Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development

Commissioned by the European Space Agency

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Foreword by ESA Director of Earth Observation Programmes

This report is the result of a close and productive collaboration between ESA and some of the key International Financial Institutions (IFIs) over the last decade. Together with the World Bank (WB), the Asian Development Bank (ADB), and the International Fund for Agricultural Development (IFAD), ESA have been evaluating the benefits (quantitative and qualitative) that satellite Earth Observation (EO) can deliver to development assistance in the framework of operations carried out in the developing countries. The report highlights both the use cases and development outcomes and impacts of satellite Earth Observation (EO) – from both ESA and additional organisations and initiatives.

Satellite Earth Observation (EO) provides a wide range of different types of environmental information that are global, comprehensive, accurate, repeatable and timely, and that are key to the effective planning and implementation of development assistance activities. In addition, Europe brings world-leading EO capabilities; both in terms of space missions (EU Copernicus, ESA, EUMETSAT, European National missions), and in terms of diversity of specialist products and services available through the downstream geo-information sector. In particular, Copernicus marks the beginning of a new era in Earth Observation with the Sentinel satellites now being launched as the basis of operational environmental information services and unprecedented volumes of data with long-term continuity to 2030 and beyond.

This initial collaboration has raised significant interest of these and other stakeholders in the development community to scale-up and mainstream the use of EO-based information in the longer-term. To achieve this ambitious goal, a joint initiative has been agreed in which ESA carry out the required technical developments, and the World Bank together the Asian Development Bank carry out complimentary activities (Capacity-building, Skills Transfer) using their own financial resources (Official Development Assistance Trust Funds) in an integrated programme of work called "Space in Support of International Development Assistance". I am very pleased to say that this highly innovative joint initiative is now underway with the ESA component financially supported by 13 Member States at the Space19+ in November 2019, and the WB and ADB components being brought into place this year through new dedicated Trust Funds (accredited by the Organisation for Economic Development - OECD).

The extraordinary period that we are experiencing now is a powerful demonstration that we live in world increasingly subject to major environmental, climatic, economic and social challenges. The 2030 Agenda for Sustainable Development is an action plan to take the bold and transformative steps that are urgently needed to shift the world onto a sustainable and resilient path. Therefore, in this context, we very much look forward putting EO technology to work in addressing some of today's grand societal challenges and to improve development assistance efficiencies and impact through wide-scale, long-term sustainable use of EO-based environmental information.

Dr Josef Aschbacher
Director of Earth Observation Programmes
European Space Agency

Background

Background

This report was commissioned by the European Space Agency (ESA). ESA is an intergovernmental organisation of 22-member states whose mission is to *"shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world"*.[1]

Since 2010, ESA has been working with various International Financial Institutions (IFIs)—including World Bank (WB), Asian Development Bank (ADB), European Investment Bank (EIB), Inter-American Development Bank (IADB), International Fund for Agricultural Development (IFAD), and the Global Environment Facility (GEF)—through the ESA Directorate of Earth Observation Programmes (EOP) and, specifically, through the Earth Observation for Sustainable Development (EO4SD) initiative.[2] EO4SD's objective was to promote the integration of satellite information products and services, as best-practice environmental information, in the planning and implementation of IFI development activities together with their respective developing country partners.

ESA is preparing a new joint initiative in partnership with WB & ADB, "Space in Support of International Development Assistance" (Space for IDA), in 2020. This initiative will extend and expand the efforts of EO4SD with a mission to *"Realise the full potential impact of environmental information from satellites in addressing core development challenges through transfer and mainstreaming into development assistance operations, activities and financing"*.

This report aims to capture and communicate the evidence of the use cases and impact of Earth Observation (EO) in sustainable development for select sectors including agriculture, forestry, disaster resilience, urban development and climate resilience.

The impact findings are primarily drawn from practical case examples in public domain literature and also based on interviews. The literature review used in this report prioritises evidence on EO use cases and impact for developing countries. However, in some areas limited information is available, and accordingly, examples from developed countries are used as needed.

The research findings within this report are expected to be of value to organisations in the development community who are interested in learning about the various use cases and impacts of integrating EO to advance their development. The audience is donors, IFIs, developing countries, national space agencies, and the broader development community e.g. NGOs. Whilst there are benefits arising from other aspects of space capabilities to the field of sustainable development (e.g., satellite communications (SatComms), global navigation satellite system (GNSS), space weather/meteorology), this report focuses on benefits arising from using EO as a unique and powerful source of environmental information.

1 European Space Agency. 'United Space in Europe'. https://www.esa.int. Accessed February 2020.
2 European Space Agency. 'Earth Observation for Sustainable Development'. http://eo4sd.esa.int/. Accessed February 2020.

Executive summary

Executive summary

What is sustainable development?

- Sustainable development is "*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*".
- The World Bank's World Development Report 2003 argues that "*Unless the transformation of society and the management of the environment are addressed integrally along with economic growth, growth itself will be jeopardised over the longer term*".
- The UN 2030 Agenda and the Sustainable Development Goals (SDGs) provide a globally agreed set of development priorities and targets to 2030.
- Accurate, global, and timely data is critical to tracking progress towards the achievement of the SDG targets and indicators, and Earth Observation (EO) can contribute to the measurement of 34 SDG indicators.
- Whilst the SDGs provide an overarching and globally agreed set of priorities, donors and IFIs provide customised assistance addressing individual developing countries' and local stakeholders' individual challenges.
- Developed countries support the economic, environmental, and social development of developing countries via their Official Development Assistance (ODA) budgets.
- Major global trends affecting development assistance include concerns on the environment and climate change and also the impact of advancing technology and innovation.
- For development assistance, robust data is the foundation for meaningful policymaking, efficient resource allocation, and effective public service delivery but widespread 'data deprivation' exists.
- Digital technologies—particularly the trinity of satellites, smartphones, and sensors can close this "data deprivation" gap by providing an increasingly detailed view of the world in which we live.

Using Earth Observation data for sustainable development

- Earth Observation (EO)—the process of gathering information about the physical, chemical, and biological systems of the planet via remote-sensing—provides unique datasets that enhance sustainable development programmes.
- Europe's Copernicus programme is the most comprehensive EO programme and is a game changer in providing an unprecedented volume of open access EO data – with operations secured for the coming decades.
- EO has global coverage including remote or conflict regions, it is diverse, affordable, objective, repeatable, continuous, and timely to acquire and process.
- EO is particularly powerful in data-scarce developing countries complementing other sources of data such as census, bespoke surveys, ground teams, or drones.

Benefits of Earth Observation for development assistance organisations

Donors and IFIs share similar multi-phase processes for designing, mobilising, delivering, and closing/evaluating their programmes, and EO can support these phases:

- EO facilitates improved policy definition and planning of future activities in the 'Design' stage,

– EO improves the efficiency of existing operations and activities, leading to increased impact in the 'Delivery' stage, and

– EO provides increased transparency, objectivity, and accountability in the 'Evaluation and Closure' stage by enhancing M&E capabilities.

- In addition, across all these programme delivery phases EO provides new and extended capabilities that allow donors and IFIs to tackle issues they could not previously address e.g. dealing with the complexity of climate resilience.
- Digital economies create benefits and efficiencies as digital technologies drive innovation, fuel job opportunities and support economic growth.
- Expansion of the EO services sector, as part of the digital economy in developing countries supports growth of local economies.

Impact of Earth Observation in agriculture

- The developing world agriculture sector faces many challenges, including lower production yields, ongoing food security concerns, growing populations, unsustainable use of natural resources, and climate change leading to unpredictable and extreme weather patterns.
- EO provides benefits within agriculture in five overarching areas:

1. Increasing agricultural production through accurate decision support tools,
2. Supporting sustainable management of environmental resources,
3. Optimising supply chains to reduce losses and improve food security,
4. Increasing accuracy of flood and drought warning systems, and
5. Ensuring affordable credit for farming inputs and insurance for crop/livestock losses.

- Several insights from public literature have contributed evidence to each of these areas, for example:

– EO has been used to provide cost-effective information that supports decisions at key points in crop cycles, optimises production, improves disease and pest response, and enables the restoration of wasteland to productive land.

– EO has proven use cases in resource management and has been shown to reduce waste (of water, fertilisers, and pesticides), reduce costs, and improve yields.

– EO has been incorporated into national food security monitoring and has improved government planning.

– EO-based services to deliver credit and insurance were shown to be timely, cost effective and deliver financial support in times of need.

– There is limited public domain evidence of EO use for reducing supply chain losses, but this represents a clear opportunity for EO.

Impact of Earth Observation in forestry

- Forests in the developing world face a wide range of challenges. These include pressure for conversion to agricultural land, illegal deforestation, habitat and biodiversity loss, and deprivation of livelihoods for forest-dependent communities.
- EO provides benefits within forestry in four overarching areas:

1. Supporting mapping and monitoring of deforestation and forest degradation,
2. Supporting precision forestry,
3. Providing resilience to natural disasters such as fires and floods in forests, and
4. Aiding local forest populations.

