5 The socio-economic benefits of earth observation (EO): Insights from the end users of EO services and applications in Italy

Gelsomina Catalano, Csil, Italy

Valentina Morretta, University of Milan, Italy

Earth observation (EO) is a strategic and fast-changing domain of the space economy that increasingly contributes to the understanding, analysis and management of different natural and societal aspects of Earth. A range of socio-economic benefits may derive from the use of EO data. This chapter aims to identify the benefits accrued by end users of EO services and applications, on which there is scarce evidence in the literature. With the objective of filling in this gap, the chapter relies on a survey distributed to the end users of EO services in Italy, a country which is active along the whole value chain of the space economy.

Introduction

Earth Observation (EO) is a strategic and fast-changing domain of the space economy. It consists of collecting chemical, biological and physical data and imagery of planet Earth via remote sensing technologies (GEO, 2020[1]; Onoda and Young, 2017[2]).

In recent years, EO infrastructure, particularly the number of satellites, has rapidly grown (Bryce Space and Technology, 2018[3]). Recent advancements in space manufacturing and digital technologies, in addition to increasingly attractive market opportunities, have fostered the involvement of the private sector along the entire value chain within the "new space" economy paradigm (Weinzierl, 2018[4]). While the public sector still drives the industry, commercially-driven space projects and their economic exploitation for commercial reasons have also become salient. The satellite database of the Union of Concerned Scientists counts more than 1 000 operational earth satellites in orbit (OECD, 2023[5]), allowing observation of phenomena that would otherwise be difficult and expensive to monitor from the ground with the same optimal coverage, accuracy and consistency.

PwC (2019[6]) estimated the global EO economy in 2017 between EUR 9.6 and 9.8 billion, only considering sales of EO satellites (the so-called upstream sector) and EO data acquisition, their processing and transformation into products, services and applications for end users (the downstream sector). However, these numbers capture only a tiny portion of the potential socio-economic impact of EO. For example, in Europe, the European Space Agency (ESA) has invested heavily in developing satellites dedicated to EO, particularly the Sentinels satellites of the Copernicus programme. According to PwC (2019[6]), investments in the European Copernicus programme – which equalled EUR 8.2 billion between 2008 and 2020 - could generate between EUR 16.2 and EUR 21.3 billion in the coming years. This excludes non-monetary benefits and considers the added value created in the upstream industry, the sales of services and applications developed in the downstream sector, and the benefits deriving from the exploitation of these services by the end users in different fields.

EO is increasingly contributing to the understanding, analysis and management of different natural and societal aspects of planet Earth, with relevant socio-economic and environmental implications. A growing variety of innovative services and applications using EO data have risen in prominence across a variety of different sectors, including climate change monitoring, human health prevention, agriculture efficiency, urban planning, ecosystems and civil protection (NEREUS, Commission and ESA, 2018[7]; Daraio et al., 2014[8]; PwC, 2019[6]).

The socio-economic benefits deriving from EO programmes are broad. Different stakeholders along the EO value chain may directly or indirectly take advantage of investments in EO, including firms operating in the industrial and information and communications technology (ICT) sectors, research institutes, scientists, and civil society (Morretta, Vurchio and Carrazza, 2022[9]).

Among European countries, Italy has a long tradition in the space sector. It is one of the few countries to actively operate along the whole EO value chain from the upstream industry (given its predominant role in the manufacturing of cutting-edge satellites) to downstream activities with high-value-added services, mainly developed and managed by small and medium-sized enterprises (Lupi and Morretta, 2022[10]; Ministero delle Impresse e del Made in Italy, 2019[11]). The growing availability of satellite data, together with advancement in ICT technologies – pushed by the development of powerful processors and machine learning – is contributing to the exponential growth of the downstream segment of the value chain (Probst, Pedersen and Dakkak-Arnoux, 2017[12]) and, therefore to the creation of new services and applications in a wide range of fields.

While recent studies have investigated the magnitude and characteristics of the Italian downstream market (e.g. firms that develop EO services and applications for end users) (Lupi and Morretta, 2022[10]), very little is known about the end users of such services and applications. Additionally, an evaluation of the benefits

deriving from such services and applications has never been carried out in Italy, except for some very narrow case studies (NEREUS, Commission and ESA, 2018[7]; Sawyer and Khabarov, 2022[13]).

In this chapter, the authors contribute to filling in this gap by focusing exclusively on the benefits accrued by end users of EO services and applications, such as national and local governments, public and private firms and individuals who use these applications or services in a wide range of fields. More specifically, the authors focus on the economic benefits that direct end users gain through the use of such services, such as increased efficacy and efficiency. At the same time, the authors exclude the benefits accrued by other indirect users and society at large. The social and environmental impacts of EO service on these latter categories have the potential to be large but are often left unexpressed and unmeasured and are thus beyond the scope of this study.

