Sentinel data at the start of it**. Overcoming this limitation would require heavier involvement of specialists/researchers (e.g. hydrologists, eco-toxicologists, epidemiologists, etc.) in the studies. Lef stressed that societal aspects also deserve further attention. For instance, the capability of EO-derived maps to create a common understanding across different stakeholders came out quite consistently across different cases as a tangible benefit. However, this value is difficult to quantify (Link).

A different experience, from another application of environmental concern that can be typically supported by EO is the monitoring of harmful algal blooms. This was presented by Joe Silke from the Irish Marine Institute through an extensive bibliography related to the global occurrence of the phenomenon as well as to the associated impacts, that touch upon human health, fisheries, tourism and costs of monitoring. **The socio-economic impacts of harmful algal blooms are difficult to be assessed but EO data provide a useful tool in this respect** and in fact about 25% of the information sources used in the Irish Primrose system derive from EO data (Link). The role of EO data in supporting streamlined environmental monitoring and reporting was addressed by Andrus Meiner (EEA) through examples of the extensive use of EO - and especially of EO-based products from the Copernicus Services (i.e. CAMS, C3S, CMEMS and CLMS) - within numerous State of the Environment Reports prepared by the European Environment Agency. Andrus highlighted **Copernicus' ability to provide additional and innovative data sources and to open new possibilities for monitoring and reporting that could serve the implementation of EU environmental policies, in a way that was not possible before** (Link).

Sarah Ryker, USGS Acting Associate Director for Energy and Minerals, expressed the need to focus on ex-ante valuations as a mean to help prioritize future EO investments, elicit unmet needs (from the same stakeholders & other communities) and focus on value to decision making, not only economic value. She illustrated these statements with examples of missed opportunities in prioritizing EO investments for lack of cross-sectoral ex-ante analysis. The examples highlighted the vegetation, disaster response, and bare earth communities' shared needs for EO to efficiently map commodities such as minerals, the potential environmental impacts of developing those resources, and the impacts of wildfire on both vegetation and soils. (Link). In conclusion, finding suitable indicators to assess environmental impacts is more difficult than in economic assessments, so the community should look on how to improve this aspect. This could open up great opportunities for more general improvements, including in a policy perspective.



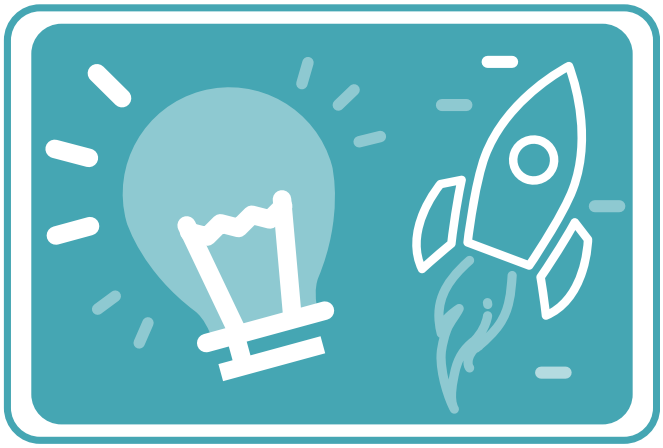
MEASURING IMPACTS ON POLICIES AND REGULATIONS

EO data can impact policies at different stages, i.e. from planning to implementation, enforcement and monitoring. Marc De Vries (The Green Land) proposed a reflection on the core definition of regulatory cases, whereby one party has an obligation to fulfil towards another party (which can be governmental but not exclusively so). **The capability of EO to ensure a common view on given phenomena can theoretically provide the agreed bases for compliance**. When made freely available to all the parties, EO data can also serve as a support for self-compliance assessments. Although some proxies can be used that help to quantify some aspects (e.g. the costs and feasibility of implementing alternative monitoring systems), this kind of impacts is actually hard to quantify. However, it is essential that they can be plainly exposed. A notable example was presented by Erik Willen (Swedish Forest Research Institute, Skogforsk) regarding the role of EO data in shaping the "light touch" forestry regulations in Sweden (Link). Katarzyna Pogorzelska from the EC Joint Research Centre (JRC) reflected on the dynamism of the EO landscape and on the fact that **policymakers need a better characterization of these changes in order to better understand the context and the impacts of policy interventions**. This is why the JRC specified a new ecosystem mapping tool (called the techno-economic landscape of the Earth Observation sector or TES) that targets complex techno-economic systems not addressed by official statistics or standard classifications (Link).

