# Global Development Assistance

## Wider Economic Benefits from Satellite Earth Observation in Developing Countries

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# Contents

# Glossary

Key definitions used in this study are outlined in section 2.1. Other technical terms and acronyms are included in the list below.

| | |
|---|---|
| **ADB** | Asian Development Bank |
| **AI** | Artificial Intelligence |
| **AWS** | Amazon Web Services |
| **CAGR** | Compound Annual Growth Rate |
| **CDR** | Call Detail Record |
| **CEOS** | Committee on Earth Observation Satellites |
| **DAC** | Development Assistance Committee |
| **DETF** | Digital Economy Task Force |
| **EO** | Earth Observation |
| **EO4SD** | Earth Observation for Sustainable Development |
| **ESA** | European Space Agency |
| **EU** | European Union |
| **EUSPA** | European Union Agency for the Space Programme |
| **GCP** | Google Cloud Platform |
| **GDA** | Global Development Assistance |
| **GEO** | Group on Earth Observation |
| **GIS** | Geographical Information Systems |
| **ICT** | Information and Communications Technology |
| **IFI** | International Financial Institutions |
| **IGIF** | Integrated Geospatial Information Framework |
| **INSPIRE** | European Union Directive to create an EU data infrastructure for environmental policies |
| **IoT** | Internet of Things |
| **IPP** | UK International Partnership Programme |
| **LDC** | Least Developed Countries |
| **M&E** | Monitoring and Evaluation |
| **ML** | Machine Learning |
| **MNC** | Multinational Corporations |
| **NRT** | Near Real Time |
| **OECD** | Organisation for Economic Co-operation and Development |
| **PII** | Personal Identifiable Information |
| **R&D** | Research and Development |
| **RCC** | Regional Climate Centres |
| **REDD+** | Reducing Emissions from Deforestation and Forest Degradation |
| **SaaS** | Software as a Service |
| **SAR** | Synthetic Aperture Radar |
| **UNGGIM** | UN Committee of Experts on Global Geospatial Information Management |
| **UNOOSA** | United Nations Office for Outer Space Affairs |
| **UNSDI** | United Nations Spatial Data Infrastructure |
| **WB** | World Bank |
| **WMO** | World Meteorological Organization |

# Executive Summary

## Context

This report has been commissioned by the European Space Agency (ESA) under its Global Development Assistance (GDA) programme. GDA has a mission to accelerate impact by fully capitalising on the power of satellite Earth Observation (EO) in international development assistance operations. The GDA programme is implemented by ESA in partnership with the World Bank (WB) and Asian Development Bank (ADB)—under the *Space for International Development Assistance (Space for IDA)* cooperation framework.

It is published as part of the Monitoring & Evaluation (M&E) and Impact Assessment activity led by Caribou Space with consortium members London Economics and Imperative Space.[1] This report will strengthen the evidence that EO activities generate wider benefits for developing countries, in terms of innovation, entrepreneurship, and job creation, in addition to the direct benefits to users of these applications that are already well evidenced. These benefits should be considered by IFIs, , National Development Agencies (NDA), and the broader development community during the planning, design, and execution of EO projects in developing countries.

GDA is building on a long history of ESA addressing sustainable development issues with the International Financial Institutions (IFIs) which started in 2008, raising **awareness** among IFIs and stakeholders in developing countries about the potential of EO in addressing key development challenges. More recently the Earth Observation for Sustainable Development (EO4SD) initiative facilitated significant increase of development practitioners' **acceptance** of using EO services.[2] GDA is now capitalising on lessons learnt and the success of EO4SD, embarking on the path to full **adoption** of EO in global development.[3] An initial set of eight thematic areas (up to 12 in the future) have been identified as priority engagement areas.

**FIGURE 1:** GDA Thematic Areas (Grey Colour Upcoming)[4]


1 ESA, M&E and Impact Assessment, 2022, https://gda.esa.int/cross-cutting-area/me
2 ESA, Earth Observation for Sustainable Development, 2022, https://eo4sd.esa.int/
3 ESA, Accelerating Impact, 2022, https://gda.esa.int/
4 ESA GDA

Earth Observation (EO) is the focus of GDA as it has many attributes that are suitable for international development activities. EO satellites are used to gather information about the planet's physical, chemical, and biological systems via satellite-based platforms. The distance of these satellites from Earth means that they possess several strengths relative to aerial, in-situ, or manual methods of data collection. These strengths include affordability, coverage, speed, continuity, impartiality, and anonymity.

Sustainable development can be defined as *"development which meets the needs of the present without compromising the ability of future generations to meet their own needs"*.[5] EO's attributes support sustainable development, for example by improving agricultural yield; enhancing disaster resilience; more efficient and effective forest management; improving water management, and protecting the marine environment.

These benefits have been documented in ESA's publication with the Committee on Earth Observation Satellites (CEOS) *Satellite Earth Observations in Support of the Sustainable Development Goals* and Caribou Space's publication *Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development* (see Figure 2).[6] Other major organisations have also documented the benefits of EO in sustainable development including, but not limited to the Group on Earth Observations (GEO) and the United Nations Office for Outer Space Affairs (UNOOSA).[7]

As there is already substantial existing literature regarding the uses and impacts of EO in sustainable development, this is a not a major focus for this report. Instead, the primary objective of this report is to document the wider benefit of EO capabilities to other areas of the economy such as "digital spillovers."

**FIGURE 2:** Existing ESA and Caribou Space EO and Sustainable Development Reports


5 Caribou Space, Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development, 2020, https://www.caribou.space/wp-content/uploads/2020/07/Caribou-Space_ESA-EO-for-Agenda-2030-v2-1.pdf

6 ESA and CEOS, Satellite Earth Observations in Support of the Sustainable Development Goals, 2018, http://eohandbook.com/sdg/; Caribou Space, Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development, 2020, https://www.caribou.space/wp-content/uploads/2020/07/Caribou-Space_ESA-EO-for-Agenda-2030-v2-1.pdf

7 GEO, Earth Observations 2030 Agenda for Sustainable Development, 2017, https://earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf; UNOOSA, Space Supporting the Sustainable Development Goals, accessed October 2022, https://www.unoosa.org/oosa/en/ourwork/space4sdgs/index.html

## Key findings

- Developing countries have a small but growing contribution to the global EO industry. A total of 241 companies based in developing countries were active in the EO industry in 2019. Together, these companies contributed a total of **€82 million in revenues in 2019, or 2.2% of the global market**, and supported 1,250 employees. They represent a higher growth rate in the industry, with a **14% CAGR between 2012 and 2019**, compared to 9% for the industry as a whole.
- The low levels of involvement from developing countries are likely explained by the high capital cost associated with upstream activities and the required investments in digital capabilities, such as human and physical capital, software, and internet connectivity, that are needed for downstream activities.
- The investment in digital capabilities that are needed to exploit EO data for end users are likely to offer value to other parts of the economy. This is because these capabilities correspond with transferable human, physical, and intangible assets that can be diffused both within the EO sector and from the EO sector to other sectors.
- These 'digital spillovers' have been shown to accelerate knowledge transfer, productivity, and innovation within a company, between competitors, across supply chains, and across industries. The return on investment from digital technologies to the economy therefore exceeds the return to the private companies that make these investments, suggesting a role for government and the development community to improve the take-up of digital capabilities.
- These spillovers are likely to be more strongly felt by the parts of the economy that are closest to the EO services industry—in terms of geographic proximity, technological proximity, labour requirement, capital and enabling technology requirements. The 'digital economy'—defined broadly as those industries that leverage digital technologies as a key factor of production—shares many of these similar characteristics to the EO downstream industry and is therefore likely to benefit most from investments in the EO industry.
- The ability of the economy to absorb these technology spillovers depends on its 'absorptive capacity' to recognise, absorb, and utilise this knowledge. This suggests that investments in human and physical capital, enabling technologies, related R&D (including complementary investments in internet access, technical expertise, and IT) remains a key driver for generating innovation and spillovers.
- The economic return from investments in digital assets has been estimated at about US$20 for every US$1 invested—an estimate that is almost seven times greater than corresponding investments in non-digital assets. This suggests a high potential rate of return from investments in EO capabilities.

## Recommendations

The findings from this report suggest several recommendations for IFIs, , National Development Agencies, the broader development community, and developing countries to consider when considering EO projects:

1. **Importance of development finance:** As stated above because the return on investment from digital technologies to the economy exceeds the return to the private companies that make these investments, there is a clear role for government and the development community to ensure that socially optimal levels of investment in digital technologies like EO are obtained, e.g., through capacity building and skills transfer activities. In the context of GDA, this strongly justifies the involvement of IFI Institutional Partners as contributors of development finance, to amplify ESA's contribution of space finance.
2. **EO data procurement for developing countries:** There is a potential role for IFIs, the development community, and/or governments in supporting the procurement of EO data over developing countries (where data capture is otherwise low) to overcome the cost barriers to accessing data and allowing more equitable access. This would enable developing countries to exploit this data through a growing downstream industry focused on converting this data into value-added applications, rather than relying on domestic provision to generate this data at high cost. Support can take the form of subsidies for (commercial) EO data provision, or efforts to support collaboration e.g., via grouped procurement, to share the costs of provision across multiple users and reduce duplicate expenditures.
3. **Direct and indirect benefits:** In the context of the cooperation framework, IFIs should communicate in their outreach to to National Development Agencies that there are both direct benefits of EO for sustainable development to users, and wider benefits to the wider economy of developing countries because of the existence of technology spillovers.
4. **Value of involvement of European industry:** GDA is structured to partner the European EO service sector with IFIs and ultimately for developing country government counterparts. Evidence of the effectiveness of embedded subsidiaries of multi-national corporations in transmitting technology spillovers to their host countries suggest that there are benefits in supporting European industry to generate spillovers and to develop their local footprint and embeddedness in developing world countries that host their subsidiaries. There is therefore a dual benefit in terms of enabling new market growth for European industry and transferring knowledge to developing countries.
5. **Geographical concentration:** The importance of geographic proximity and clusters to the transmission of spillovers suggests that the number of developing countries that will grow mature downstream EO industries is limited. Therefore, the WB and ADB activities on capacity building and skills transfer might benefit from building and strengthening regional centres of excellence, and the development of regional networks, to ensure that the spillovers from these EO clusters are distributed widely.

6 **Risks and challenges remain:** Despite these benefits from EO, there are several associated challenges that policy makers in developing countries should be aware of. These challenges fall into two categories: 1) pre-existing barriers to the adoption of digital technologies (including EO), and 2) potential unintended consequences and adverse effects following adoption of digital technologies. Within the first category are issues including data security and sovereignty, and the requirement for training, whilst a potential unintended consequence is job displacement.