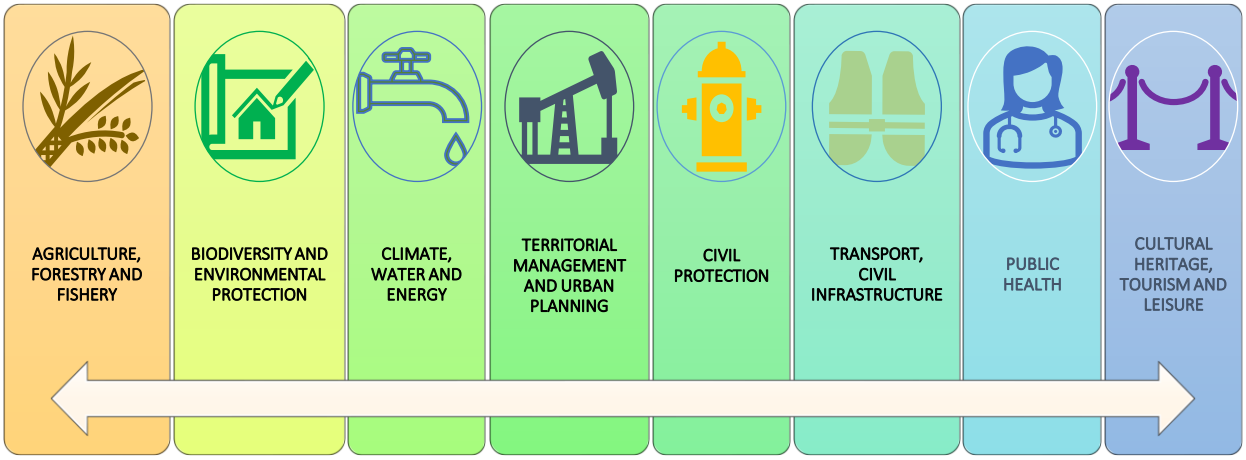
From this perspective, the authors aim to answer the following research questions: i) Who are the end users of EO services and applications in the Italian market? ii) What benefits may stem from using such services? iii) What barriers are currently hindering the development of this sector in Italy?

The final use of EO services and data: a brief overview of the literature

Identifying and investigating EO adoption areas is crucial to disentangling who the current and potential end users of EO are, and the economic benefits that they can experience. The existing literature on this topic is rich and allows us to pinpoint the main areas in which EO end users operate beyond military applications. For example, NEREUS et al. (2018[7]) report 99 end users' successful stories, highlighting how EU public administrations (being one of the most representative but not exclusive end users of EO services) are using Copernicus data to improve the quality of life of European citizens. The studies are grouped around several domains, as reported Figure 5.1.

The European Association of Remote Sensing Companies (EARSC) also monitors the new areas of EO implementation in the framework of the Sentinel Economic Benefits Study (SeBS), which provides valuable examples and case studies and seeks to identify and evaluate EO benefits.

Figure 5.1. End users' adoption areas of EO services



Thanks to the use of EO, direct end users can gain economic benefits when delivering their usual or innovative services to groups of citizens (e.g. in the case of governments) or customers (e.g. in the case of companies). Such benefits typically include saving costs, increasing revenues, gaining efficiency and increasing efficacy and quality. Other types of benefits may be reputational and strategic, among others.

A key example of this can be observed through the use of EO in the agriculture sector. Sawyer, Oligschläger and Oligschläger (2019[14]) present the case of an application using EO data by Belgian potato farmers to obtain information on field management. This application provides farmers with timely information regarding the optimal time to irrigate, plant and fertilise their crops, using satellite imagery of vegetation colour. This was estimated to increase yields by up to 20% and improve the overall quality of the potatoes farmed. The adoption of the app contributed to increasing revenues and income for the farmers and produced indirect economic benefits for the whole potato industry value chain (including agronomists, consultants, processors, distributors, supermarkets) up to the final consumers.

In the realm of forestry and environmental protection, Sawyer, Dubost and Vries (2016[15]) examined the impact of satellite imagery on forest management by the Swedish public administration. In this case, the designed EO service contributed to a decrease in illegal logging and a lack of immediate replanting and pre-commercial thinning. The cost of collecting satellite imageries was EUR 64 000 relative to a benefit of between EUR 16.1 and EUR 21.6 million per annum. Direct economic benefits derived from a decreased cost of physical inspections using aircraft, in addition to the long-term value increase as a result of higher timber quality and production volumes.

Examples of the use of EO services in climate, water and energy are also common. For instance, weather forecast information is increasingly used by decision makers to ensure the safety of the population, protect property, and add value to the economy (EUMETSTAT, 2014[16]). In energy, Leibrand et al. (2019[17]) review how many existing EO applications support rural electrification planning, renewable energy resource assessment, grid operation and reliability, as well as disaster risk reduction in interruption of the service.

In territorial management and urban planning, EO services are increasingly supporting public administrations in building more efficient and resilient urban transport facilities. For example, in Norway, a new service showing ground motion based on EO data contributes to saving costs in the construction and management of road infrastructure (Sawyer, Boyle and Khabarov, 2020[18]). In Italy, a similar service is used by Azienda Nazionale Autonoma delle Strade and produced an economic benefit of between EUR 3.8 and EUR 8.6 million per annum, predominantly influenced by a reduction in construction and monitoring highways, plus other societal and environmental benefits (Sawyer and Khabarov, 2022[13]).