- Several insights from public literature have contributed evidence to each of these areas:

– EO has been used in global platforms for forest monitoring and as a data source for UN SDG 15 and Reducing Emissions from Deforestation and Forest Degradation (REDD+) reporting.

– EO has been used to support forest governance, deter illegal logging, and conserve high-carbon forestry stocks.

– EO has been applied as a cost-effective solution to optimise forest yield while also acting as an accountability tool for corporations to adhere to zero deforestation (ZD) commitments.

– Numerous cases have demonstrated EO capabilities in detecting forest fires and improving emergency response.

– Local forest populations have used EO to secure land rights and monitor and report illegal or harmful practices.

Impact of Earth Observation in disaster resilience

- Developing countries are highly impacted by disasters. Infrastructure and buildings may not be as resilient, disaster response procedures may be less sophisticated; moreover, low-income populations are exposed to hazards more often, lose a higher share of wealth, and receive less support from financial systems and governments.
- EO provides benefits within disaster resilience in three overarching areas:
  1. Improving the accuracy and extent of disaster early warning systems,
  2. Supporting near real-time monitoring for better planning and prioritisation in disaster response, and
  3. Improving resilience via insurance through better risk calculation.
- Several insights from public literature have contributed evidence to each of these areas:
  – There is evidence of early warning systems becoming more effective using EO, particularly for weather related events. This allows for timely activation of emergency plans, which reduces the number of deaths and missing persons as well as economic losses.

  – EO use was shown to support a more coordinated and targeted disaster response, for floods, hurricanes, and earthquakes.

  – The use of EO has been demonstrated to enhance existing insurance schemes and support disaster-risk financing mechanisms. It is expected that this use case will grow, considering the urgent need to insure risk in the face of climate change.

Impact of Earth Observation in urban development

- Cities need evidence-based plans to understand the city fabric and prioritise investment. But obtaining relevant, scalable data is a significant challenge for many developing world cities.
- EO provides benefits within urban development in four overarching areas:
  1. Urban planning and monitoring,
  2. Transport planning and monitoring,
  3. Hazard assessment, early warning, and response coordination, and
  4. Monitoring of environmental issues.
- Several insights from public literature have contributed evidence to each of these areas:
  – There is evidence of EO being integrated into city plans, slums assessments, and innovations using EO to resource their development plans by improving tax revenue.

  – Examples of EO used in transportation planning and monitoring exist, primarily in developed countries, but also more recently from developing countries.

  – Evidence on the benefits of EO for disaster risk assessments and efficient response is plentiful. In addition, there are EO applications to assess urban building/infrastructure risk exposure (see Impact of Earth Observation in disaster resilience section, above).

  – Innovations in satellite sensors enable the measurement of air quality and surface temperature to provide cities with critical environmental information that can be used to support sustainable development interventions.

Impact of Earth Observation in climate resilience

- Climate change presents the single biggest threat to development, and its widespread, unprecedented impacts disproportionately burden the poorest and most vulnerable people in developing countries.
- EO can provide key inputs to understanding the potential relationships of previously un-modelled (and not intuitive) dependencies between physical climate change and social outcomes.
- EO provides benefits in these overarching areas:
  1. Measuring the state of the climate through Essential Climate Variables (ECVs),
  2. Providing indicators for climate change risk assessments,
  3. Monitoring and building resilience to slow-onset climate change events e.g. sea level rise, and
  4. Monitoring and building resilience to rapid-onset climate change events (i.e. extreme weather events).

- Several insights from public literature have contributed evidence to each of these areas, for example:
  - ECVs address public demands for transparency in environmental decision making and have helped many nations to make commitments to support systematic, sustained climate records. ESA uses EO to produce ECVs through its Climate Change Initiative programme.
  - There is evidence of EO being used to monitor slow-onset climate change events where the repeatable, historical time series of data allows the analysis of long-term trends – including numerous examples for assessing sea level rise and coastal flooding risk.
  - There is extensive evidence of use of EO for rapid-onset climate-related events such as tropical cyclones – see Impact of Earth Observation in disaster resilience section.

Earth Observation uptake and barriers for donors and IFIs

- Donors particularly in Europe, have been flagbearers for the adoption of EO in sustainable development.
- In parallel, ESA has supported IFIs adoption of EO since 2010.
- The main barriers to expanding the wider use of EO in sustainable development are referred to as the 'five As':
  - The (1) Availability and (2) Accessibility barriers are currently being addressed by existing European programmes, including the Copernicus space component and the Copernicus Data and Information Access Services (DIAS).
  - The (3) Awareness, (4) Acceptance, and (5) Adoption barriers will be addressed by a new joint initiative between ESA, WB and ADB—Space in Support of International Development Assistance (Space for IDA).

Recommendation one: Close impact evidence gaps with robust monitoring & evaluation (M&E)

- Across multiple sectors and within various EO use cases, encouraging and positive evidence on benefits of EO within sustainable development have been highlighted.
- Some sectors have a longer history with using EO and therefore have more mature evidence bases. However, this is use case specific.
- New use cases for EO are emerging more quickly than the publication of corresponding impact evaluations. Both time and commitment of resources are needed for measuring the impact of EO.
- In programmes that are integrating EO as a core data source, a robust M&E system that both articulates and can evaluate the impact of EO within the sustainable development sector should be established at the start of the programme.
- Impact evaluations should communicate and quantify the benefits of EO—using language and statistics that the development community are familiar with.
- It is recommended that impact evidence be widely shared so that others can benefit from these lessons and results

Recommendation two: Need for the Space for IDA initiative to transfer and mainstream EO into development assistance

- The primary objective of Space for IDA will be to "*Realise the full potential impact of environmental information from satellites in addressing core development challenges through transfer and mainstreaming into development assistance operations, activities and financing*". The initiative will have three activities designed directly to address the barriers identified above:
  - **Activity 1: Knowledge Development (ESA-led)**: Co-develop demonstration materials and do risk-reduction technical developments for less well-established EO product types.
  - **Activity 2: Capacity Building (IFI-led)**: For IFIs, donors, private foundations, and developing countries in the use of EO in operations; co-design and develop methodologies and guidelines.
  - **Activity 3: Skills/Knowledge Transfer (IFI-led)**: Expertise and capability transfer programme for EO production and analytics in developing countries.
- The initiative will be implemented in a joint, coordinated programme of work between ESA and newly established Trust Funds at WB and ADB.
- The estimated budget will be between US$80-100 million for the WB and ADB led components.
- 13 ESA member states have provided initial financial commitments of €30 million and the objective to initiate implementation from 2020 to 2025.

What is sustainable development?

1. What is sustainable development?

Key points

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This section provides a brief background on the evolution of the concept of sustainable development and the role of development assistance within it.

1.1 Implementing sustainable development—the 2030 Agenda

Sustainable development is "*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*".[3] The United Nations Conference on Environment and Development held in Rio de Janeiro in 1992, marked the first international attempt to draw up action plans and strategies for moving towards a more sustainable pattern of development. [4] The World Bank's World Development Report 2003 argues that "*ensuring sustainable development requires attention not just to economic growth but also to environmental and social issues. Unless the transformation of society and the management of the environment are addressed integrally along with economic growth, growth itself will be jeopardised over the longer term*".[5]

The 2030 Agenda on Sustainable Development is a transformative and integrated development agenda to drive the global agenda on sustainable development. It

3 United Nations. 'World Commission on Environment and Development: Our Common Future'. www.un-documents.net/our-common-future.pdf. Accessed February 2020.

4 United Nations. 'United Nations Conference on Environment and Development (UNCED), Earth Summit'. https://sustainabledevelopment.un.org/milestones/unced. Accessed February 2020.

5 World Bank. 'World Development Report 2003. Sustainable Development in a Dynamic World'. http://siteresources.worldbank.org/INTBELARUS/Resources/328178-1118308098981/1244859-1118308125391/WDR2003Book.pdf. Accessed February 2020.

consists of 17 Sustainable Development Goals (SDGs) and 169 SDG targets; it has been adopted by the world leaders and was ratified by the UN General Assembly in 2015.

FIGURE 1: United Nations Sustainable Development Goals

Crucial to the 2030 Agenda is "*robust follow-up and review mechanism for the implementation of the 2030 Agenda for Sustainable Development requires a solid framework of indicators and statistical data to monitor progress, inform policy and ensure accountability of all stakeholders*".[6] EO is global, comprehensive, accurate, repeatable, and timely, and therefore it is a critical source of data to monitor progress toward the SDGs. The Inter-Agency Expert Group on the Sustainable Development Goals Indicators (IAEG-SDGs) has recognised the potential for geospatial information in defining some of the indicator methodologies. In April 2016, the IAEG-SDGs formed a Working Group on Geospatial Information (WGGI) to help countries realise the full potential of geospatial information and EO in the Global Indicator Framework.[7]

ESA has commissioned an in-depth and comprehensive analysis which identifies that EO can contribute to the measurement of 34 SDG indicators.[8] This included a classification based on the level of contribution that EO could make to each indicator's measurement. This also includes a technical report detailing the methodologies for using EO to calculate these indicators.