The importance of attribution for assessing the policy and regulatory impact of Earth Observations was highlighted by Jason Gallo (from the Institute for Defense Analysis Science (IDA)), initially with specific focus on societal benefits arising from Arctic science and observations. Subsequently, Jason discussed the separate assessments undertaken in 2012 and 2016 within the US federal interagency group. IDA mapped the full portfolio of EO data that the government relies on to meet its civil objectives using expert domain knowledge to develop a hierarchical framework connecting thematic areas of different societal benefits. The **linkages are extremely complex and the attribution hard to solve, since many information products are derived from multiple and heterogeneous EO sources and are often coupled with intensive numerical modelling** (Link).

Another way in which the use of EO data can impact policy is through its **potential capability to support improvements in the overall performance of administrative work processes**, enhancing their efficiency, quality, flexibility, innovation, transparency and reliability. However, understanding this kind of impact is also not straightforward. An example was provided by Glenn Vancauwenberghe, regarding the uptake of EO/Copernicus data for improving work processes. Glenn Vancauwenberghe is an expert on public sector processes from the KU Leuven and he stressed the need to understand the often complex policy processes to see what the contribution of technology can be on these processes and to be able to identify "explanatory variables" that can justify or explain a given mechanism to the largest extent (Link). The subsequent discussions reflected on the use of value chains, decision trees and value trees[2] as ways to establish the link between the use of EO data and the policies being acted upon.

2. The reader is addressed to "Demonstrating the Value of Earth Observations—Methods, Practical Applications, and Solutions—Group on Earth Observations Side Event Proceedings" (Open-File Report 2019-1033) for compound definitions of value chains, decision trees and value trees.

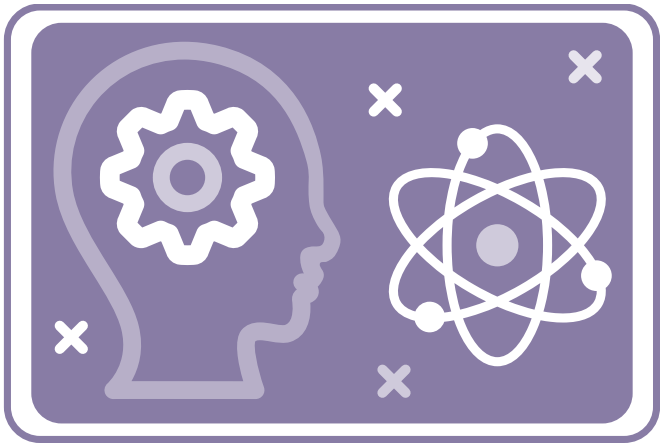


MEASURING IMPACTS ON INNOVATION AND ENTREPRENEURSHIP

This session looked very ambitious, as it is widely agreed that measuring how and how far the use of EO data can impact innovation and entrepreneurship is extremely challenging. Within the SeBS study, various use cases had developed around start-ups that had benefitted from incubation activities such as the Copernicus Masters. A lively account was provided by Stefan Józefowicz from SatAgro, a Polish start-up providing services to farmers, that has rapidly developed and built innovative business partnerships with industrial producers of fertilisers and with the banking sector. Stefan explained the impact that Sentinel data had on the development of their platform and their business. Story lines from start-ups such as Satagro are always effective to show the impact of the data on innovation.