The use of EO in civil protection is also extremely valuable, where advanced EO services have been extensively used to support crisis managers, civil protection authorities, and humanitarian aid actors dealing with natural disasters (e.g. earthquakes and landslides), human-made emergency situations, humanitarian crises and disaster risk reduction and recovery activities. For example, a report by NASA (2013[19]) using the "Value of Information" approach found that the use of EO data during the Eyjafjallajökull eruption in 2010 reduced the probability of an aircraft experiencing a volcanic ash incident by approximately 12%, saving USD 25–72 million in avoided revenue losses caused by unnecessary flight delays and aircraft damage costs.

In cultural heritage, EO contributes to tangible cultural heritage preservation and management and has been increasingly used by agencies such as the United Nations Educational, Scientific and Cultural Organization thanks to ad hoc services dedicated to archaeological site identification and monitoring, land-use change maps, natural subsidence, ground motion detection, bathymetry and climate change indicators.

In public health, EO services provide alerts on air quality, outbreaks of disease carried by water-borne vectors or insects, and assessments of access to health facilities, among other uses. As reported in Florio and Morretta (2021[20]), Dawes et al. (2013[21]) carried out a case study illustrating the benefits of EO data in monitoring air quality in some remote areas of the United States. In monetary terms, their analysis shows that satellites provide timely $PM_{2.5}$ information to 82% of the 18.1 million people currently living in unmonitored areas at no additional cost. In contrast, the purchase, installation, and operation of ground infrastructures would have cost USD 25.9 million and covered only 44% of those unmonitored people in the subsequent five years.

The above are just selected examples. The high quantity of information provided by EO data, coupled with rapid advances in artificial intelligence, has led to a constant increase in the applications and services benefiting from EO data. Its use has been extended to services monitoring oil spills in the Mediterranean Sea, in addition to applications in agri-tech solutions, biodiversity and ecosystems loss; climate services; emergency management; fisheries; infrastructure; insurance; road and automotive sectors; maritime and inland waterways; and urban development. However, the existing literature mainly focuses on identifying and describing successful stories and case studies worldwide, restricting our understanding of the impact of EO services in specific country contexts, and inhibiting the detection of other sectors that could benefit from EO adoption in the future.

Method

Ideally, economic benefits should be appraised by looking at the incremental revenues, added efficacy or efficiency (or other profit margins) of end users delivering a public/private service, using a sample comprised of units using an EO service, and a counterfactual group providing the same service without using EO. However, since this analysis is not specific to a single EO service but rather aims to provide a general overview of the Italian market by looking at different users, services and fields of application, this analysis uses primary data collected through an online survey disseminated with the support of the Italian Space Agency. The survey is based on approximately 30 semi-structured questions to explore i) who are the main end users of the services/applications offered, in which sectors they operate and how they use the service; (ii) to what extent the use of EO services in their field contributes to their economic performance, according to their perceptions; and (iii) what factors may promote or hamper their diffusion among end users. Most questions exploit a Likert scale ranging from 1 to 5.

The survey ran over six months (launched on 30 April 2022 and closed on 30 November 2022) and targeted 3 235 potential users, whose contacts were collected from different sources. A list of potential users of EO services had not previously been built. This study's contribution fills in this gap by having gradually collected contacts from different sources, including interviews with key stakeholders (e.g. speakers at relevant conferences - Prisma, ESA events, etc. COSMO-SkyMED users), Orbis databases (by selecting large companies operating in sectors where, according to the literature, the use of EO is more relevant, such as construction, agriculture, forestry and fishing, transport, mining industries, etc.), firms carrying out precision farming, national, regional and local authorities involved in civil protection, municipal companies involved in the delivery of services of general interests (e.g. water and wastewater supply, sewage collection, etc.). The invitations were sent by email, presenting the reasons and objectives of the survey and indicating the access link to the questionnaire. The survey was conducted with Computer Assisted Web Interviewing methodology and had a dedicated telephone and email assistance service to solicit answers.

Overall, the authors collected information from 106 respondents who use EO services and applications which are either internally developed or purchased by third parties.

Main results

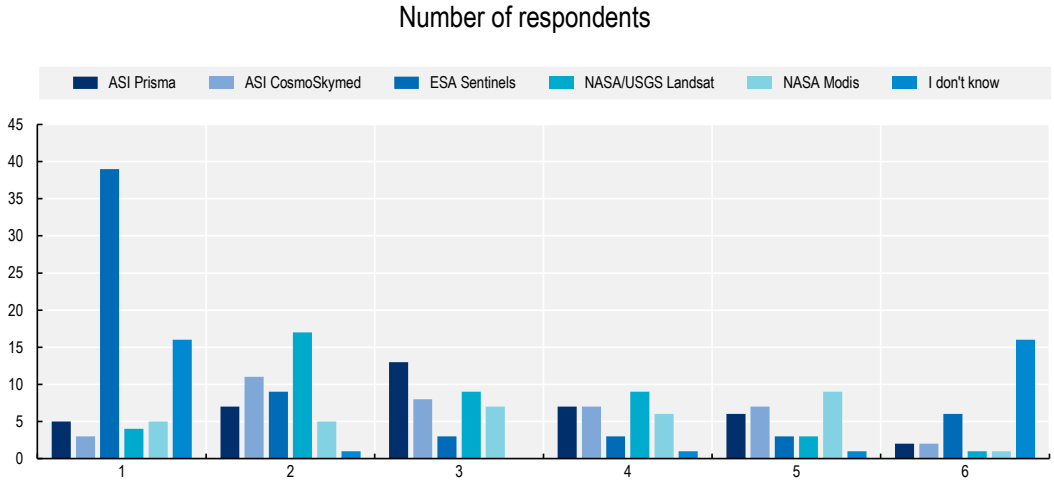
EO users' profiles and their use of EO services and applications