7 **Lack of literature on the indirect spillover benefits of EO:** Whilst the available literature on the direct benefits of EO for sustainable development is now established via efforts from ESA, Caribou Space and others, there is a major literature gap regarding the wider benefits of spillovers from EO to the wider economy. WB and ADB could attempt to address this gap by commissioning further research on this topic, for example via the WB Digital Earth Partnership and ADB EO for Development and Digital Transformation initiatives respectively.

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# Introduction

## Earth Observation (EO) satellites are used to gather information about the planet's physical, chemical, and biological systems via satellite-based platforms. Due to their distance from Earth, satellites possess several strengths relative to aerial, in-situ, or manual methods of data collection.

Thus, satellite-based EO platforms are suitable for monitoring previously inaccessible areas, including the planet's oceans, forests, deserts, ice caps, and atmosphere, and identifying changes and patterns for a range of economic and environmental applications—often more cost-effectively than other methods.

For this reason, as well as the more general desire to exploit existing investments in the Copernicus programme, ESA's GDA programme's mission is to accelerate impact by fully capitalising on the power of satellite EO for international development assistance operations. In doing so, ESA will scale up and exploit the benefits of EO-based information for development projects in developing countries.

The GDA programme is implemented by ESA in partnership with the WB and ADB under the Space for International Development Assistance (Space for IDA) cooperation framework.

This report is part of the Monitoring & Evaluation (M&E) and Impact Assessment activity led by Caribou Space, with consortium members London Economics and Imperative Space. The primary objective of this report is to document the wider benefit of EO capabilities to other areas of the economy, such as "digital spillovers."

In doing so, this report will strengthen the evidence that EO activities generate wider benefits for developing countries, in terms of innovation, entrepreneurship, and job creation, in addition to the direct benefits to users of these applications that are already well evidenced. These benefits should be considered by IFIs, National Development Agencies, and the broader development community during the planning, design, and execution of EO projects in developing countries.

# 2 Study framework

This chapter proposes a standardised framework for understanding the mechanisms through which EO delivers benefits to developing countries, including key definitions, an overview of the EO value chain, an assessment of the role of developing countries in the EO value chain, and a summary of developing countries' existing EO capabilities.

### Key points:

» Satellite platforms can be used to carry EO instruments that gather information about the planet at a distance from Earth.

» The EO market can be divided into those activities that concern the manufacturing, launch, and ground control of EO infrastructure (upstream); the processing, archiving, and distribution of raw EO data (midstream); and the conversion of data into value-added products and services for use by end users using data processing methods and integration with other data sources (downstream). The GDA programme focuses on the downstream section of the industry.

» Advances in digital technologies help the EO downstream industry to convert EO imagery into value-added services for users. Example advances include cloud computing, AI and machine learning, and crowdsourcing platforms for reference data.

» Many of the capabilities needed to exploit EO are useful in other parts of the digital economy. These digital spillovers suggest that value of EO capabilities extends beyond suppliers and users of EO to other parts of the digital economy.

» Developing countries have a small but growing contribution to the global EO industry. A total of 241 companies from developing countries were active in the EO industry in 2019. Together, these companies contributed a total of €82 million in revenue (2.2% of the global market) and supported 1,250 employees. They represent a higher growth rate in the industry, with an 14% CAGR between 2012 and 2019, compared to 9% for the industry as a whole.

» This low level of involvement from developing countries is likely explained by the high capital cost associated with upstream activities and the investments in digital capabilities, such as human and physical capital, software, and internet connectivity, needed for downstream activities.

## 2.1 Key definitions

This study set out the with the objective of evidencing the existence of satellite-derived EO capabilities in developing countries and the value of these capabilities—firstly in terms of benefits of EO applications to users, and secondly in terms of the wider benefits to other areas of the economy (e.g., because of technology "spillovers"). The scope of this research utilises the following definitions:

- **Earth Observation (EO):** EO concerns the gathering of information about the planet's physical, chemical, and biological systems via remote sensing and "in-situ" instruments on the ground. Remote sensing covers several aerial and satellite technologies that collect information at a distance. Satellite-derived EO describes satellite platforms that carry remote-sensing instruments, most typically at either a fixed point above the Earth's equator (geostationary orbit, at an altitude of ~36,000km) or in a low Earth orbit (LEO, at an altitude of 150km–2,000km). In this study, "EO" refers to satellite-derived EO platforms.
- **Digital technologies:** Digital technologies describe electronic tools, systems, devices, and resources that generate, store, or process data. These technologies are used to use and manipulate digital data and include communication systems, artificial intelligence (AI) and machine learning, Internet of Things (IoT), cloud-based computing, 3D printing, modelling software, and virtual reality. This broad definition is used in this study and describes the enabling technologies that allow the EO downstream industry to convert imagery into value-added services for end users. This definition is also used to distinguish the part of the economy where the digital skills, expertise, physical assets, software, and intangible assets that are leveraged in the EO economy can offer the most value in the form of technology "spillovers."
- **Spillovers:** In economics, the term "spillover" is used to describe any effect arising from an activity that is not reflected in the cost paid (or payoff received) by the parties directly involved in the activity, particularly to external third parties. For this reason, a spillover is also called an "externality." Spillover effects can be positive or negative, and intended or unintended.[8] In this study, spillovers refer to the value of EO capabilities in other parts of the economy.
- **Developing countries:** While there is no universally agreed upon definition of a developing country, different definitions have been formulated based on various criteria,[9] including economic indicators,[10] social indicators,[11] and integrated measures of both indicators.[12] In this review, developing countries are defined as a "least developed country", "low-income country (non-LDC)", "lower middle-income country", or "upper middle income countries and territories (excluding China)" according to the definitions of the Development Assistance Committee (DAC) of the OECD.[13]

8 London Economics, Spillovers in the space sector, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/788725/LE-UKSA-Spillovers_in_the_space_sector-FINAL_FOR_PUBLICATION_050319.pdf

9 World Atlas, What Is a Developing Country?, 2021, https://www.worldatlas.com/articles/what-is-a-developing-country.html

10 In some cases, economic criteria are used, where developing countries typically have reduced levels of industrial activity and lower incomes. The World Bank in particular determines a country's development status with regards to economic criteria by measuring the gross national income per capita. Cambridge Dictionary, 'developing country,' https://dictionary.cambridge.org/dictionary/english/developing-country

11 Social indicators, including life expectancy and education levels, are used to determine if a country is developed or developing.

12 The UN's Human Development Index integrates both social and economic measurements to form a comprehensive measure of a nation's development. World Atlas, What Is a Developing Country?, 2021, https://www.worldatlas.com/articles/what-is-a-developing-country.html

13 For the full list of countries meeting these definitions, see: https://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/DAC-List-ODA-Recipients-for-reporting-2021-flows.pdf

## 2.2 The EO value chain

The EO market can be divided into three main sectors: upstream, midstream, and downstream.[14] The upstream sector involves developing and manufacturing the infrastructure necessary for EO.[15] This comprises the space assets (the satellites) and the ground control for satellite operations (mission control and management of the payloads) that produce satellite signals. The upstream sector also involves launch operations. The midstream sector is responsible for processing, archiving, distributing, and delivering EO data to customers in the downstream segment.[16] The EO downstream sector concerns the conversion of data into value-added products used by private individuals, firms, or governments. The value-added products and services are formed using data processing methods whilst integrating data from other sources and ensuring adaptation to users' needs.

Raw data cannot be utilised directly, but the information provided through processed imagery is valuable. The role of the downstream sector is vital in the value chain as the interface between the satellite technical features and the end users' specific needs. This segment of the value chain is responsible for analysing the data to allow value-added products to be generated to provide valuable information regarding industry activities and societal challenges across several industries, including agriculture, fishing, forestry, disaster response, and resource management. The downstream segment of the value chain can be broken down to contain five main data-specific high-level activities:[17]

1. The initial stage of the data value chain involves gathering, filtering, and cleaning the data before it can be analysed. This stage is known as **data acquisition**.
2. The second stage of the value chain is **data analysis**. This stage involves making the raw data useful for a specific purpose using various technologies such as machine learning, AI, and cloud computing.
3. The third stage of the EO value chain involves quality controlling the data to ensure it meets the standards required for its intended usage. This process is known as **data curation** and is a newer stage of the value chain which is being increasingly explored.
4. The fourth stage of the value chain involves **data storage** and managing the data that has been acquired, cleaned, and cured.
5. The final stage in the value chain involves **data usage** to help with decision-making and end user needs.

14 European Commission, Big Data in Earth Observation, 2017, https://ati.ec.europa.eu/sites/default/files/2020-06/Big%20Data%20in%20Earth%20Observation%20%28v1%29.pdf

15 European Commission, Copernicus: Market report February 2019, https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf

16 European Commission, Big Data in Earth Observation, 2017, https://ati.ec.europa.eu/sites/default/files/2020-06/Big%20Data%20in%20Earth%20Observation%20%28v1%29.pdf

17 European Commission, Big Data in Earth Observation, 2017, https://ati.ec.europa.eu/sites/default/files/2020-06/Big%20Data%20in%20Earth%20Observation%20%28v1%29.pdf

## 2.2.1 Involvement of developing countries in the EO value chain

The importance of EO for monitoring current environmental problems is well recognised. Most developing countries are highly susceptible to environmental degradation; however, current capabilities are limited to more developed areas of the world. With increasing capacity for data analysis and modelling of Earth system processes using diverse remote-sensing technologies at multiple scales, these digital capabilities mean that EO applications for monitoring, diagnosis, and prediction of Earth system processes are becoming increasingly viable. However, these skills are mostly concentrated in the industrialised world; few are developed and applied in and by developing world institutions and directly benefit developing world populations.[18]

LE Europe's analysis for the European Union Agency for the Space Programme (EUSPA) for their EO market monitoring and forecasting activities, based on bottom-up analysis of individual companies,[19] suggests that a total of 241 companies based in developing countries were active in the EO industry in 2019.[20] These companies contributed a total of €82 million to the global EO market in 2019 (2.2% of the global market). Given revenues of €32 million in 2012, this suggests a compound annual growth rate (CAGR) of 14%, which is greater than the 9% CAGR for the global industry as a whole over the same period. These revenues are estimated to have supported a total of 1,250 employees, or 7.8% of total global employment, in EO-related companies in the same year.