However, to get a more comprehensive picture, other approaches are needed. **The challenge is to identify suitable and measurable proxies (e.g. number of patents? number of start-ups making use of EO?)**. Dimitri Padadakis proposed a reflection on these, explaining the ones that were addressed as part of the SeBS study. In particular, he explained how he investigated the value attributed by start-ups to Sentinels data through a dedicated survey: out of 97 respondents, most declared that their business models would be less efficient without Sentinel data while 30 start-ups stated that the open and free availability of Sentinel data provided the basis for their competitive advantage or that their business models would not be possible without it (Link). The presentation triggered a discussion on the impact of the open and free data policy on fueling innovation. EC's Martina Sindelar informed the audience about the current debates concerning the continued adoption of the policy for Copernicus. The experience of Landsat's data policy change in 2008 was recalled by USGS' Carl Shapiro. In this regard, Stefan Józefowicz reminded the audience and the agencies that "The availability of free and open Landsat data has marked a whole generation of researchers".

A complete change of perspective was proposed by Andrew Coote (Consulting Where), who proposed a parallel with the innovative applications that were staged through years of consolidation in the location-services market. Andy presented a study which was performed in the UK location-services sector (Link). Amanda Regan (ESA) provided a glimpse of what ESA is doing to help commercial EO foster innovation, reflecting on the many new technological trends that are impacting EO, in an overall extremely dynamic landscape. She exhorted the audience to reflect upon how to exploit the EO data to build actionable information and how to make sure that space capacity is delivered at the right time in the right way to the right people to make this happen (Link). The discussions following the presentations focused on how to address the challenges posed by the measurement of something which is, by definition, yet to be known. The need to find effective ways to establish the linkages and further clarify the benefits that can be attributed to the space investments was generally agreed by the audience, and the example of NASA's "International Space Station Benefits for Humanity" was offered by Cynthia Lodge. There was a lively exchange on the specificity of innovation within the sector, which so far is still heavily relying on public funds and only marginally benefitting from e.g. venture capitals. The latter seem to tend to concentrate mostly on the upstream sector, which Prof. Florio (University of Milan) noticed is at odds with respect to the experience in other sectors such as health and genome, where venture capitalists tend to invest in small, high risk but promising activities. In conclusions, the need to overcome the many challenges and to develop good practices that persistently and consistently capture innovation spill-overs was agreed.



MEASURING IMPACTS ON ADVANCEMENTS IN UNDERSTANDING

The role of EO data in advancing human understanding in Earth system sciences, especially with respect to the many challenges faced by humankind, such as e.g. climate change, has been mentioned in the discussions since the first day of the workshop. But providing evidence of it, beyond the narrative related to breakthrough scientific advancements, is not straightforward. Traditional assessments focus on bibliometric analyses applied within academic, scientific and research contexts, as it was already shown also by e.g. the OECD and ESA. Within the SeBS, some more detailed analysis has been conducted in search of the attribution to Sentinels data (i.e. filtering by type of Sentinels data and type of use). This information could not be obtained through the search levels that are normally allowed in the scholar databases and manual scrutiny was needed. The results look promising so for the future automated data mining approaches are being considered (Link).

The use of citation papers to track advancements in research is also adopted by the Copernicus Climate Change Service, which itself has to address the challenge of demonstrating the impact of its own services downstream. From another perspective, the European Center for Medium-Range Weather Forecast **(ECMWF) can provide evidence about the impact of EO data on e.g. improvements in weather forecasts and/or enhancements in climate change numerical modelling** and these can, theoretically, be selectively attributed to different EO data sources through e.g. re-analyses. Stijn Vermoote, who presented, concluded that the understanding of the main Earth system processes makes slow but constant progress at ECMWF with the relentless improvement of the numerical models, and this can be partly attributed to observations data including satellite EO (Link).