1.5.2	Disaster damage
2.4.1	Sustainable agriculture
6.3.2	Ambient water quality
6.4.1	Water use efficiency
6.4.2	Water stress
6.6.1	Water-related ecosystems
7.1.1	Access to electricity
9.1.1	All-season roads
11.1.1	Informal settlements
11.3.1	Land consumption
11.6.2	Urban air quality
14.1.1	Coastal marine pollution
14.3.1	Ocean acidification
15.1.1	Forest areas
15.2.1	Sustainable forest management
15.3.1	Land degradation
15.4.2	Mountain green cover

1.1.1	International poverty line
1.2.1	National poverty line
1.4.1	Access to basic services
2.3.1	Agricultural productivity by sector
3.3.3	Malaria incidences
3.9.1	Mortality due to air pollution
4.a.1	School facilities
6.1.1	Safe drinking water
6.3.1	Safe waste water treatment
3.4.1	Diseases induced mortality
11.2.1	Access to public transport
11.5.2	Damage to infrastructure
11.7.1	Public access to green space
13.1.1	People affected by disasters
14.4.1	Sustainable fishing
15.1.2	Terrestrial biodiversity
15.4.1	Mountain biodiversity

FIGURE 2: Categorisation of the SDG Indicators Based on the Identification of EO as a Relevant Data Source (**BLUE:** Highly Relevant; Grey: Potentially Relevant) (Credit: UNEP, GeoVille, DHIGras, UN Environment, WCMC)[9]

6 United Nations. 'Sustainable Development Goals'. https://unstats.un.org/sdgs/. Accessed February 2020.

7 UN-GGIM. 'Inter-Agency and Expert Group on the Sustainable Development Goal Indicators (IAEG-SDGS) Working Group on Geospatial Information'. https://ggim.un.org/UNGGIM-wg6/. Accessed February 2020.

8 UNEP, GeoVille, DHIGras, UN Environment, WCMC. 'Earth Observation for SDG D1.1: Compendium of Earth Observation contributions to the SDG Targets and Indicators March 2019'.

9 As above

WB and ADB have set organisational goals to achieve by 2030. WB wants to "*end extreme poverty by decreasing the percentage of people living on less than $1.90 a day to no more than 3%*" and "*promote shared prosperity by fostering the income growth of the bottom 40% for every country*".[10] Whilst under Strategy 2030, ADB will "*expand its vision to achieve a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty*".[11]

1.2 Development assistance

Whilst the SDGs provide an overarching and globally agreed set of priorities, donors and IFIs provide customised assistance addressing individual developing countries' and local stakeholders' individual challenges. Governments and other agencies provide development assistance (or comparable terms such as development cooperation) to achieve these goals.[12] Official Development Assistance (ODA) is defined by the OECD's Development Assistance Committee (DAC) as focused on "*economic development and welfare of developing countries*" and is "*concessional in character*".[13] ODA totalled US$147 billion in 2017, of which ~72% of ODA is spent bilaterally by individual national governments with the remainder channelled through multilateral institutions such as the UN, WB, and the Regional Development Banks.[14] The development assistance community includes national donors, private foundations and IFIs and shares the broad objective to reduce poverty and increase prosperity in developing countries.[15]

Donors, such as UK's DFID and Germany's BMZ, are examples of government departments responsible for administering development assistance. Donors provide financial support, typically through grants, alongside technical assistance and capacity building. At the pan-European level, Europe is considering the consolidation and streamlining of development finance and climate activities outside the EU into a single entity, a European Climate and Sustainable Development Bank.[16]

IFIs provide financing—loans and grants—and expert advisory services to low and middle-income countries. A differentiator between IFIs and donors is that many donor countries are their shareholders (multilateral assistance). IFIs are increasingly focused on addressing key environmental issues such as climate change, building climate and disaster resilience, and enhancing environmental sustainability.

A wide range of stakeholders see a critical role for IFIs in blending public and private finance to scale financing for development.[17] In 2017, it was estimated that US$160 billion in private investment was mobilised by the IFIs, of which US$59 billion went to low- and middle-income countries. The volume of private investment highlights the private sector's role in the global effort to promote inclusive and sustainable growth.

Private foundations are also significant sources of international development funding. Examples include the Bill and Melinda Gates Foundation, Mastercard Foundation, Rockefeller Foundation, and Omidyar Network. Foundations provided US$23.9 billion over 2013-15, corresponding to 5% of the amount given through ODA, and are major players in specific sectors such as health.[18]

10 World Bank. 'Ending Extreme Poverty and Promoting Shared Prosperity'. https://www.worldbank.org/en/about/what-we-do. Accessed February 2020.

11 Asian Development Bank (ADB). 'Strategy 2030'. www.adb.org/sites/default/files/institutional-document/435391/strategy-2030-main-document.pdf. Accessed February 2020.

12 Also termed development aid, development cooperation, technical assistance, international aid, overseas aid, official development assistance (ODA), or foreign aid.

13 OECD. 'Official development assistance—definition and coverage'. www.oecd.org/dac/stats/officialdevelopmentassistancedefinitionandcoverage.htm. Accessed February 2020.

14 OECD. '2016 and 2017 DAC flows at a glance'. www.oecd.org/dac/financing-sustainable-development/development-finance-data. Accessed February 2020.

15 UNDP. 'Our Partners'. www.undp.org/content/undp/en/home/partners/international_financialinstitutions.html. Accessed February 2020.

16 Council of the European Union General Secretariat. 'Europe in the World: The future of the European financial architecture for development'. www.consilium.europa.eu//media/40967/efad-report_final.pdf. Accessed February 2020.

17 Multiple IFIs. 'Mobilization of Private Finance 2017 by Multilateral Development Banks and Development Finance Institutions 2017. www.ifc.org/wps/wcm/connect/publications_ext_content/ifc_external_publication_site/publications_listing_page/2018_mdb-mobilization-report. Accessed February 2020.

18 OECD. 'Private Philanthropy for Development'. www.oecd.org/development/private-philanthropy-funding-for-development-modest-compared-to-public-aid-but-its-potential-impact-is-high.htm. Accessed February 2020.

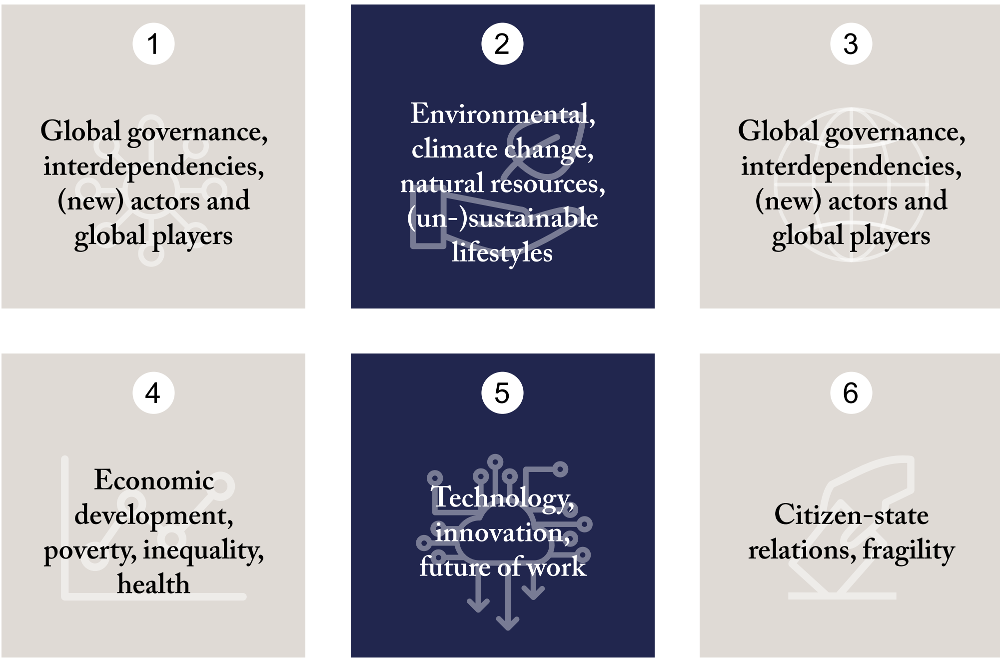

FIGURE 3: Major Trends Affecting Future Development Assistance (Credit: BMZ)[20]

1.3 Trends for development assistance

Germany's BMZ forefront that "*we are operating in a world characterised by growing complexity. An increasingly multipolar world order brings forth new actors and new technologies, which present challenges and opportunities at the same time*".[19] BMZ have defined global trends and hypotheses on future development policy and whilst all trends are relevant, two in particular for this report, deserve emphasis as highlighted in Figure 3.[20]

— *Environment and climate change*

Climate change and environmental degradation will have increasingly adverse consequences for humankind's overall quality of life. An increasing portion of the global population, especially in certain developing countries, will be vulnerable to the direct and indirect social, economic, political and security effects of climate change.[21]

Increasingly donors and IFIs are defining future strategies that address key environmental issues such as tackling climate change, building climate and disaster resilience and enhancing environmental sustainability. Since COP21, the Paris Climate Conference, access to international climate finance for many countries is assuming greater significance than ever before. Specialist global climate finance institutions plus substantial additional funds from the major IFIs support climate adaptation and mitigation, as highlighted below.