The relatively low contribution of developing countries to the global EO market could potentially be explained by the high levels of capital requirements in the upstream segment. Additionally, the lack of digital capabilities in these countries limits their potential contribution towards the downstream segment of the value chain, which focuses on processing and analysing satellite data.

The costly investments required to build and operate satellites and ground controls also limit the involvement of developing countries in the upstream segment of the value chain. There is a wide range of cost, at the lower end US$10 million and up to US$400 million, involved with launching a satellite into space.[21] The European Union's budget for the Copernicus EO programme alone was approximately €4.3 billion between 2014 and 2020.[22] In 2019, developing countries, as defined by the OECD's DAC list of ODA recipients, generated just €3.4 million in revenue for upstream data acquisition and distribution activities. This represents just 0.4% of a total segment value of €751 million, which is dominated by Europe and North America, and this percentage has remained the same since 2015.[23] Only seven companies with reported data were based in developing countries, out of a total of 169 globally.

18 Niall Patrick Hanan, Ashutosh S. Limaye, and Daniel Eric Irwin, eds., 'Use of Earth Observations for Actionable Decision Making in the Developing World,' Frontiers in Environmental Science (2020), https://www.frontiersin.org/research-topics/8597/use-of-earth-observations-for-actionable-decision-making-in-the-developing-world

19 This analysis is based on the data generated by LE Europe for EUSPA. See EUSPA, EUSPA EO and GNSS Market Report, Issue 1, 2022, https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf. This methodology measures the size of EO industry from a supply perspective based on a bottom-up approach which quantifies revenues attributable to EO of more than 500 individual companies for which financial data is available. (Those with turnover greater than the threshold exempting small firms from financial reporting—this threshold is not universal, so smaller companies may be included in some regions than in others.) Companies are allocated to a single region based on their registered headquarters (or ultimate parent).

20 London Economics Europe, European EO Market Share analysis (and industry database) for EUSPA, 2021

21 Gary Brown and William Harris, How Satellites Work, 2000, https://science.howstuffworks.com/satellite10.htm#:~:text=Another%20important%20factor%20with%20satellites%20is%20the%20cost,kilograms%29%20into%20low-Earth%20orbit%20for%20about%20%2413.5%20million

22 European Commission, Interim evaluation of Copernicus Final Report, 2017, https://www.copernicus.eu/sites/default/files/2020-05/ET0417742ENN.en_.pdf

23 London Economics Europe, European EO Market Share analysis (and industry database) for EUSPA, 2021

The significant fixed costs of data collection create entry barriers and support monopolies. The result is high prices for EO data and under-exploitation of this data by suppliers and users in the downstream.[24] The concentration of data collection in just a few providers also raises equity concerns, as image capture is focused on a few areas with high demand (e.g., large urban agglomerations in rich countries) and neglects rural, isolated, or poor regions.[25] This under-provision of relevant data to developing countries in the upstream translates to weaker provision in the downstream, as there are comparatively weaker data inputs to exploit in downstream products and services. The provision of free-to-access Sentinel and Landsat data partially mitigates this problem, but for higher temporal and spatial resolutions typically only commercial data is available.

Many existing studies highlight strong inequalities around the world, with regards to accessing the infrastructure, software, skills, and networks needed to interpret and share big data.[26] Limited access to necessary infrastructure limits the involvement of developing countries in the downstream segment of the EO value chain. Tasks including data analysis, data curation, and storage are reliant on necessary IT software, equipment, and cloud computing services. These findings are supported by the data, where developing countries generated €72 million in revenue for EO data processing activities in 2019, or just 4.2% of the global total. These revenues were generated by 13 companies with data, out of a global total of 310.[27]

Further downstream, the picture is even bleaker: developing countries contributed just 0.5% to the global market for EO data analysis activities, or just €6 million out of a global market value of €1.15 billion.[28] To increase involvement in the downstream segment, support from more developed nations is required to help less affluent nations access the education, technology, and analysis needed to analyse and use EO data.

Several developing countries, including Malaysia, Thailand, and Nigeria, have been involved in building their own smaller national satellite programmes to gain more control over EO data to map and forecast disasters, monitor crop yields, and track environmentally driven diseases such as malaria. To develop the skills and knowledge required to build a satellite, engineers are sent from developing countries to more developed areas of the world to learn and develop small satellites at a smaller cost of tens of thousands of dollars. For example, South Korea has created its own satellite programme through learning from engineers in the United Kingdom and have since used their expertise to aid engineers in other developing countries, including Malaysia.[29] At a global level, the United Nations Office for Outer Space Affairs (UNOOSA) Access to Space for All Initiative's Satellite Development Track has the objective to *"build capacity that enables the development, deployment, and operation of satellites."* [30]

24 World Bank and General Authority for Survey and Geospatial Information, Estimating the Economic Value of Geospatial Information and Technologies to the Economy of Saudi Arabia, 2022, https://gasgi.gov.sa/Documents/Maps/2022/March/KSA_GEOSPATIAL_ECONOMIC_IMPACT_STUDY.pdf

25 Nagaraj et al., 'Does data access democratize science?,' unpublished manuscript

26 World Academy of Sciences, The Big Data Challenge for Developing Countries, 2016, https://twas.org/article/big-data-challenge-developing-countries

27 London Economics Europe, European EO Market Share analysis (and industry database) for EUSPA, 2021

28 London Economics Europe, European EO Market Share analysis (and industry database) for EUSPA, 2021

29 MIT News, Satellites in the developing world, 4 August 2011, https://news.mit.edu/2011/developing-satellites-0804#:~:text=But%20now%2C%20a%20number%20of%20developing%20countries%20are,and%20track%20environmentally%20driven%20diseases%20such%20as%20malaria

30 UNOOSA, Access to Space for All and the benefits of space, accessed March 2022, www.unoosa.org/oosa/en/ourwork/access2space4all/AccSpace4All_memberstates.html

### 2.2.2 Existing digital capabilities in developing countries

Despite the opportunities that EO applications and capabilities provide for economic development, these technologies cannot be fully exploited in developing countries due to their lack of domestic digital capabilities. The lack of human capital available with the required digital skills to analyse satellite data limits developing countries' abilities to participate in the downstream segment of the EO value chain. The lack of affordability, inaccessibility of data and unreliable access to the internet are contributing factors to the reduced participation in the downstream sector of the value chain.

Only 47% of households are estimated to have access to the internet in developed countries, with just 19% having access in the least developed countries.[31] Access to the internet and IT infrastructure is a particularly major problem across the sub-Saharan Africa region. This is a challenge, as IT infrastructure is required to use and produce satellite applications. This includes access to local or cloud-based processing and storage platforms and the internet to access EO data and the outputs of executed algorithms. Cloud platforms, such as Google Cloud Platform (GCP), Amazon Web Services (AWS), and Microsoft Azure, address these challenges by storing and processing large EO datasets in the cloud rather than on local IT infrastructure.[32] These cloud technologies are significantly more cost-effective and have enabled large processing that was previously not possible without sophisticated computing clusters. Whilst cloud platforms reduce storage and processing requirements, a robust internet connection is still required to access outputs.

Moreover, unreliable access to the internet across different regions within countries limits the pool of citizens with the requisite digital skills to exploit EO data and may also lead to constraints on where high-level analytical tasks can be carried out. This means that tasks may only be carried out in more affluent areas of developing countries, leading to greater divides between richer and poorer regions. Many countries have invested in National Spatial Data Infrastructures to efficiently manage geographic data, metadata, users, and tools that are interactively connected.[33] However, the majority of these are in developed countries or multi-governmental institutions, such as the European INSPIRE Initiative, United Nations Spatial Data Infrastructure (UNSDI), World Meteorological Organization (WMO) Regional Climate Centres (RCCs), UN Committee of Experts on Global Geospatial Information Management (UNGGIM), and Integrated Geospatial Information Framework (IGIF).

Additionally, high dropout rates from schooling in developing countries prevent students from attaining the required skills for use in industry. For example, the current gross tertiary education enrolment ratio is 9.4% across sub-Saharan Africa—considerably below the global average of 38%.[34] The low uptake of tertiary-level education means that fewer individuals have developed skills required to utilise EO data. However, there are efforts to address these issues, such as the World Bank's Education Global Practice programme "Western and Central Africa Education Strategy From School to Jobs."[35]

31 UNESCO, New report on global broadband access underscores urgent need to reach the half of the world still unconnected, 2019, https://en.unesco.org/news/new-report-global-broadband-access-underscores-urgent-need-reach-half-world-still-unconnected

32 Caribou Space, Beyond Borders: Satellite Applications for Humanitarian Emergencies, 2022, https://www.caribou.space/library/beyond-borders-satellite-applications-for-humanitarian-emergencies/

33 Wikipedia, Spatial data infrastructure, 6 October 2022, https://en.wikipedia.org/wiki/Spatial_data_infrastructure

34 World Bank, COVID-19 Impact on Tertiary Education in Sub-Saharan Africa, 2020, https://documents1.worldbank.org/curated/en/109901592405885723/COVID-19-Impact-on-Tertiary-Education-in-Sub-Saharan-Africa.pdf

35 World Bank, Western and Central Africa Education Strategy From School to Jobs: A Journey for the Young People of Western and Central Africa, 2022, https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099316106202221243/p17614904920570fa0b35f0661410cd7c3c

Specific skills are required to produce EO applications. For example, a software engineer may need skills in EO, remote sensing, Geographical Information Systems (GIS), data science, machine learning, and co-development with domain-specific expertise to ensure relevance and usefulness. All these skills are highly prized, and staff turnover following training programmes is an issue for skills retention.[36] Skills are also required by the users of EO applications. This includes skills in model development, application operation, data interpretation, combination with other datasets, integration of machine learning approaches, and linkage of outputs to existing workflows.

To address these issues, the WB and ADB will implement capacity building and skills transfer activities through the cooperation framework with the GDA programme. This is a long-term barrier which will require continued, extensive effort from multiple parties to address it. Development interventions to support technical expertise and skills are a classic public good with both direct benefits to the uptake of satellite applications and spillover benefits to other sectors from general upskilling.