The 106 users of EO services and applications answering the survey are mostly territorial public bodies (31%) or national public bodies (18%), followed by private (14%) and public-owned companies (10%), municipalities (11%), regions (10%), national government (2%) and others (3% e.g. research entities). They are mostly large or medium-sized institutions/companies (49% and 18% respectively), accounting for more than 150 employees. Their headquarters are mostly located in the north and centre of Italy (41% and

36% respectively), with the highest number concentrated in large cities such as Rome and Milan. Over a third (36%) of respondents operate in the public administration and are responsible for managing housing construction and regional planning projects; ensuring environmental protection; carrying out activities of the fire brigade and civil protection; general planning activities; and general statistical services. The sample also includes a high portion of respondents (10%) dealing with professional, scientific and technical activities (including weather forecasting), with the supply of water, sewerage, waste management and remediation activities (12%), as well as working in the agriculture, forestry and fishing sectors (9%).

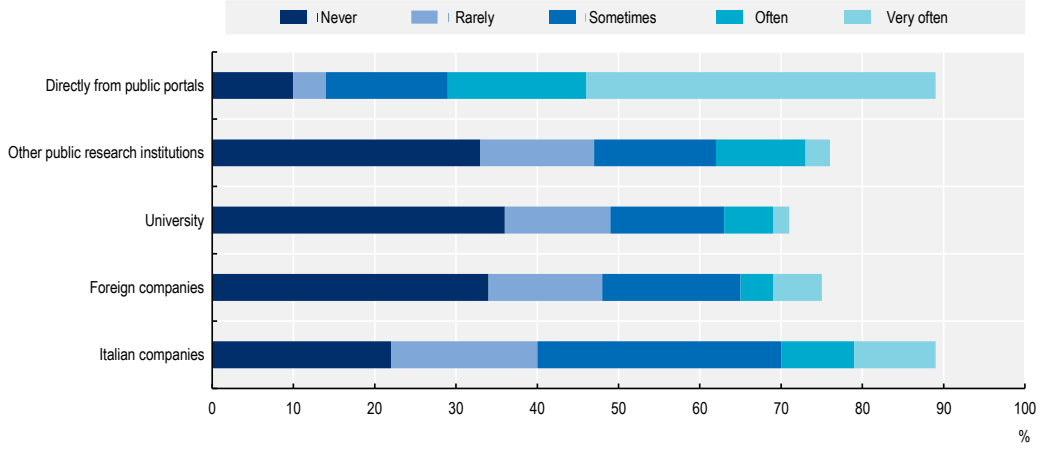
The majority of respondents (87%) use EO services and applications which rely on data provided by satellites. ESA Sentinels rank first amongst data providers, followed by NASA Landsat and ASI Prisma (Figure 5.2). Over three quarters (80%) of user respondents also declare that EO services and applications that they use take data from drones and/or aerial images. The acquisition of this data mostly occurs directly from public portals and or Italian companies, whilst rarely from foreign companies, universities or other public institutions (Figure 5.3).

Figure 5.2. Most frequently used satellite data providers for EO services/applications



Notes: The frequency scale ranges from 1 (most frequent) to 6 (least frequent). N=106.

Figure 5.3. Main sources of EO services and applications



Amongst respondents, there is a significant number (55 out of 106 users) who use EO services and applications which have been internally developed or both internally and externally provided. The most effective channels to obtain knowledge about EO services and applications are through direct contacts (65 respondents), and participation in research programmes/project (55 respondents).

A certain level of experience with the use of these services and applications has been detected among the surveyed respondents (Figure 5.4). The institutions and companies where respondents currently work predominantly started using EO services and applications over the last 10 years (51 respondents, 48%); a significant number of respondents (30, 28%) declared that their institutions started to use these applications and services between 10-20 years ago while a relatively low number of respondents (21, 20%) starting more than 20 years ago.