The Global Environment Facility (GEF)—has provided over US$20 billion in grants and mobilised an additional US$107 billion in co-financing for more than 4,700 projects in 170 countries.[22] GEF has published a report recommending "*GEF agencies should develop their internal capacity to use Earth observation data and technologies over the project cycle*".[23]

Green Climate Fund (GCF)—was established to limit or reduce greenhouse gas (GHG) emissions in developing countries, and to help vulnerable societies adapt to the unavoidable impacts of climate change. The GCF has implemented 124 projects worth US$3.6 billion.[24]

Climate Investment Funds (CIF)—is a US$8 billion fund that accelerates climate action by empowering transformations in clean technology, energy access, climate resilience, and sustainable forests in developing

19 BMZ. 'Development Policy in 2032. Global Trends and Hypotheses on Future Development Cooperation. Discussion Paper | March 2018'. www.bmz.de/en/publications/type_of_publication/strategies/Strategiepapier445_02_2018.pdf. Accessed February 2020.
20 As above.
21 As above.
22 Global Environment Facility. 'About Us'. www.thegef.org/about-us. Accessed February 2020.
23 Global Environment Facility. 'Earth Observation and the GEF: A STAP Document'. www.stapgef.org/earth-observation-and-gef. Accessed February 2020.
24 Green Climate Fund. www.greenclimate.fund/home. Accessed February 2020.

and middle-income countries. CIF has raised an expected US$53bn of co-financing for projects in 72 developing countries.[25]

Adaptation Fund (AF)—finances projects and programmes that help vulnerable communities in developing countries adapt to climate change. Since 2010 AF has committed US$720 million to 100 projects.[26]

International Finance Agencies (IFIs)—are now closely coordinating their climate finance activities. For example, the WB has made a commitment to increase the climate-related share of its lending from 21% to 28% by 2020.[27] For ADB, climate finance from their own resources will reach US$80 billion cumulatively from 2019 to 2030.[28]

— *Technology and innovation*

BMZ highlights *"emerging technologies and digitalisation as one of the strongest drivers of transformation in all spheres of life"* and "*the need to factor in the risks and opportunities provided by new technologies in development measures as well as to test and adopt technical solutions where feasible*".[29] Whilst there are numerous areas where future technologies will impact development assistance, of particular relevance to this report, is the use of technology to improve the availability of data for informed decision making in the development community.

European donors highlight the need for robust data for informed decision making. UK DFID's Digital Strategy 'Doing Development in a Digital World' states an objective to effectively use data for "*better decision-making in our programmes and operations, and strengthen our accountability, transparency and public engagement*".[30] Equally, BMZ highlight that "*In particular, development policy will require increased analytical capacities to be able to track and understand complex developments and their underlying drivers*" and that "*development policy could promote access to high quality data as a global good*".[31] BMZ's report 'Digital technologies for development' includes 'Goal 5: Data for Development' that states "*This means strengthening capacities in these countries and improving access to digital data. The analysis of satellite data, for example, holds huge potential for improving agricultural value chains*".[32]

In development assistance, robust data is the foundation for meaningful policymaking, efficient resource allocation, and effective public service delivery but widespread 'data deprivation' exists. The WB identifies 77 countries that lack sufficient data to adequately measure poverty.[33] Traditional methods of collecting data for sustainable development purposes include civil registration and vital statistics, census, administrative data, and household surveys. Increasingly, these sources are complemented by new technologies and thus new sources of data that save time, increase accuracy, enhance precision, and provide previously unavailable insights.

Digital technologies— and in particular the trinity of satellites, smartphones, and sensors can close this "data deprivation" gap by providing an increasingly detailed view of the world in which we live.[34] Satellite-based EO is a powerful and unique source of data for development because it is global, comprehensive, repeatable and frequently updated—providing a view to the past—and to the future.

25 Climate Investment Funds. www.climateinvestmentfunds.org/. Accessed February 2020.

26 Adaptation Fund. 'About the Adaptation Fund'. www.adaptation-fund.org/about/. Accessed February 2020.

27 World Bank. 'Climate Finance'. www.worldbank.org/en/topic/climatefinance#3. Accessed February 2020.

28 Asian Development Bank (ADB). 'ADB Strategy 2030'. www.adb.org/sites/default/files/institutional-document/435391/strategy-2030-main-document.pdf. Accessed February 2020.

29 BMZ. 'Development Policy in 2032 Global Trends and Hypotheses on Future Development Cooperation Discussion Paper | March 2018'. www.bmz.de/en/publications/type_of_publication/strategies/Strategiepapier445_02_2018.pdf. Accessed February 2020.

30 DFID. 'DFID Digital Strategy 2018 to 2020: Doing Development in a Digital World'. www.gov.uk/government/publications/dfid-digital-strategy-2018-to-2020-doing-development-in-a-digital-world. Accessed February 2020.

31 As above.

32 BMZ. 'Digital technologies for development'. https://www.bmz.de/en/publications/type_of_publication/strategies/Strategiepapier459_01_2019.pdf. Accessed February 2020.

33 World Bank. 'Data for development impact: Why we need to invest in data, people and ideas'. https://blogs.worldbank.org/voices/data-for-development-impact-why-we-need-to-invest-in-data-people-and-ideas. Accessed February 2020.

34 Caribou Digital. 'Five reflections on five years'. https://medium.com/caribou-digital/five-reflections-on-five-years-cc63120363d2. Accessed February 2020.

Using Earth Observation data for sustainable development

2. Using Earth Observation data for sustainable development

Key points

- Earth Observation (EO)—the process of gathering information about the physical, chemical, and biological systems of the planet via remote-sensing—provides unique datasets that enhance sustainable development programmes.
- Europe's Copernicus programme is the most comprehensive EO programme and is a game changer in providing an unprecedented volume of open access EO data – with operations secured for the coming decades.
- EO has global coverage including remote or conflict regions, it is diverse, affordable, objective, repeatable, continuous, and timely to acquire and process.
- EO is particularly powerful in data-scarce developing countries complementing other sources of data such as census, bespoke surveys, ground teams, or drones.

This section introduces how the EO sector is evolving and providing a new wealth of EO data, which can be a game changer for developing, implementing, and monitoring sustainable development programmes.

2.1 Advances in Earth Observation

Earth Observation (EO) is the process of gathering information about the physical, chemical, and biological systems of the planet via remote-sensing technologies. EO is used to monitor and assess the status of and changes in natural and built environments.[35] EO data comes from a variety of satellite-mounted sensors offering different capabilities.

Significant developments in EO are enabling its use in a range of sustainable development domains. Space technology is not new—in August 1959 the Explorer 6 took the first pictures of Earth[36]—60 years later there are over 400 EO satellites in orbit, with hundreds more over the coming years.[37] The technology is advancing rapidly, with numerous trends enabling the effectiveness and impact of EO within sustainable development including cost, accuracy, computing power, and a mature applications sector.

Europe's Copernicus programme is the most comprehensive EO programme and is a game changer in providing an unprecedented volume of open access EO data.[38] ESA is responsible for coordinating the Copernicus space component and is developing the fleet of Sentinel satellites. Although funded by Europe with €8.2 billion (2008-20), and built to European specifications, Copernicus is a global system, and the Copernicus data policy is committed to providing "free, full and open" data. Over the same period this investment will generate economic benefits between €16.2 and €21.3 billion.[39] Copernicus data is available to the public via the Sentinel Open Access Data Hub, which has 294,373 users, who have downloaded over

35 Wikipedia. 'Earth Observation'. https://en.wikipedia.org/wiki/Earth_observation. Accessed February 2020.

36 ESA. '50 years of Earth Observation'. www.esa.int/About_Us/ESA_history/50_years_of_Earth_Observation. Accessed February 2020.

37 The Parliamentary Office of Science and Technology, Westminster, London. No. 566, November 2017. 'Environmental Earth Observation'. https://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-0566. Accessed February 2020.

38 Copernicus is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies, and Mercator Océan.

39 PwC for the European Commission. 'Copernicus Market Report—February 2019'. www.copernicus.eu/sites/default/files/2019-02/PwC_Copernicus_Market_Report_2019_PDF_version.pdf. Accessed February 2020.