ESA's EO4SD initiative included extensive capacity-building and training activities within each of the thematic areas, for example in Urban Development,[37] Water Resources Management,[38] and Climate Resilience.[39] Additionally ESA's EO Africa programme fosters an African-European R&D partnership, facilitating the sustainable adoption of EO and related space technology in Africa.[40] Other similar initiatives include online training courses, both paid and free, for developing or using satellite applications, including those provided by UNITAR.[41] There are many online learning resources available that support the development of these skills, including tools, platforms, workshops, and tutorials. For example, Radiant Earth's ML Hub provides such resources specifically for machine learning for EO.[42]

36 Caribou Space, Beyond Borders: Satellite Applications for Humanitarian Emergencies, 2022, https://www.caribou.space/library/beyond-borders-satellite-applications-for-humanitarian-emergencies/

37 ESA EO4SD Urban Development, Webinars, 2018, https://eo4sd-urban.info/webinars/

38 ESA EO4SD Water Resource Management, Capacity Building, accessed March 2022, http://eo4sd-water.net/content/capacity-building

39 ESA EO4SD Climate Resilience, EO4SD CR Capacity Building Material, accessed March 2022, https://prepare.gmv.com/content/material

40 ESA, EO AFRICA, accessed March 2022, https://eo4society.esa.int/eo-africa/

41 UNITAR, UN Satellite Centre UNOSAT, 2022, https://unitar.org/event/event-pillars/united-nations-satellite-centre-unosat

42 Radiant Earth Foundation, Machine Learning for Earth Observation, 2022, https://www.radiant.earth/mlhub

# 3 Benefits to users of EO for sustainable development

## The value of EO data is derived from the fact that it can be used to improve a data-driven decision-making process.

This value is particularly high where decision-makers face a high degree of uncertainty, where the consequences of the decision are significant, and where the costs of using the data are more favourable than alternatives.[43] The distance of EO satellites from Earth means that they possess several strengths relative to aerial, in-situ or manual methods of data collection.

ESA has been working with IFIs since 2018 to exploit these unique strengths in the context of sustainable development. This chapter presents an overview of these user benefits. This is not a major focus of this report, as there is already substantial existing literature documenting the uses and impacts of EO in sustainable development.

### Key points:

- Satellites' distance from Earth means that they possess several strengths relative to aerial, in-situ, or manual methods of data collection:
  - **Affordability.** Along with the increase in commercial satellites, there has also been an increase in satellites that allow free and open access to data, such as the Copernicus Sentinel missions.
  - **Coverage.** Satellites have global coverage that makes it possible to monitor vast, remote, and even conflict regions across countries and continents.
  - **Frequency.** The time needed to revisit and acquire data for the same location can be daily or every few days, depending on the satellite and ground infrastructure.
  - **Speed.** Increasingly, EO data is available for use just days or even hours after it is acquired, enabling users to receive the EO-derived information they need to act quickly.
  - **Continuity.** The coverage of satellites over the same areas means that a time series of data can be created, which allows consistent monitoring of changes of Earth's key characteristics.
  - **Impartiality.** Observations are derived from satellite instrument measurements, which have a known and controlled range of error and are thus less susceptible to many of the biases detected in other measures of the same phenomena.
  - **Anonymity.** The remoteness of satellites means they can make observations about phenomena on the ground unnoticed, whilst limiting the privacy risks associated with detecting individuals or accessing Personal Identifiable Information (PII).
- GDA is building on its long history of exploiting these unique data advantages to address sustainable development issues with IFIs since 2008.

43 Molly K. Macauley, 'The Value of Information: A Background Paper on Measuring the Contribution of Space-Derived Earth Science Data to National Resource Management,' Discussion Paper 05-26, Resources for the Future, May 2005, https://media.rff.org/documents/RFF-DP-05-26.pdf

## 3.1 Benefits of EO as a data source for sustainable development

### 3.1.1 Affordability

EO data is becoming increasingly affordable due to multiple trends. First, there is a huge increase in the availability of free and open data, such as that from Europe's Copernicus programme. Second, the cost of commercial, high-resolution data is reducing due to an increase in the volume and quality of EO data. Third, the cost of data processing is falling due to increased availability of cloud platforms (e.g., ESA's openEO Platform[44]) and advancements in data science and software engineering techniques, such as machine learning, that are used to extract information from satellite data cost-efficiently. EO products can be scaled across large geographies far more cost-effectively than traditional data sources, such as ground teams or remote sensing from drones or planes. Specifically, over the long-term, they are 12 times more cost-effective than non-space alternatives in forestry management projects, seven times more in agricultural projects, and approximately two times more in disaster resilience projects.[45]

Development assistance stakeholders, such as governments, NGOs, and private sector actors, will only adopt EO-based applications if they can afford the solutions within their available budgets. Within certain domains, such as forestry, marine, and agriculture, the geographical areas to monitor are vast, and the use cases have comparatively smaller financial flows compared to, for example, the urban, energy, or extractives domains. Therefore, use cases such as forest degradation monitoring, ocean ecosystems monitoring, or national crop yield forecasting commonly make use of free and open EO data.

### 3.1.2 Coverage

EO satellites have global coverage that makes it possible to consistently monitor vast, remote, and even conflict regions across countries and continents. This includes monitoring of remote areas where data has previously been unobtainable. Additionally, as satellites orbit Earth, they are not constrained by national and international airspace management issues, increasing the availability of data across the globe.[46]

Within development assistance, domains such as forestry, marine, agriculture, and climate resilience require monitoring of vast areas that are difficult or even impossible to access. For example, monitoring continental scale forests such as the Amazon, the ocean health of the Pacific, national crop forecasts, or global climate patterns. Also, as EO imagery is taken from Earth's orbit, it is not constrained by severe weather conditions such as hurricanes, making it plausible to track severe weather events and assess potential threat levels.

In addition, many of the highest priority areas for development assistance are in or near conflict regions, which are often inaccessible to ground teams. Conversely, satellite EO provides a method of monitoring such regions for evidence of conflict, urban and infrastructure damage, and movements of refugees.

44 ESA, openEO Platform, accessed March 2022, https://openeo.cloud

45 London Economics and Caribou Space, Economic evaluation of the International Partnership Programme (IPP): Cost Effectiveness Analysis, 2019, https://www.caribou.space/wp-content/uploads/2020/05/UKSA-IPP-Cost-Effectiveness-Analysis-FINAL-for-web-1.pdf

46 DLT, Satellite Imagery: An Essential Government Tool is Within Reach, 2010, https://www.dlt.com/blog/2010/08/26/satellite-imagery-essential-government-tool-reach

### 3.1.3 Frequency

The smaller the period between capturing two consecutive images at the same location, the higher the frequency/temporal resolution.[47] The frequency of the Copernicus programme's Sentinel satellites, with a free and open data policy, is every five days. In contrast, commercial, costed EO data might update multiple times a day, for example, that from Airbus's Pléiades Neo.

Within development assistance, the ability to capture imagery of the same area of Earth's surface at different times is one of the most crucial elements for applying remote-sensing data to development domains and use cases. It provides monitoring of vegetation and crops in the agricultural sector to enable recommendations on time-sensitive events like irrigation or planting timings. Monitoring climate change relies on assessing satellite data that observes changes in Earth's surface over time. Satellites with high temporal resolution are also useful in predicting disasters, for example, the landfall timing and location of hurricanes, and support the emergency response phase with timely damage assessments.

### 3.1.4 Speed

EO data is often available days or even hours after it is acquired by a satellite. Rapid access to imagery refers to the capability of a satellite or constellation to be tasked and capture images within the fastest time. It also considers the availability of smooth downlink and processing procedures. In the case of the Sentinel-1 satellite, access to data is made available within one hour of observation over Near Real Time (NRT) areas with a subscription, or within 24 hours of observation without one.[48]

Within development assistance, quick and easily accessible satellite data enables use cases that require sudden and unpredictable changes to be detected and continually monitored. This is particularly critical in domains such as disaster resilience and fragility, conflict, and security, where events on the ground change rapidly, often with life-threatening implications. Highly time-sensitive use cases include monitoring and reporting violence, damage assessments, planning evacuations, and coordinating emergency response teams.

### 3.1.5 Continuity

The consistent supply of data provided by EO satellites also enables observation of the same variables at the same areas of interest at different times. For instance, in the case of Landsat imagery, satellite images from Landsat 9 will be added to the 50 years of available data from the mission, making it the longest data record of Earth's landscapes taken from space.[49] As satellite images are taken from Earth's orbit, they are not constrained by the conditions that may limit aerial or drone photography, such as poor weather conditions or flightpath restrictions, and can provide data at more regular intervals than alternative methods. However, optical imagery is affected by cloud cover and therefore is often combined with Synthetic Aperture Radar (SAR) for cloud-affected regions.

47 Atlas AI, What is temporal resolution?, accessed March 2022, https://www.atlasai.co/learn/what-is-temporal-resolution

48 ESA Sentinel Online, Data Distribution Schedule, accessed March 2022, https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/data-distribution-schedule

49 NASA USGS, Landsat 9, accessed March 2022, https://www.nasa.gov/specials/landsat/#:~:text=The%20Spacecraft,-The%20Landsat%20spacecraft&text=From%20orbit%2C%20the%20Landsat%209,and%20USGS%20develop%20Landsat%20Next

Within development assistance, the continuity and length of EO data enables the monitoring of changes that are characteristically slow-moving, such as assessing success of reforestation efforts, forecasting slow-onset disasters like drought, measuring sea levels and coastal erosion, tracking urban extents, or long-term agricultural land use changes. Also, combinations of these use cases and comparisons to past environmental conditions are particularly crucial for monitoring and mitigating climate change.[50]

The continuity of data records from space, such as from the Copernicus missions, also provides the certainty that downstream application providers need to make investments in products or services that leverage particular sources of data.[51]

### 3.1.6 Impartiality

Satellite observations are derived from the satellite instrument's measurements, which have a known and controlled range of error. They are therefore less susceptible to many of the biases found in other measures of the same phenomena, such as human observations, which can be subject to internal bias.

Within development assistance, EO-based observations provide a level of transparency, impartiality, and accountability when reporting both social and environmental factors. There are many EO use cases where impartiality and objectivity are increasingly critical, not only for development assistance stakeholders, such as IFIs, National Development Agencies, NGOs, but also for national governments and the private sector. Examples of such use cases include reporting changes of forest carbon stocks and emissions to the UN Reducing Emissions from Deforestation and Forest Degradation (REDD+) and energy and mining companies reporting for environmental compliance. Finally, this impartiality, as witnessed currently in the Ukraine conflict, brings clarity to the misinformation that surrounds conflict zones.