Figure 5.4. Respondents' years of experience in using EO services/applications

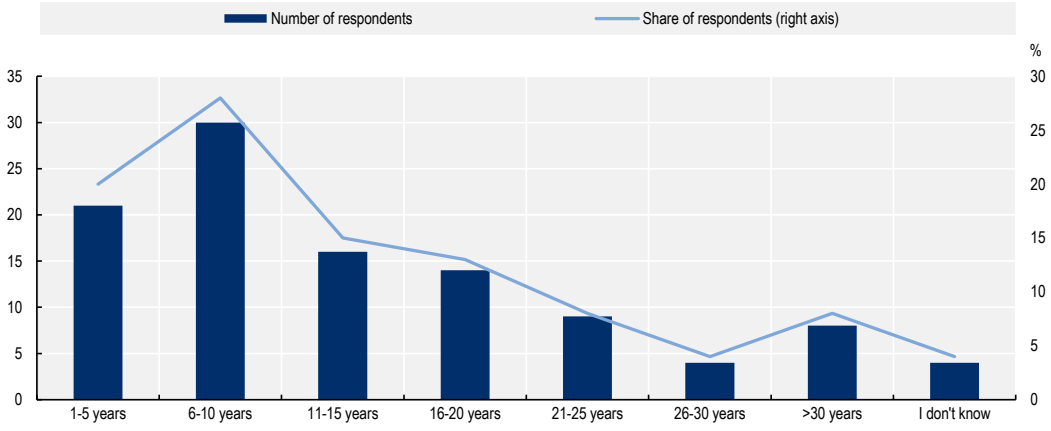
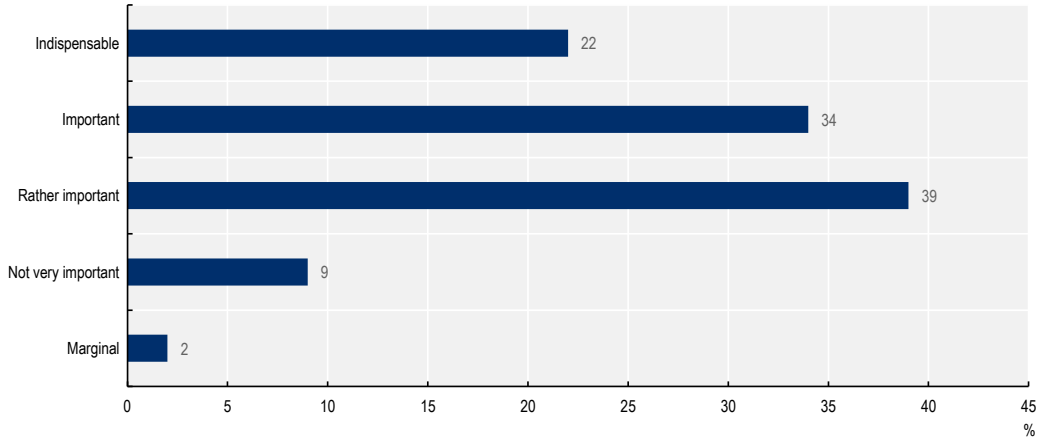


Figure 5.5. The importance of the use of EO services/applications for daily activities

Number and share (%) of respondents



Overall, more than half of the respondents agree that the use of these applications and services is important, or even indispensable, for the daily activities carried out at their institutions/companies (Figure 5.5). The evidence collected confirms that EO data are used for a variety of purposes: detecting inefficiencies in the transport sector and identifying the restoring interventions that are needed; monitoring territories and coastlines to prevent natural risks (e.g. headquarters, flooding, etc.); planning and designing environmental and urban interventions; monitoring specific areas subject to environmental crimes, as well

as marine and coastal areas (chlorophyll, turbidity, algal blooms, dispersion of floating waste, etc.); monitoring and classifying land use; providing licences for mining activities; reconstructing glacier perimeters to detect glacial lakes; analysing and monitoring cultivated areas; monitoring weather and supporting flight planning; monitoring water loss and planning restoring interventions; developing cartographic rendering; and assessing the technical feasibility of new infrastructure.

The socio-economic benefits of EO services and applications

The use of EO services and applications has allowed the majority of respondents to improve the quality of the products and services offered (57% of respondents agreed), R&D capabilities (56%), and the efficiency of production processes and/or service provision (51%), as shown in Figure 5.6. The use of these services and applications also contributes to increased collaborations with other subjects (38%) and the development of new services and products (42%), new software and technologies (30%), and new research projects (34%). Conversely, the contribution of EO services and applications was limited in the development of new trademarks and registered patents (52% of respondents disagreed), in entering new markets and industries, and in starting a new business or research and development unit.