Another way to evaluate the impact of EO data on scientists' activities is to ask them directly. This is what was done by the Earth Science Information Partnership (ESIP) as described by its president Karl Benedict. One of ESIP's strategic goals is in fact to promote techniques to articulate and measure the socio-economic value and benefit of Earth science data, information and applications and the organization has engaged in a survey with the community that feeds into the 2019 ESIP Organizational Assessment. Karl highlighted that scientific progress is a collective endeavour within research communities, and pointed out **the necessity to adopt a qualitative macro-level approach to evaluate ESIP's impact on the research community. He noted that qualitative data do not lend themselves towards quantitative depictions in the way that many of us are most familiar with (such as graphs, trendlines, tables). So, expertise should be developed also in qualitative data collection and analysis to perform effective community impact assessments** (Link). Finally, some practical perspectives were brought from the South African Space Agency from Imraan Salooje, who presented the agency's assessments and urged the community to link EO socio-economic benefit statistics to other relevant National Statistics such as R&D surveys, innovation surveys, bibliometric studies and patents (Link). In summary, the role of EO data in rooting science and applications to enhancements in understanding should be better understood. Noteworthy, the discussions highlighted also the need to monitor the impacts on education in order to forecast the preparation of the next generations and maximize the future benefits from EO exploitation.

Tying it all together: open discussion

The final session, moderated by Cynthia Lodge, offered a recall of the main conclusions from all the sessions and drew some lines across all of them, starting from the summaries provided by the moderators. The discussions highlighted how far expertise and understanding varies across the different types of benefits. Unsurprisingly, it was highlighted that there is consolidated knowledge with corresponding techniques about the cost-benefits analysis and the evaluation of economic benefits. Various participants in the workshop highlighted the importance of not reinventing the wheel and instead leverage work accomplished to date on cost benefit analysis. However, the same level of understanding is not available for the other types of benefits and considerable progress needs to be made. In particular, EO has an important function in stimulating innovation and scientific research, thereby unlocking progress in society and enabling substantial benefits from consequent operational exploitation. This role should be adequately captured but the identification of meaningful proxies for this is far from straightforward. In particular, **it would be essential to find ways to attribute the heritage and impacts of full-blown operational applications to the corresponding R&D preparatory activities**.

A robust methodology should be sought to articulate non-monetizable impacts through convincing narratives leveraging on trustable and defensible information. All participants agreed on the importance to feed models and estimates with reliable information about the actual uses and users of EO data and on the value that they attribute to EO. In fact, despite increasing efforts (e.g. Landsat User Surveys, Copernicus Market Reports...), this information is still largely unavailable.

> *"You want to make real progress on valuing EO? Go to the trenches, guys...do primary research!"*
>
> **Andrew Coote** | *Consulting Where*

This is especially true when considering the dynamic evolution of the sector. In the provocative words of one of the participants, we should roll up our sleeves and engage both users and application developers to find out how society is actually using the data and extracting value out of them. In this respect, case studies are key to communicate about EO value but specially **to improve knowledge and delineate realistic scenarios about the many ways in which the use of EO data creates value**. The accumulation and sharing of a rich set of case studies could bring concrete improvements through the elicitation of the identified models and practices and on their cross-comparison across different applications, scales of assessment and geographic areas.

Jay Pearlman talked about "benchmarking of case studies" to help consolidate findings and analyse their boundaries of application and their potential for extrapolation. Value chains provide an effective tool here because they help to improve the understanding of the mechanisms through which EO data affect economy and society, and this is at least as important as the quantitative estimates themselves.

DAY 3 - THE WAY AHEAD

AREAS FOR IMPROVEMENT AND RECOMMENDATIONS FOR NEXT STEPS

The third day of the workshop was focused on getting broader involvement of the participants through splinter working sessions, where they were randomly divided in four groups of 10-12 people each and asked to reflect upon possible areas for improvements and practical recommendations. The objective was to get different perspectives and to set priorities as envisioned by each of the four breakout sessions. The groups engaged in lively and open discussions, exploring the areas needing the most advances and having the greatest leverage (benefit) in moving forward during the next few years. The results were reported by each breakout lead and session rapporteur and debated in an open fashion during the final round table. The reports addressed two themes: "what are the recommendations and areas for improvement?" and "what are the next steps?" The identified areas for improvement in the end were not so numerous, and it was meaningful that most of the recommendations consistently showed up in the separate group discussions.