### 3.1.7 Anonymity

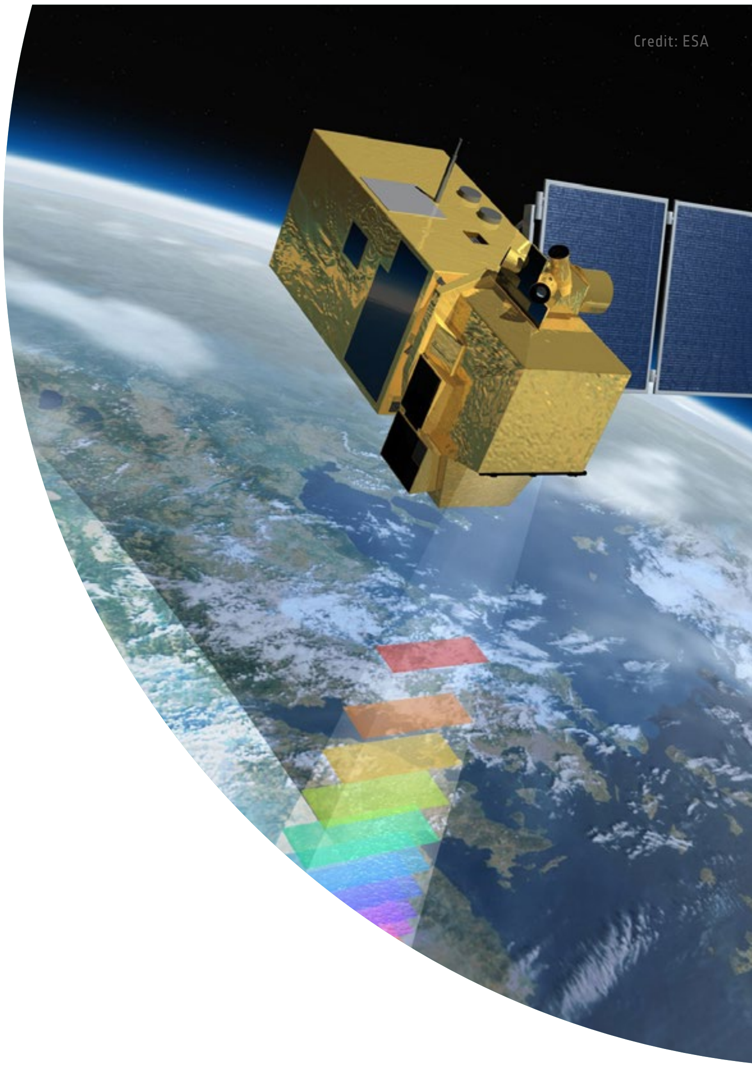
The remoteness of satellites means they can make observations about on-the-ground phenomena unnoticed. As stated above, this allows observations to occur, for example, in inaccessible or conflict regions. Also, populations, both human and wildlife, can be monitored without disturbance. Conversely, when observing human/social phenomena, for example, tracking refugee movements, EO data has advantages over other data sources, such as mobile call records (CDRs) or social media activity. Using EO limits the privacy risks associated with detecting individuals or accessing Personal Identifiable Information (PII).

Whilst EO offers these benefits, there are also related risks. For example, the remoteness of satellites carries a "big brother" perception of being monitored and potential for concerns of espionage for national governments. Additionally, as EO technology advances and spatial resolution continues to improve, it might become plausible to infer individuals and PII from EO data. Finally, informed consent is also impossible when using satellite data sources. The people or groups involved may not be aware of this invasion of privacy or, if they are aware, are unlikely to be able to contest it or easily take remedial action, in real time or retrospectively.

50 Caribou Space for ESA GDA, D1: Development Assistance Landscape, Task 1: Strategic Analysis, 2022

51 London Economics, Value of satellite-derived Earth Observation capabilities to the UK Government today and by 2020, 2018, https://londoneconomics.co.uk/wp-content/uploads/2018/07/LE-IUK-Value-of-EO-to-UK-Government-FINAL-forWeb.pdf

Within development assistance, this anonymity carries the most value in use cases related to social/human, rather than environmental observations. Examples in the domain of conflict and security include evidencing conflict-related violence, monitoring extraction and trafficking of illegal resources or humans, and tracking refugee movements and camps. In health, use cases that benefit from anonymity include forecasting disease prevalence and transmission and microplanning for health interventions.



Credit: ESA

# 4 Wider benefits of spillovers from EO to the wider economy

This chapter presents evidence of the benefits of investments in EO to the wider economy, including the role that EO plays as a source of technology spillover to the wider economy, and the general returns to digital skills and data processing.

## Key points:

- The investment in digital capabilities that are needed to exploit EO data for end users are likely to offer value to other parts of the economy.
- These capabilities correspond with transferable human, physical, and intangible assets that can be diffused both within the EO sector and from the EO sector to other sectors.
- These "digital spillovers" have been shown to accelerate knowledge transfer, productivity, and innovation within a company, between competitors, across supply chains, and across industries.
- The return on investment from digital technologies to the economy exceeds the return to the private companies that make these investments. This market failure justifies a role for government and members of the development assistance community, such as IFIs, in supporting digital capabilities and the adoption of digital skills.
- These spillovers are likely to be more strongly felt by the parts of the economy closest to the EO services industry, in terms of geographic proximity, technological proximity, labour requirements, capital, and enabling technology requirements. The "digital economy"—defined broadly as those industries that leverage digital technologies as a key factor of production—shares many characteristics with the EO downstream industry and is therefore likely to benefit most from investments in the EO industry.
- The ability of the economy to absorb these technology spillovers depends on its "absorptive capacity" to recognise, absorb, and utilise this knowledge. This suggests that investments in human and physical capital, enabling technologies, and related R&D (including complementary investments in internet access, technical expertise, and IT) remain key drivers for generating innovation and spillovers.
- The economic return from investments in digital assets has been estimated at about US$20 for every US$1 invested—an estimate that is almost seven times greater than corresponding investments in non-digital assets. This suggests a high potential rate of return from investments in EO capabilities.
- While codified knowledge can be widely transmitted across actors, tacit knowledge—knowledge that is hard to formally teach or record—is geographically bounded. For this reason, studies have shown that some knowledge spillover often depends on the geographic proximity of organisations. Geographical proximity increases the face-to-face interactions that enable transmission, fosters more competition, and increases both the size and diffusion rate of knowledge spillovers. These benefits from geographical proximity are termed "agglomeration economies."

## 4.1 How do investments in digital technologies like EO generate benefits to the wider economy?

Currently, there is limited understanding of the wider impact of EO capabilities on developing economies. Specifically, the investment in digital capabilities, such as skills, software, infrastructure, and enabling technologies, that are needed to exploit EO data and provide value-adding services to end users are, once they are obtained, likely to offer value to other parts of the economy. This is because these capabilities correspond with transferable human, physical, and intangible assets that can be diffused, both within the EO sector and from the EO sector to other sectors.

These wider benefits are called "spillovers"—a term commonly used in economics to describe the wider effects from an activity that are not accounted for in the cost paid (or payoff received) by the parties directly involved in the activity.[52] These spillovers refer to knowledge generated by an organisation (innovator) and used by another that does not fully compensate the innovator for the full value of the knowledge.[53] This is possible due to the "non-rivalrous" characteristic of knowledge, where its use by one agent does not prevent others from using it. This transfer can occur through several mechanisms, including: the movement of labour between organisations; knowledge exchange between workers; international exchanges, such as through trade, foreign direct investment (FDI), and direct learning; and via the commercialisation of innovation.[54] Within the space sector, these spillovers are typically the result of technology transfers.

The payoffs from investments in digital technology, such as those that enable users in developing countries to use EO technology, have been shown to accelerate knowledge transfer, productivity, and innovation horizontally (i.e., within a company and between competitors), vertically (i.e., across supply chains), and across industries.[55]

52 London Economics, Spillovers in the space sector, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/788725/LE-UKSA-Spillovers_in_the_space_sector-FINAL_FOR_PUBLICATION_050319.pdf

53 Yifei Sun and Peilei Fan, 'Technology Spillover,' International Encyclopedia of Geography: People, the Earth, Environment and Technology, 6 March 2017, https://doi.org/10.1002/9781118786352.wbieg0654

54 London Economics, Spillovers in the space sector, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/788725/LE-UKSA-Spillovers_in_the_space_sector-FINAL_FOR_PUBLICATION_050319.pdf

55 Huawei and Oxford Economics, Digital Spillover: Measuring the true impact of the digital economy, 2017, https://www.huawei.com/minisite/gci/en/digital-spillover/files/gci_digital_spillover.pdf

As a case study example, the UK Space Agency's International Partnership Programme (IPP) ran from 2016 to 2022 and utilised the UK space sector's capabilities to deliver measurable and sustainable economic, societal, and/or environmental benefits in partnership with over 40 developing countries. The programme identified benefits to the UK companies who received grant funding to supply EO products and services in partnership with developing countries, including commercial, network, reputation, and knowledge benefits:[56]

» 62% of all respondents agree that the IPP has already benefited sales in other areas of their business.

» Over 80% of all respondents agree that the IPP has already had a positive impact on their relationship with customers.

» More than three-quarters of respondents agree that the IPP has already had a positive impact on the levels of technical (95%), commercial (76%), developing country (86%), and measurement evaluation (81%) knowledge or expertise.

» Over 80% of all respondents believe the IPP has a positive impact on their organisation's overall competitiveness.

» In addition, almost 90% of respondents have already shared knowledge (e.g., project outputs and project lessons) with other organisations or plan to do so.

Together, these benefits suggests that involvement in EO programmes like GDA generates benefits that extend significantly beyond the user benefits to other areas of the wider industry and economy. This fact suggests that the return on investment from digital technologies to the economy exceeds the return to the private companies that make these investments. Without government support, private companies are therefore likely to under-invest in digital capabilities since they cannot fully capture the benefits of these activities.

This market failure justifies a role for government and members of the development assistance community, such as IFIs, in supporting digital capabilities and the adoption of digital skills. This is a key justification for the implementation of capacity building and skills transfer activities by WB and ADB through the cooperation framework with the GDA programme. In addition, within IFI organisations' teams there will be further knowledge sharing and an expected sustainable increase in the awareness and adoption of EO.

56 London Economics and Caribou Space, Economic evaluation of the International Partnership Programme (IPP): Cost Effectiveness Analysis, 2019, https://www.caribou.space/wp-content/uploads/2020/05/UKSA-IPP-Cost-Effectiveness-Analysis-FINAL-for-web-1.pdf

## 4.2 Who benefits from—and how large are—these spillovers?

Based on evidence for the space industry more broadly, these spillovers are likely to be more strongly felt by the parts of the economy that are closest to the EO services industry, in terms of geographic proximity (location),[57] technological proximity (similarity of industry),[58] labour requirement (similarity of skill sets), and capital and enabling technology requirements (similarity of needs for equipment, hardware, software, AI, and machine learning).