Figure 5.6. Miscellaneous benefits from the use of EO services/applications

Share (%) of respondents

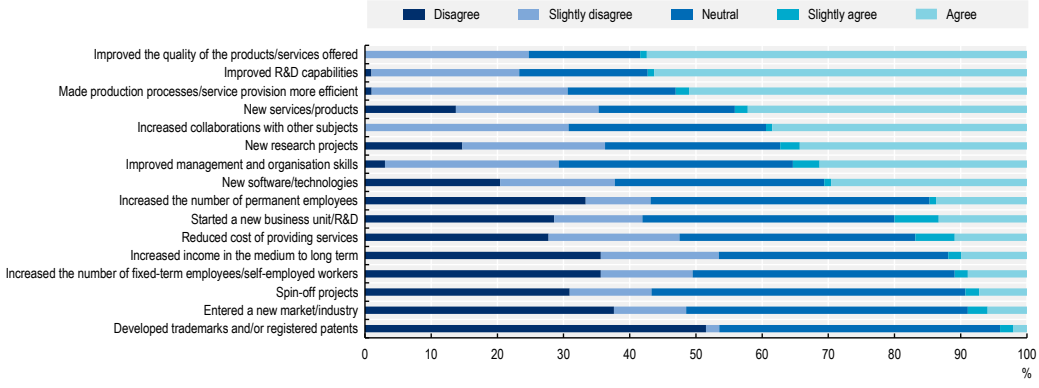
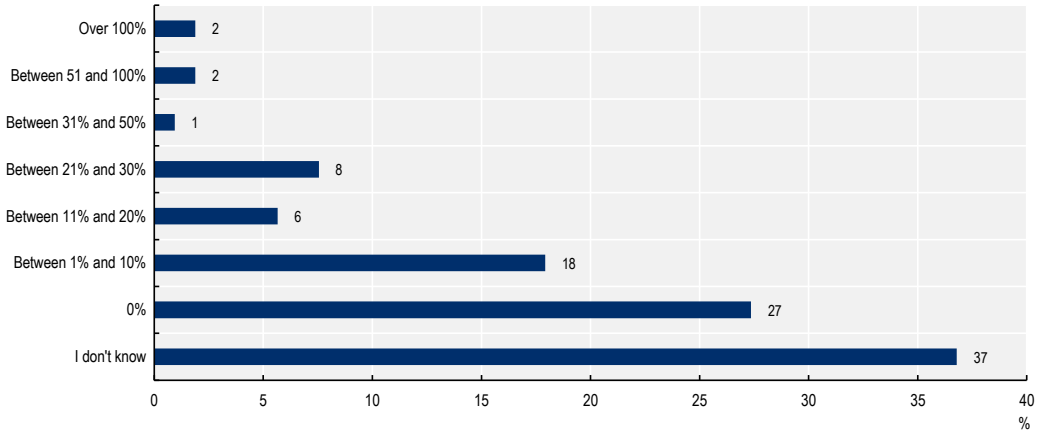


Figure 5.7. EO services and applications' contribution to average increases in revenue

Trend observed between 2019 - 2022, number and share (%) of respondents



The majority of respondents were not able to answer the questions about how much the use of these services and applications allowed them to increase revenues (37% declared “I don’t know”) or to reduce production costs (41% declared “I don’t know”) (Figure 5.7). A significant percentage of respondents suggested that the use of EO services and applications had no effect on either revenues or production costs (27% and 24% respectively). They mostly ascribe this trend to the effects of COVID-19, which slowed down sales and production processes. They would have declared a higher impact considering the trend observed over the last ten years. Nevertheless, it is worth pointing out that 38% of respondents observed a positive effect on revenues, mostly in the range of 1-30%. Additionally, 30% of user respondents reported a reduction in production costs resulting from the use of EO services and applications in the range of 1-30% (Figure 5.8).

Figure 5.8. EO services and applications’ contribution to reducing production/provision costs

Trend observed between 2019 - 2022, number and share (%) of respondents

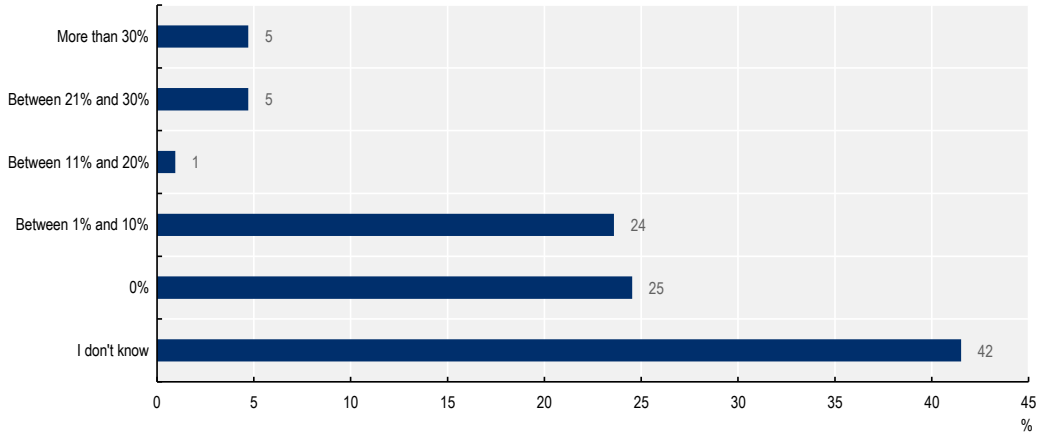
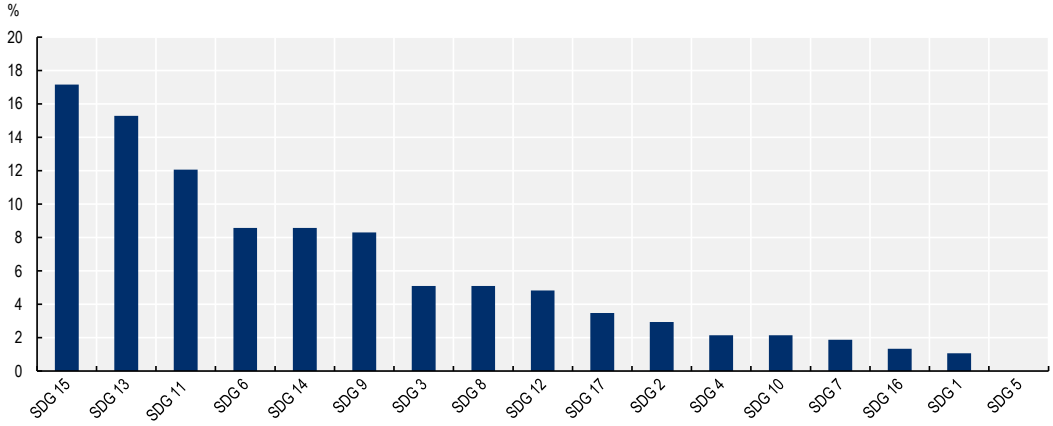