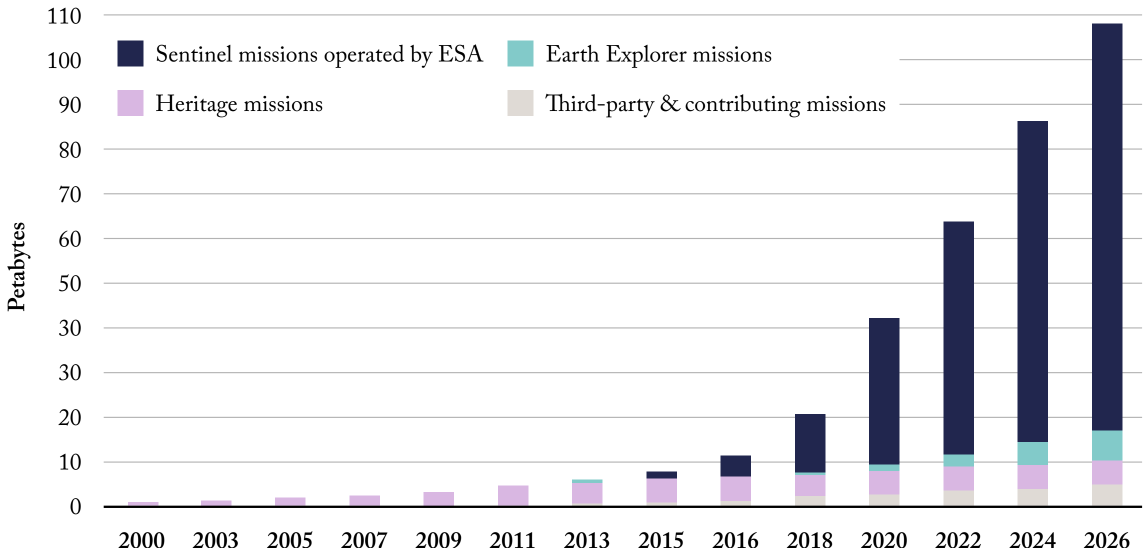

FIGURE 4: Projected Volume of Data Available from ESA's EO Data Archive (Petabyte) (Credit: ESA)[42]

211 PB of data.[40] At ESA's Ministerial Council in November 2019, European governments committed, in collaboration with the European Commission, to funding Copernicus's operations for the coming decades.[41]

The costs of commercial data, such as very high resolution data (<1 m) are falling. Copernicus Sentinel data is provided for free whereas commercial data has a cost. However, prices for commercial EO data are also forecast to fall over the next five years.[43]

Spatial and temporal accuracy has increased. Advances in on-board technologies are constantly improving spatial resolution, measurement accuracy, and frequency of observations. There are a wide range of very high resolution (<1 m) and high resolution (<10 m) satellite missions operated either nationally or commercially.

Private sector entrepreneurs are bringing innovation from other industries. The space sector is undergoing rapid evolution, characterised by a new playing field including the emergence of private companies, participation with academia, industry and citizens, digitalisation and global interaction.[44] New entrants into the EO sector, for example Planet, are bringing further innovations using small satellites to provide high resolution imagery on a daily update basis.[45]

Advances in computer processing power and data analytics. Major ICT players offer specialised cloud platforms for hosting, managing, and presenting EO data sets and algorithms.[46] Machine learning algorithms that automatically identify objects and land cover are advancing rapidly. Crowdsourcing platforms[47] collect and enhance the reference data to train those machine learning algorithms. High quality ground truth data, to calibrate and test the accuracy of the algorithms, such as traditional development Microdata, is more available.[48] Finally, open-source annotated datasets, and other publicly available resources allow the data to be processed and documented.[49]

Specialist companies and organisations in the European EO information services sector (and global equivalents) that create EO applications are proliferating. ESA and the European Commission have invested ~€250 million in R&D over the last decade to ensure these products are robust and accurate. The European EO information services sector (private companies, government institutes,

40 Copernicus. 'Copernicus Open Access Hub'. https://scihub.copernicus.eu/reportsandstats/. Accessed February 2020.

41 ESA. 'ESA ministers commit to biggest ever budget'. www.esa.int/About_Us/Corporate_news/ESA_ministers_commit_to_biggest_ever_budget. Accessed February 2020.

42 Personal communication. Stephen Coulson. ESA. September 2018.

43 Northern Sky Research. 'Satellite-Based Earth Observation Market Report, 11th Edition (EO11)'. www.nsr.com/research/satellite-based-earth-observation-eo-11th-edition/. Accessed February 2020.

44 ESA. 'What is Space 4.0?'. https://www.esa.int/About_Us/Ministerial_Council_2016/What_is_space_4.0. Accessed February 2020.

45 Planet. 'Planet Imagery and Archive'. www.planet.com/products/planet-imagery/. Accessed February 2020.

46 For example, Amazon with Earth from AWS, Microsoft with Azure, and Google Earth Engine.

47 For example, MTurk, Figure-eight, and Tomnod.

48 World Bank. 'Microdata Library'. https://microdata.worldbank.org/index.php/home. Accessed February 2020.

49 Chrieke. 'Awesome Satellite Imagery Datasets'. https://github.com/chrieke/awesome-satellite-imagery-datasets. Accessed February 2020; World Bank, 'World Bank Open Data'. https://data.worldbank.org/. Accessed February 2020; NASA. 'Introduction—Cumulus Documentation'. https://nasa.github.io/cumulus/docs/cumulus-docs-readme. Accessed February 2020; and Development Seed. 'Label Maker: Data Preparation for Satellite Machine Learning'. https://github.com/developmentseed/label-maker. Accessed February 2020.

universities) has grown as a world leader through these investments. These capabilities are not confined to Europe and can be leveraged for challenges in developing countries.

2.2 Advantages of Earth Observation

In the context of sustainable development, EO is almost always a complement to other data sources such as traditional maps, census data, bespoke surveys, ground teams, or drones. EO has many advantages over these traditional alternatives, including:

- **Coverage**: Satellites have global coverage making it possible to consistently monitor vast, remote, and even conflict regions across countries and continents.
- **Objectivity:** Satellite observations derive from the satellite instrument's 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.
- **Repeatability:** The nature of satellite observations, being collected along a periodic orbit of the Earth's surface, means that they are repeatable and comparable over time.
- **Continuity:** The continuity of EO data streams allows time to build experience and refine the systems that use the data.
- **Thematic detail:** The range of satellite sensors now available allows for application to a wide range of domains including climate change, agriculture, forestry, urban development, and disaster resilience.
- **Analysis-ready data:** Satellite data is organised and processed according to defined industry standards and provided in a form that allows immediate further analysis.
- **Speed:** Increasingly, EO data is available for use soon (days or even hours) after it is acquired, enabling stakeholders to receive the EO-derived information they need to act quickly—critical in, for example, disaster scenarios.
- **Affordability:** Along with the increase in commercial satellites, there is also an increase in satellites, such as the Copernicus Sentinel missions, that allow free and open access to data.

> *"The results from the satellite data were stunning… quick, cost-effective and technically sound. They gave us visually impressive products that easily communicated the magnitude of the problem to our counterparts in government".*

Sameh Wahba, Global Director, Urban, Disaster Risk Management, Resilience and Land Global Practice, WB[50]

> *"There was a sheer absence of data before, and now there is the data* [from EO]*, but also the data is more reliable rather than being tweaked for whatever statistical creativity that people want to use. So, it is giving us all new insights, things people knew before, only intuitively".*

Pieter Waalewijn, Global Lead Water in Agriculture, WB[51]

> *"Earth Observation, you know, it brings consistent data. It brings it quickly. And, it's unbiased".*

Bekzod Shamsiev, Senior Agriculture Economist, WB[52]

> *"The government do not have enough data to objectively decide where they want to prioritise. So, it helps. It saves a lot of time, because if we do it manually, and visit the whole city in mega cities like Karachi and Dhaka, it will be extremely time consuming, it would also be very subjective. I think this provides a very good methodology of consistency in trying to analyse a whole city quite quickly".*

Interviewee – World Bank Dhaka and Karachi neighbourhood improvement project

> *"Nowadays with this data* [from EO] *alongside many open-source applications at your fingertips you have access to loads of data and can get a sense of what's happening now and also in the past. We can almost readily use many of these products to validate our traditional data sources and fill in any gaps".*

Andrea Juarez-Lucas, Water Resources Management Specialist at The World Bank

50 World Bank. 'High Above Earth, Satellites Help Direct Ground-Breaking Development Work'. https://www.worldbank.org/en/news/feature/2013/08/20/earth-observation-for-development-success-stories. Accessed January 2020.

51 Caribou Space interview with Pieter Waalewijn on 23rd January 2020

52 Caribou Space interview with Bekzod Shamsiev on 24h January 2020

Benefits of Earth Observation for development assistance organisations

3. Benefits of Earth Observation for development assistance organisations

Key points

- Donors and IFIs share similar multi-phase processes for designing, mobilising, delivering, and closing/evaluating their programmes, and EO can support these phases:
  - EO facilitates improved policy definition and planning of future activities in the 'Design' stage,
  - EO improves the efficiency of existing operations and activities, leading to increased impact in the 'Delivery' stage, and
  - EO provides increased transparency, objectivity, and accountability in the 'Evaluation and Closure' stage by enhancing M&E capabilities.
- In addition, across all these programme delivery phases EO provides new and extended capabilities that allow donors and IFIs to tackle issues they could not previously address e.g. dealing with the complexity of climate resilience.
- Digital economies create benefits and efficiencies as digital technologies drive innovation, fuel job opportunities and support economic growth.
- Expansion of the EO services sector, as part of the digital economy in developing countries supports growth of local economies.