While globalisation and the mobility of labour and capital suggest that individual companies, sectors, and companies can benefit from knowledge spillovers without making their own investments in R&D, the effectiveness of this strategy also relies on having sufficient "absorptive capacity" to recognise, absorb, and utilise this knowledge.[59] This suggests that investments in human and physical capital, enabling technologies, and related R&D remain a key driver for generating innovation and spillovers, even as knowledge becomes more internationally mobile.[60] The ability of developing countries to benefit from certain types of tacit knowledge, such as that generated by prior investments in EO, will therefore depend on complementary investments in other digital capabilities, such as internet access, technical expertise, IT, etc. Therefore, the wider effect of investments in EO is likely to be uneven across countries.

The "digital economy" shares many of these characteristics with the EO downstream industry. While the term lacks a commonly accepted definition, digital economy has been defined by the Digital Economy Task Force (DETF) as the *"broad range of economic activities using digitised information and knowledge as the key factor of production, modern information networks as an important activity space, and the effective use of information and communication technology as an important driver of productivity growth and economic structural optimisation."*[61]

**57** Numerous studies evidence this, including: Sasan Bakhtiari and Robert Breunig, 'The Role of Spillovers in Research and Development Expenditure in Australian Industries,' Economics of Innovation and New Technology 27, no. 1 (2018): 14–38, https://doi.org/10.1080/10438599.2017.1290898; Adam B. Jaffe, 'Demand and Supply Influences in R&D Intensity and Productivity Growth,' Review of Economics and Statistics 70, no. 3 (1988): 431–37, https://doi.org/10.2307/1926781; Sergey Lychagin, Joris Pinkse, Margaret E. Slade, John Van Reenen, 'Spillovers in Space: Does Geography Matter?,' Journal of Industrial Economics 64, no. 2 (2016): 295–335, https://doi.org/10.1111/joie.12103; Laura Bottazzi and Giovanni Peri, 'Innovation and spillovers in regions: Evidence from European patent data,' European Economic Review 47 (2003): 687–710

**58** See Lucio Biggiero and Alessia Sammarra, 'Does geographical proximity enhance knowledge exchange? The case of the aerospace industrial cluster of Centre Italy,' International Journal of Technology Transfer and Commercialisation 9, no. 4 (2010): 282–305, https://doi.org/10.1504/IJTTC.2010.035397; Patrick Cohendet, 'Evaluating the industrial indirect effects of technology programmes: the case of the European Space Agency programmes,' Proceedings of the OECDC Conference "Policy Evaluation in Innovation and Technology (1997), https://www.oecd.org/sti/inno/1822844.pdf; Giancarlo Graziola, Annalisa Cristini, and Simona Di Ciaccio, 'The Importance of the Technological Spillovers for the Returns to Space Investments, with an Empirical Application to the Italian High-Tech and Space Sectors,' New Space 3, no. 3 (2015): 179–90, http://dx.doi.org/10.1089/space.2015.0010

**59** The term originated in Wesley M. Cohen and Daniel A. Levinthal, 'Absorptive Capacity: A New Perspective on Learning and Innovation,' Administrative Science Quarterly 35 no. 1 (1990): 128, https://doi.org/10.2307/2393553. At the organisation level, many studies find organisations with higher absorptive capacities benefit from more spillovers. See Francesco Aiello and Paola Cardamone, 'R&D spillovers and firms' performance in Italy,' Journal of Empirical Economics 34 (2008): 143–66, https://doi.org/10.1007/s00181-007-0174-x; W. Liu, 'An Empirical Study on Factors that Affect Knowledge Spillover of FDI,' (2012); Bruno Cassiman and Reinhilde Veugelers, 'R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium,' American Economic Review 92, no. 4 (2002): 1169–84, http://doi.org/10.1257/00028280260344704. Empirical findings reach similar results at the sectoral level—see Andrea Poldahl, 'The Two Faces of R&D: Does Firm Absorptive Capacity Matter?,' Journal of Industry, Competition and Trade 12, no. 2 (2012): 221–37, https://link.springer.com/article/10.1007/s10842-010-0094-x: David T. Coe T, Elhanan Helpman, and Alexander W. Hoffmaister, 'International R&D spillovers and institutions,' Working Paper 14069, National Bureau of Economic Research, June 2008, http://www.nber.org/papers/w14069; Patrick Cohendet, 'Evaluating the industrial indirect effects of technology programmes: the case of the European Space Agency programmes,' Proceedings of the OECDC Conference "Policy Evaluation in Innovation and Technology (1997), https://www.oecd.org/sti/inno/1822844.pdf; Giorgio Petroni, Karen Venturini, and Stefano Santini, 'Space technology transfer policies: Learning from scientific satellite case studies,' Space Policy 26, no. 1 (2010): 39–52, https://doi.org/10.1016/j.spacepol.2009.11.004; Chiara Verbano and Karen Venturini, 'Technology transfer in the Italian space industry: organizational issues and determinants,' Management Research Review 35, no. 3/4 (2012): 272–88, https://doi.org/10.1108/01409171211210163; Jonathan Haskel, Sonia C. Pereira, and Matthew J. Slaughter, 'Does Inward Foreign Direct Investment Boost the Productivity of Domestic Firms?,' Working Paper 03-10, Tuck School of Business, February 2002, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=301192

**60** Leo Sveikauskas, 'R&D and productivity growth: A review of the literature,' BLS Working Papers 406, US Bureau of Labor Statistics, 2007, https://www.bls.gov/osmr/research-papers/2007/ec070070.htm

**61** G20 DETF, G20 Digital Economy Development and Cooperation Initiative, 2016, https://www.mofa.go.jp/files/000185874.pdf

Prior investments in an earlier generation of digital technologies, such as highspeed broadband and advanced analytical techniques like machine learning, have generated technological spillovers that amplify together—reducing costs and improving the power and capabilities of digital technologies. Together, this has made digital technologies more accessible and useful to a broader spectrum of businesses with incentives to innovate and achieve productivity improvements. For example, the rollout of mobile networks and highspeed broadband have meant that codified knowledge (i.e., knowledge that can be written down and transferred to other entities) can be transmitted more easily than before.[62]

The digital economy therefore covers a broad scope, including sectors such as mining, agriculture, construction, and utilities that, while not thought to be "digital," are increasingly undertaking digital investments and leveraging digital applications in their business processes, operations, and decision-making.[63] This suggests that the scope of economy that could benefit from the kind of technology spillovers generated by the EO downstream industry is much broader just the EO industry or businesses that are directly involved in technology manufacturing.

IFIs have extensive efforts promoting the growth of digital economies, including WB's Digital Development Global Practice, and specific programmes focused on Africa, such as the Digital Economy for Africa Initiative.[64]

By considering the value from both the production of digital technologies and the indirect value across the economy that flows from their use (the Gross Value Added of productivity gains, economic growth, etc.), the economic return from investments in digital assets is estimated at about US$20 for every US$1 invested—an estimate that is almost seven times greater than corresponding investments in non-digital assets (i.e., stock of capital all other capital assets excluding Information and Communications Technology (ICT) capital).[65]

62 London Economics, Spillovers in the space sector, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/788725/LE-UKSA-Spillovers_in_the_space_sector-FINAL_FOR_PUBLICATION_050319.pdf

63 Huawei and Oxford Economics, Digital Spillover: Measuring the true impact of the digital economy, 2017, https://www.huawei.com/minisite/gci/en/digital-spillover/files/gci_digital_spillover.pdf

64 World Bank, The Digital Economy for Africa Initiative, accessed March 2022, https://www.worldbank.org/en/programs/all-africa-digital-transformation

65 Huawei and Oxford Economics, Digital Spillover: Measuring the true impact of the digital economy, 2017, https://www.huawei.com/minisite/gci/en/digital-spillover/files/gci_digital_spillover.pdf

## 4.3 How important is geographic proximity to the transmission of spillovers?

While codified knowledge can be widely transmitted across actors, tacit knowledge—knowledge that is hard to formally teach or record—is often geographically bounded. For this reason, studies have shown that some knowledge spillover often depends on the geographic proximity between organisations where new economic knowledge is created.[66] This is because geographical proximity increases the face-to-face interactions that enable transmission, fosters more competition, and increases both the size and diffusion rate of knowledge spillovers.[67] Likewise, the skills and expertise (absorptive capacity) needed to recognise an innovation opportunity may only exist in certain clusters.

A large body of literature suggests that such clusters, defined as geographic concentrations of interconnected companies and institutions in a particular field,[68] generate different types of externalities, also referred to as economies of agglomeration.[69] Greater concentration provides firms with advantages, including greater strategic interaction between institutions that may generate research (academia) and those that apply it for profit (innovators), and between customers within the supply chain; access to a larger pool of specialist labour; the development of sector-specific infrastructure; and greater knowledge sharing through both formal and informal networking. Such clustering in cities or regions can therefore lead to higher productivity,[70] and explains why firms typically concentrate in large cities, even though the prices of production inputs (land, labour, capital) and other costs, such as congestion, transportation, pollution, or crime, may be higher than in the rest of the country.[71]

Local job multipliers provide indirect evidence of agglomeration economies; these include improvements in local business productivity related to either larger size of a local economy or greater local clusters of some industries.[72] According to the literature, there are large job multipliers for the IT sector, suggesting that each job in the IT sector results in the creation of several jobs in the wider economy. For example, Morretti estimates the local job multiplier of "high-tech" in a US city to be in the order of 4.9, while others suggest that the multiplier is closer to 3.[73]

66 Yifei Sun and Peilei Fan, 'Technology Spillover,' International Encyclopedia of Geography: People, the Earth, Environment and Technology, 6 March 2017, https://doi.org/10.1002/9781118786352.wbieg0654

67 Numerous studies evidence this, including: Sasan Bakhtiari and Robert Breunig, 'The Role of Spillovers in Research and Development Expenditure in Australian Industries,' Economics of Innovation and New Technology 27, no. 1 (2018): 14–38, https://doi.org/10.1080/10438599.2017.1290898; Adam B. Jaffe, 'Demand and Supply Influences in R&D Intensity and Productivity Growth,' Review of Economics and Statistics 70, no. 3 (1988): 431–37, https://doi.org/10.2307/1926781; Sergey Lychagin, Joris Pinkse, Margaret E. Slade, John Van Reenen, 'Spillovers in Space: Does Geography Matter?,' Journal of Industrial Economics 64, no. 2 (2016): 295–335, https://doi.org/10.1111/joie.12103; Laura Bottazzi and Giovanni Peri, 'Innovation and spillovers in regions: Evidence from European patent data,' European Economic Review 47 (2003): 687–710