The major recommendations reported here are those that came from two or more of the breakouts. These include (not in order of priority):

- Understand and attribute clearly the value of EO information considering the entire value chain from data to decisions. This introduces the value chain approach as a foundation of socioe-conomic benefits and impacts analyses.
- Identify and encourage the use of common practices (sometimes called "best practices") in the analyses. This follows the approach used by many communities to furthering interdisciplinary work.
- Create a common knowledge base and a common set of definitions which includes a shared taxonomy of benefits assessment. This would support work with end users and across disciplines.
- Maintain an open repository of both published studies (including use cases) and best practices which provide an open reference for sharing developments.

- Further motivate and expand the existing GEOvalue community of practice to increase both participation levels and the breadth of topics relating the value of information for policy relevant issues including decision making and societal impacts. This could support increased stakeholder engagement.
- Improve understanding and trust of outcomes and recommendations. This should include increased use of peer review.
- Consider the identification of a topical interdisciplinary open-access journal as a focus for new developments and reporting of case studies.

This includes a foundation to build ex ante studies.

The discussions following noted that there is a body of knowledge that already exists for cost-benefit analyses and impact assessments so one should **not reinvent the wheel!** However, the body of knowledge is fragmented and there can be important opportunities to make it more accessible through a repository. When it comes to areas such as environmental benefits and especially benefits on innovation, techniques are not consolidated and there is less experience.

Improvements are also needed in how to approach the unknown, both to track the dynamic evolution of value as well as to forecast the impacts of future systems in ex- ante assessments. One of the participants highlighted that the potential of this is not negligible: in making (and maintaining) the EO data available, agencies create options for people and for the future generations and this is an intrinsic value that must be brought into the picture. Many participants agreed that the community of practice, being so heterogeneous, is fragmented and uses different terms and expressions for similar things. This is as an obstacle to advancements. The need for a common language across disciplines was noted and the development of a consistent set of ontologies is essential to facilitate interdisciplinary collaboration.

Recognizing that the attribution of value to EO within complex systems remains a challenge, open and transparent models and techniques should be developed upon improved knowledge about the EO users and uses.

In practice, this advancement and the maturing of value and impact assessments needs a strong and enduring community of practice. This would not only stimulate collaboration, but would provide a home for access to case studies, key exemplars for best practices and standards and a foundation for building trust of the adopted techniques and outputs by the end-user communities. The need to develop appropriate strategies to build trust upon EO valuation studies was strongly advocated.

Based on the breakout recommendations and considering the discussions, a series of near-term steps was proposed by the breakout sessions. Many of the list below were offered by more than one breakout. The list is a consolidation of such proposals.

- Develop strategy and objectives including identifying a framework for GEOValue assessments.
- Engage end-users early in the evaluation processes as much as possible.
- Build a repository of usage stories and best practices; capture various uses of EO data.
- Develop a process to identify best practices and to encourage their adoption and use.
- Motivate and expand the GEOvalue community of practice. This could then address approaches for a common language across disciplines for benefit and impact analyses. It will also facilitate communication strategies and user engagement.
- Motivate institutional support for studies over time and the consistent submission of documentation of studies into open repositories.

The priorities and timeframes for implementation of these next steps needs to be addressed and will depend on resources that are or can be made available. The interest of the GEO in this respect was noted and the Geovalue community is coordinating with GEO in the organization of a dedicated side event at the forthcoming GEO plenary in Canberra (November 2019). Offers were made to host the next GEOvalue workshop and this is a subject which will also be addressed in the near future.

CONCLUSIONS

The workshop presentations and discussions provided evidence about a dynamic research field, in which a remarkable body of knowledge has been developed, although not homogeneously across different benefit areas. The development of a comprehensive strategy widely accepted within an international and interdisciplinary community can greatly contribute to advance the understanding and the measurement of the benefits derived from EO. Possible areas for improvement and concrete actions were identified based on the suggestions elaborated by the workshop participants, and these are summarised in the following:

- **Create a common body of knowledge regarding best practices in the field**, including stories, models, glossaries, with explicit declarations of applicability and limitations of the studies. The need for a dedicated repository or a sharable database of studies was recognized as a necessary step to aggregate the community and develop a common language across different disciplines.