This section highlights the cross-cutting, pan-sector benefits of EO in sustainable development by assessing how donor agencies and IFIs have and could continue to benefit from the integration of EO in their programmes and their policies.

3.1 Benefit of Earth Observation to donors and IFIs

Using the programme life cycle as a framework, EO can both supplement and enhance information and support critical decisions across the cycle. Donors and IFIs share similar multi-phase processes for designing, mobilising, delivering, and closing/evaluating their programmes as per Figure 5.

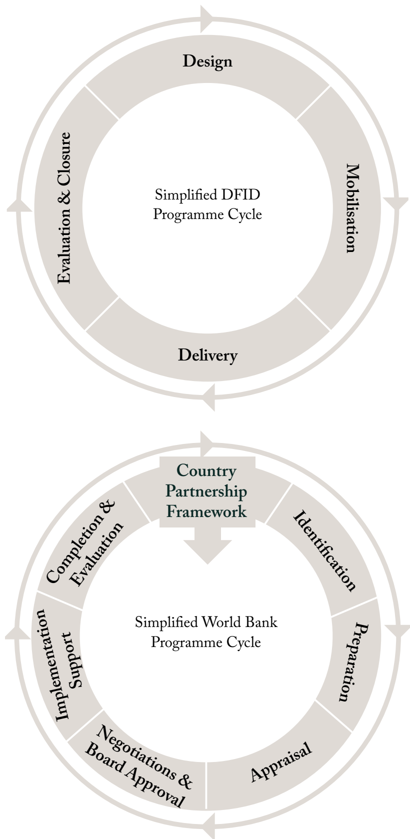

FIGURE 5: Example Donor (DFID) and IFI (WB) Programme Delivery Cycles[53]

53 DFID. 'Smart Rules: Better Programme Delivery'. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/840802/Smart-Rules-External-Oct19.pdf.pdf. Accessed February 2020; World Bank. 'World Bank Project Cycle'. https://projects.worldbank.org/en/projects-operations/products-and-services/brief/projectcycle. Accessed February 2020.

"Earth Observation provides the development community with an unbiased, consistent and timely perspective that can inform data-driven decision making. Geospatial data and analytics are increasingly considered key elements for making development policy and have proven to be effective in supporting the planning, implementation, monitoring and evaluation of sustainable development projects. It therefore helps us to achieve our core mission at the World Bank to eliminate extreme poverty and boost shared prosperity, and to better serve our clients. The well-established partnership with the European Space Agency is illustrating the value of EO-derived services for World Bank operations".

Laura Tuck, Former Vice President Sustainable Development, WB[54]

EO facilitates improved policy definition and planning in the 'Design' stage. This stage involves the identification of context, problem, evidence, cumulating into decisions on the appropriate delivery plan. EO provides granular, current, and historical environmental information to identify and track trends over large regions. In addition, EO products have been developed for core sectors such as agriculture, urban development, disaster resilience, climate change, maritime, and forestry. As donors and IFIs develop country-level diagnostics and strategies to identify significant development challenges and opportunities to create change, EO can contribute significant value during the diagnostic. EO has been applied to substantiate the severity of the development challenge, helping to appraise a range options for development programmes. EO also improves the design of large-scale investments and programmes of the donors and IFIs.

"Satellites provide spatially explicit, consistent and comparable city-level observations. These observations have significantly reduced the uncertainty about the evolution of cities, creating the opportunity for better planning of infrastructure investments and services. The on-going collaboration with ESA is helping ADB to explore the value of Earth Observation-based maps and applying them in designing our lending projects".

Vijay Padmanabhan, Director, Urban Development and Water, Southeast Asia Department, ADB[55]

"One of the key sectors where EO is growing and contributing for analysis are exploring the dynamics of water resources endowments and water quality monitoring. We present our water & sanitation programme designs to the board, which includes representatives from all the developing countries involved. In those designs, having Earth Observation imagery is a powerful way to show them the information that is most relevant".

Christian Borja-Vega, Senior Economist, WB[56]

EO improves the efficiency of existing operations and activities, leading to increased impact in the 'Delivery' stage of individual programmes and projects. This benefit has been the primary focus of existing European programmes such as ESA Earth Observation for Sustainable Development (EO4SD), UK Space Agency International Partnership Programme (IPP) and the Dutch Geodata for Agriculture and Water (G4AW), and examples of this benefit are numerous—see the later sections of this report for detail. Commonly, the role of EO here is to enable a decision support tool/platform for developing country stakeholders to address problems in their respective sectors. Such as an illegal deforestation monitoring system in the forestry sector.

"EO services bring a powerful analytical tool to the development context. They make you see the hidden and complex dynamics between the bio-physical and the socio-economic components of the livelihood systems; they make you reach better targeting and they make you see the difference you bring in the ground and in the lives of people".

Naoufel Telahigue, Country Program Manager, IFAD Near East, North Africa, Europe and Central Asia Division[57]

"ADB is increasingly applying EO data and products in the design and implementation of projects across the region… We hope enhanced cooperation with agencies such as ESA and EO service providers will lead to strengthened capacity among our developing member countries to better exploit the potential of geo-information for sustainable development".

Nessim Ahmad, Previously: Deputy Director General, ADB Regional and Sustainable Development Department[58]

54 ESA and CEOS. 'Satellite Earth Observation in support of the sustainable development goals'. http://eohandbook.com/sdg/index.html. Accessed February 2020.

55 Same as above

56 Caribou Space interview with Christian Borja-Vega on 24h January 2020

57 ESA and CEOS. 'Satellite Earth Observation in support of the sustainable development goals'. http://eohandbook.com/sdg/index.html. Accessed February 2020.

58 Asian Development Bank (ADB). 'Satellite Data Bring Innovation to Development'. www.adb.org/news/features/satellite-data-bring-innovation-development. Accessed February 2020.

EO provides increased transparency, objectivity, and accountability, in the 'Evaluation and Closure' stage of IFIs and donors by enhancing M&E capabilities. High-resolution EO can demonstrate progress made with implementation activities and greatly reduce the cost of M&E. Using imagery to estimate changes in crop yields, levels of forestation, or water levels can reduce the need for expensive ground surveys for rigorous, and expensive, impact evaluations. Real-time data feeds of implementation activities can also act as feedback loops for programme managers, enabling them to adjust programme activities or reallocate resources to maximise the impact and cost-effectiveness of the project. One particular example is in Environmental Safeguards Systems (ESS). Development projects are often accompanied by environmental policy and procedures to screen proposed projects and, once implemented, assess the impacts and performance of projects. These policies and procedures are termed broadly Environmental Safeguard Systems (ESS), and in recent years the receipt of development assistance by developing country partners has become conditional upon on the use of these safeguard mechanisms.

> *"For good monitoring and evaluation of progress, outputs and outcomes, one needs good baseline information. Because if you don't have that baseline, then you can pretty much claim whatever you want. I would see that remote sensing has a key role to play in deriving robust baselines and for the reliable monitoring and evaluation stages. Also, before one invests resources, remote sensing can greatly help in the identification of a potential problem and the confirmation that a real problem exists – it's not just a hunch".*

Erick Fernandes, Global Lead Technology, Innovation & Climate Smart Agriculture, WB[59]

Across all these programme delivery phases EO provides new and extended capabilities that allow IFIs and donors to tackle issues that were not previously possible to address. EO enables agencies to monitor activities in fragile and conflict-affected settings when some locations are inaccessible to the personnel on the ground. In the aftermath of conflict or a natural disaster, EO can be used to ascertain the extent of the damage to buildings and communities and estimate the location of any possible survivors so that agencies can direct their resources to the highest priority settings. EO can also be used to track the activities of armed groups so that organisations can work to minimise—or at least plan a response for—any casualties from a conflict situation. ESA has also promoted the use of EO to detect and clear landmines.[60] And, in refugee settings, EO can be used to monitor mass forced movements of people.

> *"EO can measure things that we cannot measure otherwise. For example, in agriculture, we're interested in not just general agriculture sector performance, but instead we want to know the performance of the top ten percent of farmers. So, we can see what the best performing farmers are doing— that others are not doing. And that we cannot get from national statistics".*

Bekzod Shamsiev, Senior Agriculture Economist, WB[61]

59 Caribou Space interview with Erick Fernandes on 23rd January 2020

60 ESA. 'HOPE for detecting landmines'. www.esa.int/Our_Activities/Space_Engineering_Technology/TTP2/HOPE_for_detecting_landmines. Accessed February 2020; ESA. 'MIDAS—Mine & Ied detection augmented by satellite'. https://business.esa.int/projects/midas. Accessed February 2020.