68 Michael E. Porter, On Competition (Boston: Harvard Business School Press, 1998)

69 Luc Anselin, Attila Varga, and Zoltan Acs, 'Local Geographic Spillovers between University Research and High Technology Innovations,' Journal of Urban Economics 42, no. 3 (1997): 422–48, https://doi.org/10.1006/juec.1997.2032

70 Edward L. Glaeser, Agglomeration Economics: Introduction, in Agglomeration Economics, ed. Edward L. Glaeser (Chicago: University of Chicago Press, 2010)

71 Romain Esteve et al., Decentralising Britain. The big push towards inclusive prosperity, Institute for Public Policy Research, July 2019, https://www.ippr.org/files/2019-07/decentralising-britain-july19.pdf

72 Timothy J. Bartik and Nathan Sotherland, 'Local Job Multipliers in the United States: Variation with Local Characteristics and with High-Tech Shocks,' Working Paper 19-301, W.E. Upjohn Institute for Employment Research, 2019

73 Enrico Moretti, 'Local Multipliers,' American Economic Review: Papers & Proceedings 100 (2010): 1–7, https://eml.berkeley.edu/~moretti/multipliers.pdf?msclkid=9034abcfb9aa11ec84fa6be0b7c3cb5c; Timothy J. Bartik and Nathan Sotherland, 'Local Job Multipliers in the United States: Variation with Local Characteristics and with High-Tech Shocks,' Working Paper 19-301, W.E. Upjohn Institute for Employment Research, 2019

The difficulty that some countries may have in absorbing knowledge because of low levels of absorptive capacity may therefore be lessened in larger cities with existing digital clusters. Therefore, such clusters may have an important role in diffusing this knowledge to other areas.[74]

The benefits of single agglomerations like New York, Tokyo, or London—particularly for codified knowledge—may be lessened by the existence of technologies such as the internet, which allow companies and employees to reap agglomeration benefits remotely.[75] Nevertheless, geographically concentrated investments in digital technologies, such as in EO, may support the development of a larger digital industry cluster. These clusters may create larger markets for digital capabilities and skills, leading to greater availability, increased specialisation, or better matching of those supplies and skills, thereby enhancing productivity. Industry clusters may lead to firms being better able to take good ideas and workers from one another, thereby enhancing productivity. When technological sectors agglomerate, they have greater spillover effects into the wider economy comparative to other sectors, including non-tradable services. Industry-specific multipliers indicate that high tech industries have the largest multiplier.[76]

The existence of multinational corporations (MNCs) with a presence in developing economies has also been thought to be a key source of the transmission of technology spillovers to developing countries. This "knowledge pipeline model" assumes that MNCs possess and exploit technological assets, that this knowledge is a "public good" within MNCs and therefore mobile across their entire internal boundaries, and that MNCs are tightly integrated such that subsidiaries are influenced by the actions of their parents. In this way, knowledge generated by the MNC parent (i.e., in developed countries) can be transmitted to developing countries via their subsidiaries, even if they are at a large distance from each other.[77] While the historical literature has assumed that these spillovers will happen regardless of the actions of local subsidiaries, a 2011 study has shown that spillovers are likely to be strongest among the most entrepreneurial subsidiaries. This is because these subsidiaries are more likely to generate assets of value to local firms and because they are more likely to develop deep and meaningful networks in host countries, thereby extending the reach of any spillover that is developed.[78] Together, this literature suggests that large MNCs that participate in EO and other technology programmes are important mechanisms for transmitting spillovers far beyond to developing countries, and that the extent of this transmission depends on the sophistication and connectedness of subsidiaries. Activities like GDA-facilitated skills transfer efforts that attempt to strengthen the local footprint and embeddedness of subsidiaries can therefore improve the extent to which developing countries can benefit from technology spillovers generated in other countries.

**74** Gilles Duranton, 'Growing through cities in developing countries,' World Bank Research Observer 30, no. 1 (2015): 39–73, https://openknowledge.worldbank.org/handle/10986/24808

**75** Michael Jacobs et al., Industrial Strategy: Steering structural change in the UK economy, Institute for Public Policy Research, 2017, https://www.jstor.org/stable/24582397

**76** Enrico Moretti, 'Local Multipliers,' American Economic Review: Papers & Proceedings 100 (2010): 1–7, https://eml.berkeley.edu/~moretti/multipliers.pdf?msclkid=9034abcfb9aa11ec84fa6be0b7c3cb5c

**77** For a literature review of this model, see Anabel Marin and Elisa Giuliani, 'MNC subsidiaries' position in global knowledge networks and local spillovers: evidence from Argentina,' Innovation and Development 1, no. 1 (2011): 91–114, https://doi.org/10.1080/2157930X.2010.551057

**78** Anabel Marin and Elisa Giuliani, 'MNC subsidiaries' position in global knowledge networks and local spillovers: evidence from Argentina,' Innovation and Development 1, no. 1 (2011): 91–114, https://doi.org/10.1080/2157930X.2010.551057

## 4.4 What are the returns to digital technologies and data processing skills?

To make useful applications of EO data, users are required to have several capabilities, including knowledge of where to find the data and methods to access the data through downloads or online data platforms.[79] Users are also required to find storage solutions for the data and understand how to process the data. The data must be transformed into usable formats to support analysis and decision-making by non-technical experts. These tasks all require substantial time, skills, software, hardware, and significant computer processing power.

As EO missions and assets continue to grow in number, there will be a large amount of raw data available across different satellites that requires processing and distribution.[80] Machine learning algorithms and scalable cloud computing technologies have played key roles in allowing large volumes of EO data collected by satellites to be processed. For example, the Copernicus satellite produces 12 terabytes of data daily, an amount that would be impossible to process without these technologies.

The adoption of cloud technologies and the potential for their future development will have spillover impacts in several industries and across wide-ranging aspects of developing countries. Cloud technologies help to reduce barriers to entry for entrepreneurs by offering customised and scalable computing, storage, and development solutions. Cloud technologies provides these solutions without requiring significant capital infrastructure—converting potentially significant and duplicative capital expenditures into affordable operating expenditures where services are used only on demand. This "software as a service" (SaaS) model makes these data storage solutions significantly more accessible to developing countries and SMEs that face cost constraints. After accessing this data, developing world capabilities can be used to focus their resources on producing products, services, or applications that are specific to the economic and cultural needs of the area. Moreover, the lower operating costs for these firms increases their competitiveness in the global marketplace, therefore leading to lower prices of final products.

Knowledge may also spill over into other areas of the economy, as described above. One example is the health sector. In areas where qualified medical facilities are limited, there is great potential for cloud technologies to implement telemedicine, which allows providers to assess patients remotely, monitor outbreaks, and lower the burden on physical hospital resources by prioritising care. Data storage in hospitals will also benefit from the use of cloud technologies, allowing storage and management of medical records to be more streamlined, therefore reducing operating costs.

The low levels of capital infrastructure required for cloud computing, including lower electrical, computing, and storage requirements, will also lead to spillover impacts for government applications. Like medical records management in the healthcare sector, the use of cloud computing and storage could immensely expand the quality, reliability, and affordability of government services. This would also tackle the problems of redundancy of recordkeeping in areas susceptible to conflict, reducing the time required to return to normalcy following conflict. For example, municipal governments in the Balkans are facing the effects of the targeted destruction of land records during conflicts in the area over two decades ago, and cloud storage provides a solution for preventing similar problems in the future.[81]

79 UK Government, Making it easier to access and use earth observation data, Defra digital, data and technology (blog), 18 June 2020, https://defradigital.blog.gov.uk/2020/06/18/making-it-easier-to-access-and-use-earth-observation-data/

80 EFPPA, Unlocking the benefits of Earth Observation for all, 2021, https://efppa.org/unlocking-the-benefits-of-earth-observation-data-for-all/

81 Stanford Management Science and Engineering, Cloud Computing in Developing Economies: Opportunities and Challenges, 13 July 2017, https://mse238blog.stanford.edu/2017/07/bgarlick/cloud-computing-in-developing-economies-opportunities-and-challenges/#:~:text=The%20ongoing%20adoption%20of%20cloud%20services%20and%20the,infrastructure%20required%2C%20including%20electrical%2C%20computin

The rise of AI platforms that aggregate and distribute data and EO processing algorithms are vital in allowing the data to be usefully applied. The surge in the number of commercial satellites in operation means that there is now a large amount of overlapping EO data. Data from different satellites can be merged to detect changes in any ground-level activity, including vegetation, terrain, erosion, and human activity.[82] These platforms make it easy to combine and analyse datasets from multiple large-scale data providers to gain new insights. Capabilities in these areas ensure that the growing availability of datasets and observations from different satellites can be usefully amalgamated to help form policy or produce services that aid the development of developing countries.

Previous literature has found that the digital economy contributed towards 18.4% of advanced economies' GDP, compared to 10% of GDP in developing economies.[83] This result varied among different developing economies, with leading economies such as Malaysia, Chile, and China matching advanced economies in their accumulation and use of digital assets and demonstrating the contribution digital technologies can make at any stage of development. Amongst the least digitalised countries, the digital economy accounts for 10% of GDP, suggesting that digital technologies are highly prevalent in the modern global economy. In countries with a small technology manufacturing sector, businesses are increasingly making use of broadband, benefiting from cloud technologies, and increasing preparation for the adoption of new technologies.

The benefits of digitalisation are estimated to be higher in developing economies than advanced economies. However, the risks are greater too. Developing economies could see a 2.2% boost to 2025 GDP in the high digitalisation scenario, relative to the baseline, compared with a 2.7% reduction in GDP in the low digitalisation scenario.[84]

82 Terris, Change Detection: Enables Faster, Smarter Crisis Management, 2021, https://www.terrisei.com/change-detection/

83 Huawei and Oxford Economics, Digital Spillover: Measuring the true impact of the digital economy, 2017, https://www.huawei.com/minisite/gci/en/digital-spillover/files/gci_digital_spillover.pdf

84 The baseline projection assumes the average return on investment to digital investments remains the same as it has been historically. In the high-digitalisation scenario, it is assumed that if successful in overcoming the difficulties of adopting new, returns on investment from digital investment increases. See Huawei and Oxford Economics, Digital Spillover: Measuring the True Impact of the Digital Economy, 2017, https://www.huawei.com/minisite/gci/en/digital-spillover/files/gci_digital_spillover.pdf

5

# Potential challenges

## This chapter summarises some potential challenges of increasing the use of digital technologies in developing countries.