- **Develop strategies to build trust in EO valuation and to enhance the quality and hence the credibility of the findings through participated scrutiny within the community** (e.g. peer reviews involving different expertise, community fora, benchmarking of use cases using the value chain approach across different countries and domains...). Some common relevant indicators for value chains could even be developed down the road. Improvements in modelling the attribution of value to EO could be gained through cross comparisons of findings applied to different cases and domain areas.

- **Develop strategies to engage EO beneficiaries (i.e. data and users along the value chain) to contribute their experiences and help develop case studies.** This could be pursued by competent agencies and/or institutions through the set-up of an appropriate framework to crowd source information in a structured way. In order to make these processes more effective, toolkits and/or templates should be designed in order to gather in a consistent manner meaningful information appropriate to the category of beneficiaries (e.g. industry, research institutes...).

- **While leveraging on the existing works for the measurement of socio-economic benefits, strengthen the foundations for the evaluation of the benefits on the environment, innovation and scientific research, finding appropriate proxies and non monetary indicators**.

- **Follow the evolutions (or not) of benefits over time**, given the present expanding and dynamic nature of data exploitation scenarios and their related benefits. This would imply regular (re)assessments and re- analyses. This should also be done in view of improving the capability to forecast future benefits (ex-ante studies) and also capture unexpected ones.

- **Maintain continuity of these efforts** and their outcomes by working with sponsor organizations.

It was proposed to bring the findings of the workshop to the Group on Earth Observation (GEO) Community through a side-event at the GEO Plenary in November 4-5 and to continue discussions with GEO to promote wider engagement in the activity. A next workshop will be considered in 12 to 18 month's time.

WORKSHOP PROGRAMME AND PRESENTATIONS

DAY 1 - SETTING THE FRAME: ABOUT THE MOTIVATION AND THE CHALLENGES OF VALUING EO

14:30 | Welcome and Workshop Goals

14:40 | Keynotes: Visions and Perspectives

- **Josef Aschbacher** (ESA, Director of the Earth Observation Programmes) (Link)
- **Cynthia Lodge** (USGS, Deputy Director) (Link)
- **Kamil Kiljanski** (European Commission DG-GROW, Unit head of Space Data for Societal Challenges and Growth)

- Open discussion with the audience

15:30 | Opening session: Motivations, Approaches, and Practice for valuing EO

Moderator: ***Rudy Aernaudt (EC)***

- **Claire Jolly** (OECD, Head of Unit, Directorate for Science, Technology and Innovation) (Link)
- **Steven Ramage** (GEO Secretariat, Head of External Relations) (Link)
- **Carl Shapiro** (USGS, Science and Decisions Center Director and Senior Economist) (Link)
- **Mary Ann Kutny** (NOAA, Satellite and Information Service International and Interagency Affairs Division, Deputy Director) (Link)
- **Charlotte Mathieu** (ESA, Head of the Industrial Policy and Economic Analysis Section) and **Mark Doherty** (ESA, EOP Senior Advisor) (Link)

- Open discussion with the audience

17:00 | Round Table: Measuring impacts: experiences from different domains

Moderator: ***Jay Pearlman (FourBridges)***

- **Michael Obersteiner** (IIASA) – The measurement of environmental impacts: examples from IIASA
- **Yakob Mudesir Seid** (Office of the Chief Statistician, UN Food and Agriculture Organisation) - Use of Geospatial Data at FAO (Link)
- **David Haight** (Canadian Space Agency) – The socio-economic benefits of space utilization in Canada (Link)

- Open discussion with the audience

18:00 | *Networking Cocktail on the terrace*

18:00 | Close of 1st Day

DAY 2 - INTO THE FIELD: EXAMPLES OF IMPACTS MEASUREMENTS THROUGH SHOWCASES FROM THE SENTINELS BENEFITS STUDY AND OTHER PROGRAMMES

09:00 | Overview of the day

- **Alessandra Tassa** (ESA)