61 Caribou Space interview with Bekzod Shamsiev on 24h January 2020

3.2 The Earth Observation sector contributes to the growth of digital economies

Digital economies create benefits and efficiencies as digital technologies drive innovation and fuel job opportunities and economic growth.[62] The term *digital economy* refers to a broad range of economic activities that use digitised information and knowledge as key factors of production. EO is one such digital technology, and as the EO information services sector grows in developing countries there will be a multiplier benefit for their local economies. Local organisations will generate products, jobs, and revenues, providing economic benefit to the local economy.

The economic benefits in the growth of the EO information services sector and the wider economy can be quantified. The UK Space Agency IPP's primary objective is to deliver a sustainable, economic, or societal benefit to undeveloped nations and developing economies. The secondary objective is to develop valued and sustainable partnership arrangements which lead to growth opportunities for the UK space sector. London Economics (Space Division) were sub-contracted to Caribou Space, on behalf of UK Space Agency, to quantify the economic benefit of IPP to the UK economy. Albeit a developed-country example, the results are compelling, and such economic evaluations could be replicated for developing countries: IPP has generated £279 million in GVA for the UK economy and supports 3,300 jobs. In total the UK gets more than £2 of benefit back for every £1 invested in IPP projects.[63]

62 Asian Development Bank (ADB). 'Understanding the Digital Economy: What Is It and How Can It Transform Asia?'. www.adb.org/news/events/understanding-digital-economy-what-it-and-how-can-it-transform-asia. Accessed February 2020.

63 Caribou Space and London Economics. 'Economic evaluation of the International Partnership Programme (IPP): Economic return to the UK'. www.spacefordevelopment.org/wp-content/uploads/2019/10/UKSA-IPP-UK-Economic-Return-FINAL-for-web.pdf. Accessed February 2020.

Impact of Earth Observation in agriculture

4. Impact of Earth Observation in agriculture

Key points

- The developing world agriculture sector faces many challenges, including lower production yields, ongoing food security concerns, growing populations, unsustainable use of natural resources, and climate change leading to unpredictable and extreme weather patterns.
- EO provides benefits within agriculture in five overarching areas:
  1. Increasing agricultural production through accurate decision support tools,
  2. Supporting sustainable management of environmental resources,
  3. Optimising supply chains to reduce losses and improve food security,
  4. Increasing accuracy of flood and drought warning systems, and
  5. Ensuring affordable credit for farming inputs and insurance for crop/livestock losses.
- Several insights from public literature have contributed evidence to each of these areas, for example:
  - EO has been used to provide cost-effective information that supports decisions at key points in crop cycles, optimises production, improves disease and pest response, and enables the restoration of wasteland to productive land.
  - EO has proven use cases in resource management and has been shown to reduce waste (of water, fertilisers, and pesticides), reduce costs, and improve yields.
  - EO has been incorporated into national food security monitoring and has improved government planning.
  - EO-based services to deliver credit and insurance were shown to be timely, cost effective and deliver financial support in times of need.
  - There is limited public domain evidence of EO use for reducing supply chain losses, but this represents a clear opportunity for EO.

4.1 The value of agriculture

The human population is predicted to increase to 9.7 billion by 2050 and could peak at 11 billion by 2100.[64] Most of the additional people will be in developing countries—and investment in sustainable and productive agricultural systems is required to ensure sufficient food is available for the world's growing population.

Additionally, agriculture is crucial to economic growth—in 2014 it accounted for one-third of global gross-domestic product (GDP).[65] Agriculture employs 1.3 billion people globally and over 60% of the workforce in sub-Saharan Africa.[66] Growth in the agriculture sector is two to four times more effective in raising incomes among the poorest compared to other sectors.[67]

64 United Nations Department of Economic and Social Affairs. 'World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100'. www.un.org/development/desa/en/news/population/world-population-prospects-2019.html. Accessed February 2020.

65 World Bank. 'Agriculture and Food: Overview'. www.worldbank.org/en/topic/agriculture/overview. Accessed February 2020.

66 CropLife. 'Agriculture: A $2.4 Trillion Industry Worth Protecting'. https://croplife.org/news/agriculture-a-2-4-trillion-industry-worth-protecting/. Accessed February 2020.

67 World Bank. 'Agriculture and Food: Overview'. www.worldbank.org/en/topic/agriculture/overview. Accessed February 2020.

4.2 Agricultural challenges

The global agriculture sector faces many challenges, many of which are more acute in developing countries. Low agricultural production remains a major issue in developing countries and contributes to ongoing hunger and malnutrition. Concurrently, there is a growing demand for food and decreasing availability of agricultural land, therefore access to and the sustainable use of natural resources, such as land and water is under increasing pressure. Furthermore, unpredictable and extreme weather patterns, loss of land, and changes in growing conditions caused by climate change compounds challenges for the agriculture industry globally.

4.3 EO's role in agriculture

EO is well placed to contribute to the solution to these challenges in both developed and developing countries. The unique benefit of EO is global, repeatable, accurate, and scalable environmental information, providing high-value, cost-effective insights to the agricultural sector and supporting:

- Increased agricultural production through accurate decision support tools,
- Sustainable management of environmental resources such as land and water,
- Optimisation of supply chains to reduce losses and improve food security,
- Accuracy of flood and drought warning systems, and
- Affordable credit for farming inputs and insurance for crop and livestock losses.

The UK Space Agency IPP has forecast that satellite solutions for agriculture will be almost seven times more cost-effective in the long term than non-space alternatives at improving crop yield.[68] This corresponds to a cost of £0.05 per £1 of additional crop yield gained. The large scale that space solutions cover, with frequent in-season data, provides unprecedented intelligence on plant health, crop performance and land use which can then support decision-making to improve productivity and protect against losses.

Figure 6 highlights both the role and impact of EO data within the agricultural sector. The following section forefronts how EO data has been and is being used to solve various challenges in the agricultural sector.

Impact	EO products contribute to the achievement of UN SDG 2 "Zero Hunger"				
Outcomes	Increase production	Sustainable use of natural resources	Improved supply forecasting	Increased climate and disaster resilience	Improve access to financial services
	Improved agricultural productivity	Uptake of sustainable practices to enhance yields and protect ecosystems	Increased accuracy of yield forecasts and improved supply chain efficiencies	Resilience to climate change and disasters	Access to affordable financial services
Outputs	EO supports increased agricultural production through accurate decision support tools	EO supports sustainable management of environmental resources	EO supports optimisation of supply chains to reduce losses and improve food security	EO supports flood and drought early warning systems	EO supports affordable credit for farming inputs and insurance for crop/livestock losses
Agricultural challenges	Low yield / livestock production	Unsustainable use of natural resources	Limited supply chain forecasting	Increase in frequency and severity of extreme weather	Low access to financial services for small-holder farmers
	Lack of scalable data for agricultural mapping and monitoring				

FIGURE 6: Outcomes and Impacts of EO in Agriculture

68 Caribou Space and London Economics. 'Economic evaluation of the International Partnership Programme (IPP): Cost-effectiveness Analysis'. www.spacefordevelopment.org/library/economic-evaluation-of-the-international-partnership-programme-ipp-cost-effectiveness-analysis/. Accessed February 2020.

FIGURE 7: WeatherSafe Platform used in the ACCORD Project Showing Coffee Field and Normalised Difference Vegetation Index (NDVI) Heatmap, and Seven-day Weather Forecast (Credit: Weathersafe)[72]

— *EO supports increased agricultural production through accurate decision support tools*

Agricultural productivity in developing countries is significantly lower than in developed markets; yields of wheat and rice in low-income countries are currently about half those in high-income countries.[69] This yield gap needs to substantially decrease to support the needs of the growing population. Central to yield optimisation is accurate and timely information to support decisions. EO has been used to provide cost-effective environmental information that supports decisions at key points in crop cycles, improves disease and pest response, and enables the restoration of wasteland to productive assets.

EO supports localised and national agricultural information for decision making. One factor of the yield gap is a lack of accurate and timely information to support decisions. EO-enhanced decision support tools have enabled actors in the agricultural value chain to make evidence-based and timely decisions. Examples from Mozambique, Bangladesh, and Kenya showcase the value and cost-effectiveness of EO in providing information for crop management, food security, and explicit examples of the impact of information on framing practices and, ultimately, yield and income.

- G4AW-supported GEOBIS uses geospatial data for providing time and location specific advisory services to smallholder farmers in Bangladesh. It aims to improve agricultural productivity, income, and the management of weather-related emergencies. Farmers receive information through mobile phones, a call centre, a website, app-based services, and personal advice via extension officers. 240,000 farmers have been reached and a 7% increase in production and a 12.5% increase in income was observed.[70]
- The UKSA IPP-supported Advanced Coffee Crop Optimisation for Rural Development (ACCORD) project, led by Earth-i, provides coffee farmers in Rwanda and Kenya with access to timely, geotargeted advice through a simple mobile application and text messaging. ACCORD combines EO data with ground observations and a custom, high-resolution localised weather forecast model. To date, approximately 45,500 farms have been mapped to the platform, while quarterly surveys indicated that 94% of farmers are taking the recommended actions and 98% have reported a positive change in their farming practices.[71] By the end of the project period, ACCORD forecasts a doubling of coffee yields and improved income.