### Key points:

- Potential challenges fall into two categories: 1) pre-existing barriers to the adoption of digital technologies (including EO), and 2) potential unintended consequences and adverse effects following adoption of digital technologies.
- **Data security and sovereignty** is a concern that may limit the free flow of data and the adoption of digital technologies such as cloud computing. This challenge could compromise the benefits associated with EO data and services.
- Like many digital technologies, there is a **requirement for training** to ensure users can process and analyse EO data. Moreover, widespread gaps in basic digital skills suggest high levels of investment to fund training courses to equip developing countries to use digital technologies.
- An increase in digitalisation and the use of technologies across the world could have negative impacts of **job displacement** in developing countries. This is because such technologies may erode the traditional labour-cost advantage of developing countries.
- Higher productivity jobs in digital sectors that leverage digital technologies may offset these job losses, but these will be fewer in number and may be concentrated in richer countries that dominate digital service provision, where economies of scale and the low marginal cost of service delivery at scale mean that the "winners" are likely to take all.
- Successful transition of the labour market also requires government resources to provide a social safety net and support retraining, which may often be beyond the capacity of developing countries.

The potential challenges detailed below fall into two categories: 1) pre-existing barriers to the adoption of digital technologies (including EO), and 2) potential unintended consequences and adverse effects following adoption of digital technologies. Within the first category are issues including data security and sovereignty and the requirement for training, whilst a potential unintended consequence is job displacement.

## 5.1 Data security and sovereignty

There is growing interest from the G8 nations, international organisations, and the European Union to promote national laws and policies for full, free, and open access to public sector digital data to ensure the benefits of public investment in such data can be maximised with as few barriers to use as possible. Open data enables a cross-fertilisation of creative ideas among individuals, organisations, and nations and supports improved decision-making based on evidence. Only a small amount of open data has currently been released in Africa. In many countries, economically important datasets, including geospatial data, are of poor quality or nonexistent.[85]

While open data for society at large is a relatively new phenomenon, the space sector has been accustomed to open data for all its existence, especially in astronomy and navigation, but also in EO.

However, data security is a concern that may threaten this free flow of data and the adoption of digital technologies such as cloud computing. For example, some countries (e.g., India) have introduced strict data laws that require all data centres handling Indian data to be within the borders of the country. This is linked to the concept of data sovereignty, which can be defined as the notion that the data an organisation collects, stores, and processes is subject to the nation's laws and general best practices where it is physically located. With an increase in the use of digital technologies, including cloud computing, many countries have passed various laws around storage and control of data, which all reflect measures of data sovereignty.[86] More than 100 countries have a form of data sovereignty law in place.[87] In some countries, technological sovereignty may also limit the ability to freely share technological infrastructure, as the use of the technology and infrastructure is aligned to the laws, needs, and interests of the country in which users are located.[88]

## 5.2 Requirement for training

Moreover, a potential challenge in increasing the use of digital technologies to analyse EO data in developing countries may be the requirement to train users to be able to process and analyse EO data. Widespread gaps in basic digital skills may require high levels of investment to fund training courses to allow for the usage and application of digital technologies. Skills required by these users, such as an analyst in government or a first responder, include skills in model development, application operation, data interpretation, combination with other datasets, integration of ML approaches, and linkage of outputs to existing workflows.

There are extensive online training courses, both paid and free, for developing or using satellite applications, including those provided by UNITAR.[89] However, training is a long-term issue that will require continued, extensive effort from multiple parties to address. The GDA programme will contribute to streamlining such efforts, including a specific activity to develop guidelines and best practices for EO capacity building in developing countries under the GDA Knowledge Hub (to be launched in 2023).

85 AfDB, Economic benefits of Open data in Africa, 2017, https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Economic_Benefits_of_Open_Data_in_Africa_March_2017.pdf

86 Kristina Irion, Government Cloud Computing and National Data Sovereignty, Policy & Internet 4, no. 3–4 (2013): 40–71, https://doi.org/10.1002/poi3.10

87 Bloomberg News, Google Scrapped Cloud Initiative in China, Other Markets, 8 July 2020, https://www.bloomberg.com/news/articles/2020-07-08/google-scrapped-cloud-initiative-in-china-sensitive-markets

88 Berlin Forum on Global Politics, "All your Internet are Belong to Us": On Nation States' Claims of Sovereignty over ICT Architecture and Contents, 2016, https://bfogp.org/blog/2016-04-all-your-internet-are-belong-to-us-on-nation-states-claims-of-sovereignty-over-ict-architecture-and-contents/

89 UNITAR, UN Satellite Centre UNOSAT, accessed March 2022, https://unitar.org/event/event-pillars/united-nations-satellite-centre-unosat

The WB and ADB commonly include a variety of training mechanisms in their programmes. These include training mechanisms related to specific projects or operations (e.g., the provision of EO products for a Brazilian forestry programme), one-off trainings (e.g., training toolkits and product manuals), training webinars, on the job "hand-holding" with experts, and train-the-trainer methods.

Other training mechanisms might be broader and more institutional, for example, supporting development of university curricula and partnering between local and international universities. The WB Resilience Academy is a stand-out example of the latter, as it *"transfers digital tools and practical risk management skills to benefit the next generation through universities' education and research activities and cooperation with the society."* [90]

## 5.3 Job displacement

An increase in digitalisation and use of technologies across the world could also have negative impacts to employment levels in developing countries. The increased use of technology in developed countries risks eroding the traditional labour-cost advantage of producing in developing countries.[91] Many jobs have already been replaced by technology in developing countries. Low-skilled jobs in developing countries are more vulnerable since these jobs can be more easily replaced by technology, thus displacing human low-skill labour. Two-thirds of all jobs in developing countries could potentially be displaced due to automation.[92]

The impact of technologies including AI on job displacement will vary greatly across countries, industries, education levels, socioeconomic status, age, and gender.[93] High levels of job displacement may have long-term impacts on earnings, income prospects, consumption, health, and mortality.[94] These job losses are likely to be displaced by higher-paying, higher productivity jobs in those sectors that leverage digital technologies, but these will be fewer in number and may be concentrated in richer countries that dominate digital service provision, where economies of scale and the low marginal cost of service delivery at scale mean that the "winners" are likely to take all. Successful transition of the labour market also requires government resources to provide a social safety net and support retraining, which may often be beyond the capacity of developing countries.

90 Resilience Academy, About Resilience Academy, accessed March 2022, https://resilienceacademy.ac.tz/about-us

91 World Economic Forum, In the developing world, two-thirds of jobs could be lost to robots, 14 November 2016, https://www.weforum.org/agenda/2016/11/in-the-developing-world-two-thirds-of-jobs-could-be-lost-to-robots#:~:text=Artificial%20Intelligence%20In%20the%20developing%20world%2C%20two-thirds%20of,Automated%20industry%20is%20gathering%20pace%20in%20developing%20nations

92 World Bank, World Development Report 2016: Digital Dividends, 2016, https://documents1.worldbank.org/curated/en/896971468194972881/pdf/102725-PUB-Replacement-PUBLIC.pdf

93 Skynet Today, Job Loss Due To AI—How Bad Is It Going To Be?, 2019, https://www.skynettoday.com/editorials/ai-automation-job-loss

94 World Bank, Tackling the impact of job displacement through public policies, 2020, https://www.worldbank.org/en/news/feature/2020/10/20/tackling-the-impact-of-job-displacement-through-public-policies

# 6 Recommendations

The findings from this report suggest several recommendation for IFIs, National Development Agencies, the broader development community, and developing countries when considering EO projects.

1. **Importance of development finance:** As stated above, because the return on investment from digital technologies to the economy exceeds the return to the private companies that make these investments, there is a clear role for government and the development community to ensure that socially optimal levels of investment in digital technologies like EO are obtained, e.g., through capacity-building and skills transfer activities. In the context of GDA, this strongly justifies the involvement of IFI Institutional Partners as contributors of development finance to amplify ESA's contribution of space finance.
2. **EO data procurement for developing countries:** There is a potential role for IFIs, the development community, or governments in supporting the procurement of EO data over developing countries (where data capture is otherwise low) to overcome the cost barriers to accessing data and allowing more equitable access. This would enable developing countries to exploit this data through a growing downstream industry focused on converting this data into value-added applications, rather than relying on domestic provision to generate this data at high cost. Support can take the form of subsidies for (commercial) EO data provision, or efforts to support collaboration, e.g., via grouped procurement, to share the costs of provision across multiple users and reduce duplicate expenditures.
3. **Direct and indirect benefits:** In the context of the cooperation framework, IFIs should communicate in their outreach to National Development Agencies that there are both direct benefits of EO for sustainable development to users and wider benefits to the wider economy of developing countries because of the existence of technology spillovers.
4. **Value of involvement of European industry:** GDA is structured to partner the European EO service sector with IFIs and, ultimately, government counterparts in developing countries. Evidence of the effectiveness of embedded subsidiaries of multinational corporations in transmitting technology spillovers to their host countries suggests that there are benefits in supporting European industry to generate spillovers and to develop their local footprint and embeddedness in developing countries that host their subsidiaries. There is therefore a dual benefit in terms of enabling new market growth for European industry and transferring knowledge to developing countries.
5. **Geographical concentration:** The importance of geographic proximity and clusters to the transmission of spillovers suggests that the number of developing countries that will grow mature downstream EO industries is limited. Therefore, the WB and ADB activities on capacity building and skills transfer might benefit from building and strengthening regional centres of excellence, and developing regional networks to ensure that the spillovers from these EO clusters are distributed widely.

6 **Risks and challenges:** Despite the benefits of EO, there are several associated challenges that policymakers in developing countries should be aware of. These include data sovereignty concerns that restrict the free flow of data and adoption of enabling technologies needed to exploit EO; the potential negative impact that increased digitalisation might have on developing world employment outcomes; and the need for governments to make significant investments in digital capabilities to equip developing countries with the capabilities to fully exploit EO and transition towards a higher productivity knowledge-based economy.

7 **Lack of literature on the indirect spillover benefits of EO:** Whilst the available literature on the direct benefits of EO for sustainable development is now established via efforts from ESA, Caribou Space, and others, there is a major literature gap regarding the wider benefits of spillovers from EO to the wider economy. WB and ADB could attempt to address this gap by commissioning further research on this topic.

Explore GDA #AcceleratingImpact at gda.esa.int
Contact us via gda@esa.int