09:05 | Round Table I: Measuring socio-economic impacts

Moderator: ***David Haight (CSA)***

- **Geoff Sawyer** (EARSC) – Outputs from SeBS study and the example Sea Ice Navigation in Greenland (Link)
- **Martina Sindelar** (EC DG-GROW) - Measuring socio-economic impacts of Copernicus (Link)
- **Alan Smart** (Acil Allen Consulting) - Economic Perspectives (Link)
- **Crista Straub** (USGS National Land Imaging and the Fort Collins Science Center) – Using Contingent Valuation Methodology to Measure the Value of Landsat Imagery: 2018 User Survey (Link)

- Open discussion with the audience

10:35 | Round Table II: Measuring socio-environmental impacts

Moderator: ***Nikolai Kabharov (IIASA)***

- **Lef Mamais** (Evenflow/EARSC) and Steven Krekels (VITO) - Outputs from SeBS study and the example of potatoes growing in Belgium (Link)
- **Joe Silke** (Irish Marine Institute) - An example of measuring impacts in a case of harmful algal blooms detection in Ireland (Link)
- **Andrus Meiner** (European Environment Agency) - Role of Earth Observation in current state of environment reporting (Link)
- **Sarah Ryker** (USGS) – Use of valuation to prioritize future Earth Observations (Link)

- Open discussion with the audiencew

11:50 | Round Table III: Measuring socio-regulatory (policy) Impacts

Moderator: ***Claire Jolly (OECD)***

- **Marc De Vries** (The Greenland) and Erik Willen (Skogforsk – Swedish Forest Research Institute)
- Outputs from the SeBS study and the example of forest management in Sweden (Link)
- **Katarzyna Pogorzelska** (EC JRC) – Advancing the measurement of EO value: the TES methodology (Link)
- **Jason Gallo** (Institute for Defense Analysis) – Importance of Attribution for Assessing the Policy and Regulatory Impact of Earth Observations (Link)
- **Glenn Vancauwenberghe** (KU Leuven) - Uptake of EO/Copernicus data for improving the performance of work processes (Link)

- Open discussion with the audience

14:00 | Round Table IV: Measuring impacts on innovation & entrepreneurship

Moderator: ***Massimo Florio (University of Milan)***

- **Dimitri Papadakis** (Evenflow/EARSC) and Stefan Józefowicz (SatAgro) - Outputs from the SeBS study and the example of Farming in Poland (Link)
- **Andy Coote** (ConsultingWhere) - The UK location industry - a market survey (Link)
- **Amanda Regan** (ESA) - Impact of EO on innovation and entrepreneurship at ESA (Link)

- Open discussion with the audience

15:45 | Round Table V: Measuring impacts on advancements in understanding (in science and technology)

Moderator: ***Alessandra Tassa (ESA)***

- **Dimitri Papadakis** (Evenflow/EARSC) – Outputs from the SeBS study (Link)
- **Stijn Vermoot**e (European Centre for Medium- Range Weather Forecasts ECMWF) - EO data and its impacts on operational weather and climate services (Link)
- **Karl Benedict** (Earth Science Information Partners) - Assessing community impact: a sample of ESIP's activities (Link)
- **Imraan Saloojee** (South Africa Space Agency) Economic impacts of space in South Africa (Link)

- Open discussion with the audience

17:00 | Tying it all together: open discussion looking across the Roundtables

Moderator: ***Cynthia Lodge (USGS)***

18:00 | Close of 2nd Day

DAY 3 - THE WAY AHEAD: AREAS FOR IMPROVEMENT AND RECOMMENDATIONS FOR NEXT STEPS

09:00 | Overview of the day

09:15 | Splinter Sessions Part A

- Group 1 Moderator: **Mary Ann Kutny** | Rapporteur: **Bob Downs**
- Group 2 Moderator: **Nikolai Khabarov** | Rapporteur: **Chady Jabbour**
- Group 3 Moderator: **Steve Ramage** | Rapporteur: **Crista Straub**
- Group 4 Moderator: **Jay Pearlman** | Rapporteur: **Jared Berenter**

11:15 | Splinter Sessions Part B

12:30 | Lunch in the ESRIN canteen

13:30 | Round Table: summary areas for improvements (Link)

Moderators: **Stephen Coulson (ESA) and Sarah Ryker (USGS)**

15:00 | Round Table: conclusions and recommendations for next steps (Link)