Figure 5.9. Organisations’ contribution to Sustainable Development Goals thanks to the use of EO

Number of respondents, multiple answers allowed



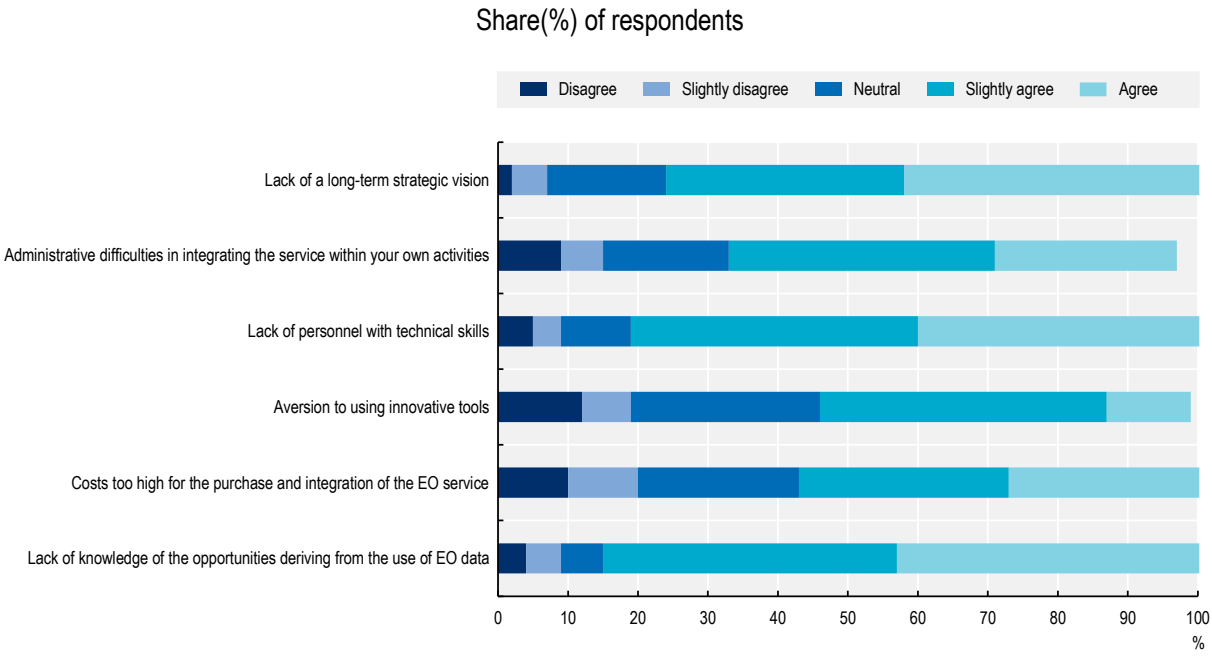
Thanks to the use of EO services and applications, respondents confirmed that they were also contributing to the achievement of Sustainable Development Goals (SDGs), and in particular to SDG 15 (to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss), SDG 13 (to take urgent

action to combat climate change and its impacts), SDG 11 (to make cities and human settlements inclusive, safe, resilient and sustainable), SDG 14 (to conserve and sustainably use the oceans, seas and marine resources for sustainable development), SDG 6 (to ensure availability and sustainable management of water and sanitation for all) and SDG 9 (to build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation), as shown in Figure 5.9.

Obstacles to the use of EO services and applications

According to their experience, respondents largely agree that the factors which mostly hamper the diffusion and use of EO services and applications in Italy include: the lack of knowledge of the opportunities deriving from the use (45% of respondents); the lack of a long-term strategic vision (43%); and the lack of personnel with technical skills (see Figure 5.10). Regarding the required expertise (Figure 5.11), the majority of respondents report that they face difficulties in finding and hiring qualified personnel who know how to effectively use EO services and applications (33% of respondents face this issue often, 22% sometimes, and 10% always). To ensure an effective use of these services and applications, they mostly need engineers, computer scientists and geologists. One respondent also mentions agronomists, experts in geographical information systems and data scientists.