Moderators: **Geoff Sawyer (EARSC) and Francoise Pearlman (FourBridges)**

16:10 | Conclusive remarks

Alessandra Tassa (ESA), Carl Shapiro (USGS)

16:30 | End of workshop

LIST OF WORKSHOP ATTENDEES

Name	Affiliation
Josef Aschbacher	ESA
Cynthia Lodge	USGS
Kamil Kiljanski	EC
Rudy Aernaudt	EC
Claire Jolly	OECD
Steven Ramage	GEO
Carl Shapiro	USGS
Mary Anne Kutny	NOAA
Charlotte Mathieu	ESA
Marc Doherty	ESA
Michael Obersteiner	IIASA
Yakob Mudesir Seid	UN
David Haight	CSA
Alessandra Tassa	ESA
Geoff Sawyer	EARSC
Steven Krekels	VITO
Martina Sindelar	EC
Alan Smart	ACIL
Crista Straub	USGS
Lef Mamais	Evenflow/EARSC
Stefan Józefowicz	SatAgro
Joe Silke	Irish Marine Institute
Andrus Meiner	EEA
Sarah Ryker	USGS
Marc de Vries	The Greenland
Erik Willen	Sweden
Katarzyna Pogorzelska	JRC
Jason Gallo	Inst. Defence Analysis
Glenn Vancauwenberghe	KU Leuven
Dimitri Papadakis	Evenflow/EARSC
Andy Coote	ConsultingWhere
Amanda Regan	ESA
Stijn Vermoote	ECMWF
Karl Benedict	Earth Science Information Partnership
Imraan Saloojee	SANSA
Jay Pearlman	FourBridges
Francoise Pearlman	FourBridges
Cristina Andra Vrinceanu	ESA
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Gaetano Volpe	Penta technology
Emanuela Sirtori	CSIL Milan
Alessandra Caputo	CSIL Milan

Name	Affiliation
Greg Sadler	London Economics
Davide Vurchio	University of Milan
Julie Autuly	ESA
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Michele Castorina	ESA
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Valentina Morretta	University of Milan
Sandra Cabrera Alverado	University of Luxemburg
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Simon Jutz	ESA
Steven Krekels	VITO
Robert Meisner	ESA
Stephen Coulson	ESA
Ivan Petiteville	ESA
Rob van de Velde	Geonovum
Robert Downs	Columbia University
Chris Oligschlaeger	EARSC
Nikolay Khabarov	IIASA
Jared Berenter	MSI
Massimo Florio	Univ Milan
Bartosz Buszke	Wasat
Stefano Clo	University of Florence

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These notes were prepared by the organizing committee on our best recollection of the main discussions. They shall in no way be taken to reflect the official opinion of the European Space Agency, the US Geological Survey, the National Oceanic and Atmosphere Administration, the European Commission.

The organizing committee was composed by: Alessandra Tassa and Paola Berretta (ESA), Geoff Sawyer and Christopher Oligschlaeger (EARSC), Jay Pearlman and Francoise Pearlman (FourBridges), Carl Shapiro (USGS) and Monica Grasso (NOAA).

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We also thank the other workshop participants, whose comments and questions contributed to stimulate the debates.

Part of the Organizing Committee and a well-deserved relaxing sunset in Frascati at the end of the workshop.

The organisers

The European Space Agency (ESA) co-organised and hosted the Workshop at its premises in the ESRIN centre located in Frascati (Italy). ESRIN is ESA's centre for Earth Observations. GEOvalue is an international community with focus on the value and socioeconomic impacts of geospatial information for decision-making. The US Geological Survey (USGS), the U.S. National Oceanic and Atmospheric Administration (NOAA) and FourBridges participate in the GEOValue community and co-organised the workshop. The European Association of Remote Sensing Companies (EARSC) undertakes the Sentinels benefits study under an assignment from ESA funded by the European Union as part of the Copernicus Programme. The Project findings provide streamlined and concrete inputs for the Workshop. The European Commission (EC) manages the Copernicus programme and co-organised the workshop.