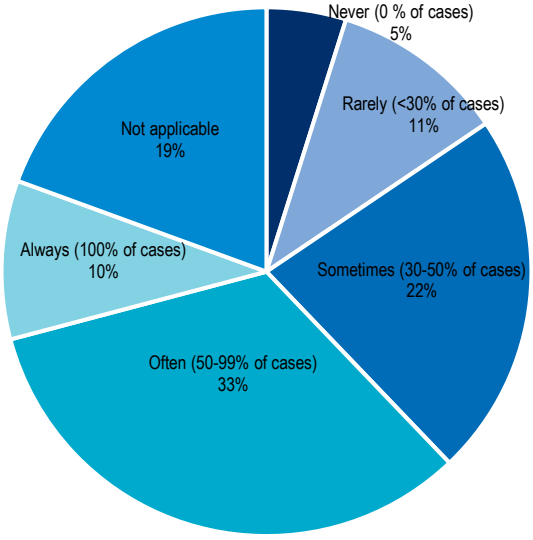
Figure 5.10. Main factors hampering the diffusion and use of EO services and applications in Italy



Despite these difficulties, respondents confirm their willingness not only to use existing but also new EO services and applications in the future. Some of them expect that their use will be enhanced for monitoring water service infrastructure, as well as for the prevention of natural disasters (e.g. flooding), supporting the restoration of natural habitats and fostering the development of precision agriculture.

Figure 5.11. Difficulty finding/hiring qualified personnel

Share (%) of respondents



Conclusions and next steps

This chapter contributes to gaps in the existing literature by providing an assessment of the benefits derived from EO services and applications from the perspective of end users. An evaluation of the benefits derived from such services and applications had previously never been carried out, except in the context of narrow case studies, and acts as a fundamental exercise to fully assess the potential impact of EO.

The analysis specifically focuses on the Italian economy, and the results confirm the use of EO services and applications by end users covering a range of purposes. Based on the evidence collected, the authors can draw the following conclusions:

- Survey respondents reporting the use of EO services and applications are mostly territorial public bodies (31%) or national public bodies (18%), followed by private (14%) and public-owned companies (10%), municipalities (11%), regions (10%), national government (2%) and others (3% e.g. research entities). They are mostly large or medium institutions or companies (49% and 18% respectively), accounting for more than 150 employees; their headquarters are mostly located in the north and centre of Italy (41% and 36% respectively), with the highest number concentrated in large cities, such as Rome and Milan.
- The majority of respondents (87%) use EO services and applications which rely on data provided by satellites. ESA Sentinels rank first amongst data providers, followed by NASA Landsat and ASI Prisma. Eighty per cent of respondents also declare that EO services and applications they use take data from drone and/or aerial images. The acquisition of this data mostly occurs directly from public portals and or Italian companies, rather than from foreign companies, universities or other public institutions.
- The results suggest that the use of EO services and applications has allowed the majority of respondents to improve the quality of the products and services offered (57% of respondents agreed), R&D capabilities (56%), and the efficiency of production processes and/or service provision (51%). There is also evidence that the use of these services and applications contributes to increased collaborations with other subjects (38%) and the development of new services and products (42%), new software and technologies (30%), and new research projects (34%).

- Conversely, the contribution of EO services and applications was limited in the development of new trademarks and registered patents (52% of respondents disagreed), in entering new markets and industries (38% disagreed), and in starting a new business or research and development unit (29% disagreed).
- According to their experience, respondents largely agreed that the factors hampering the diffusion and use of EO services and applications in Italy include the lack of knowledge of the opportunities deriving from the use (45%), the lack of a long-term strategic vision (43%), and the lack of personnel with technical skills (41%).
- Regarding expertise, the majority of respondents report that they face difficulties in finding and hiring qualified personnel who know how to effectively use EO services and applications, especially among engineers, computer scientists and geologists. Despite these difficulties, user respondents confirm their willingness to use both existing and new EO services and applications in the future.

The authors are aware that their results would need additional and complementary analysis to produce more robust findings. They can consequently be considered as simulations of what-if scenarios trying to assess the potentialities of earth observation for the Italian economy. Beyond providing preliminary predictions of the benefits accruing to end users from EO services and applications, this exercise points to some methodological findings which can be taken into account for future research and replications in other countries.

- Having a large, comprehensive database of potential users of EO services and applications is a crucial starting point for this type of analysis. This would require some time to be built. From the authors' experience, both desk research (e.g. on public authorities portals, speakers at relevant conferences, etc.), as well as consultations with sectoral stakeholders (e.g. firms belonging to relevant sectors), and national public agencies are relevant sources which can be used for this purpose.
- A concise and efficient questionnaire, including mostly closed questions, should be drafted and fine-tuned before the launch of the survey based on tests with 4-5 selected stakeholders.
- The questionnaire should be uploaded on a web platform (e.g. SurveyMonkey) which is easily accessible to respondents.
- A management survey plan should be adopted to solicit answers. The plan should define the timing and approach to send reminders, either by email or phone calls. Also, it should detail the allocation of resources (e.g. time of the staff involved) to carry out this activity.
- If needed, the evidence collected through the survey may be complemented with in-depth interviews with selected stakeholders. This complementary evidence may help in the interpretation of results.

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