69 Food and Agriculture Organisation (FAO). 'The Future of Food and Agriculture. Trends and Challenges'. www.fao.org/3/a-i6583e.pdf. Accessed February 2020.

70 Geodata for Agriculture and Water (G4AW). 'GEOBIS Bangladesh: Geodata Based Information Services for smallholder farmers in Bangladesh'. https://nso-g4aw.akvoapp.org/en/project/5311/#report. Accessed February 2020.

71 Personal communication. Ody Mbonu. Earth-i. January 2020.

72 Caribou Space for UK Space Agency. 'Space Solutions for Development'. https://www.spacefordevelopment.org/library/space-solutions-for-development/. Accessed February 2020.

EO supports agricultural and wasteland restoration. Land degradation is a growing concern with the current increase in demand for arable land. Sustainable land management and land restoration practices are required to meet the demands to provide food and other services. In India, EO has enabled the government to map and invest in land restoration programmes, which has increased the availability of productive land.

- In India, a WB funded U.P. Sodic Land Reclamation Project was undertaken and supported by Remote Sensing Applications Centre Uttar Pradesh (RSACUP), which provided satellite-based information. The resulting wastelands maps were used to identify areas with various levels of severity. After reclamation, the lands are producing cereals to the extent of 2.6 tonnes per hectare and increasing family incomes by 50%, benefiting 228,000 smallholder families.[73]
- Wasteland management can be a powerful strategy for poverty alleviation, food security, and environmental protection. In India, the Department of Space carried out national wasteland mapping using EO data, estimating 63 million hectares of wasteland. Based on this mapping, the Ministry of Agriculture has implemented a variety of wasteland development activities and eight million hectares have been turned into productive land.[74]

EO can improve crop health through early warnings on crop disease and pest management. Annually, an estimated 10-16% of the global harvest is lost to plant pests—a loss of about US$220 billion.[75] Use cases in Zambia and Bangladesh demonstrate EO capabilities in developing crop disease and pest management systems. These systems enable farmers to anticipate issues, respond to them, and avoid crop losses.

- The UKSA IPP supported Pest Risk Information Service (PRISE) project, led by CABI, brings together EO technology, satellite positioning, plant-health modelling, and on-the-ground real-time observations in sub-Saharan Africa. PRISE predicts the environmental conditions that allow pest populations to grow and gives sufficient warning to mitigate threats to productivity. Through PRISE at least 1,350 farmers have indirectly received information from plant doctors about pests and diseases. A Zambian agricultural expert stated, *"the alerts were useful to farmers and,* [for those] *who followed the right management options available for the pests and used proper inputs, their crops were not highly affected* [by the pest outbreak]*".*[76]
- The G4AW supported project, GEOPOTATO, aims to sustainably improve resource-use efficiency in potato production in Bangladesh by providing farmers with an EO-derived decision-support service to control the late blight fungal disease. The alert service will be provided on subscription to farmers, through SMS or voicemail. Expected farmer benefits range between €100-250 per hectare. To date 40,339 farmers have been reached, covering approximately 475,355 hectares of farmland.[77]

EO provides information to support decisions for optimal sowing dates. Many crops have an optimal window in which to sow to achieve the highest yields. Evidence from India demonstrates how EO data has been used to calculate optimal sowing time and thus to optimise yield.

- In India, EO data has been used to understand and improve decision-making around optimal sowing dates for wheat. Drawing together experimental evidence using EO data, it was estimated that the decision to sow wheat one week earlier on average led to an overall yield gain of 5% nationally.[78]

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73 Srivastava, 2011. 'Case Study: Harnessing new tools and techniques for making agricultural statistics more efficient and evidence based to support food security policy decisions in India'. https://bit.ly/2v2mMRa. Accessed February 2020.

74 As above.

75 UN News. 'UN-sponsored group tightens controls on spread of crop-attacking pests'. https://news.un.org/en/story/2018/04/1007582. Accessed February 2020.

76 Caribou Space for UK Space Agency. 'UK Space Agency International Partnership Programme: Three Year Review'. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833424/UKSA_IPP_Three_Year_Review_Final_web.pdf. Accessed February 2020.

77 Geodata for Agriculture and Water (G4AW). 'GEOPotato Bangladesh: Geodata to control potato late blight in Bangladesh'. https://nso-g4aw.akvoapp.org/en/project/5299/#report. Accessed February 2020.

78 Lobell, David B., J. Ivan Ortiz-Monasterio, Adam M. Sibley, and V.S. Sohu, 2013. 'Satellite detection of earlier wheat sowing in India and implications for yield trends'. Agricultural Systems 115 (2013): 137-143. www.sciencedirect.com/science/article/pii/S0308521X12001400. Accessed February 2020.

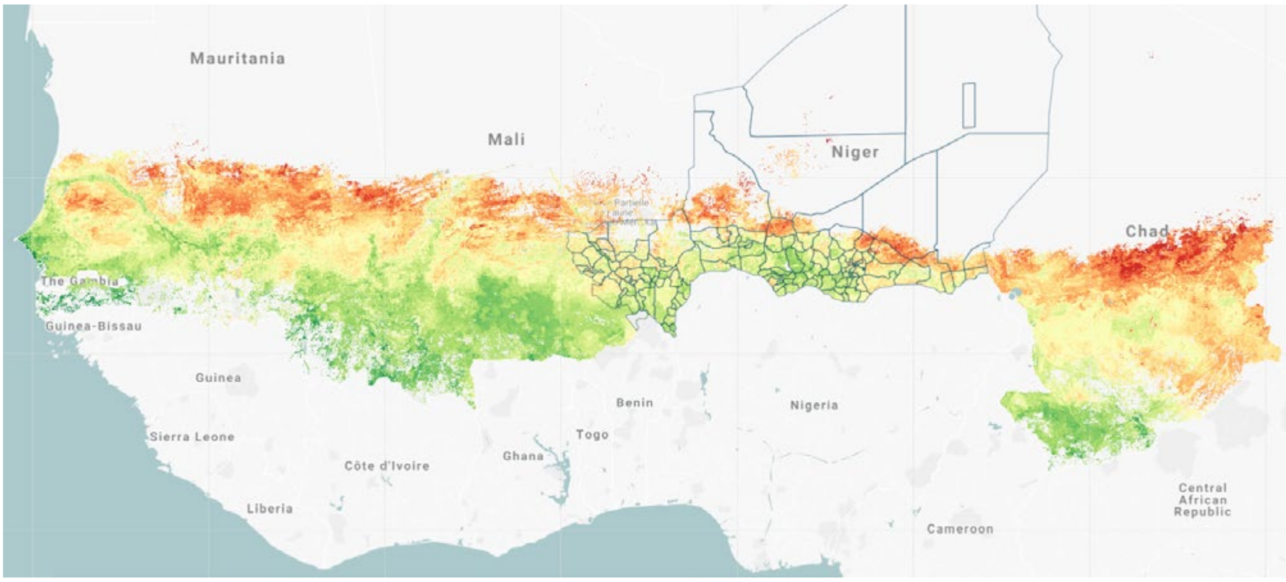


FIGURE 8: EO4SD-Agriculture Showing Land Suitability for Irrigation Across Multiple African Countries ('Suitable' in Green, 'Not Suitable' in Red) (Credit: ESA EO4SD Water Resources Management)

— *EO supports sustainable management of environmental resources*

Natural resources are under pressure to meet global agricultural production demands and it is critical that finite resources are used sustainably. This applies to land and water but also the use of synthetic fertilisers and pesticides, which, if not well managed, cause environmental harm. EO has proven use cases in water management, sustainable use of fertilisers and pesticides, and EO has emerging uses in ecosystem mapping. This has been shown to reduce water, fertiliser, and pesticide waste therefore reducing costs.

EO supports the management of scarce water resources for crop irrigation. The unsustainable use of water places pressure on water tables and rivers leading to drought and local and cross-border tensions. However, advances in EO have markedly improved the accuracy of measurements of evapotranspiration and surface soil moisture. There is evidence from Mexico, Chile, and South Africa that EO data is a cost-effective approach to improve water management practices, thereby increasing yields and reducing water consumption.

- UK Space Agency IPP has funded the COMPASS project in Mexico & Argentina, led by Rezatec. This provides EO based decision support tools via a mobile app to local wheat, maize and sugarcane farmers—targeting up to 12% increase in yields for wheat farmers initially across 12,000 hectares. The project is also providing the local irrigation company an application that improves the forecasting of irrigation demand in the naturally arid Yaqui Valley.[79]
- In Chile drought conditions and water shortages are frequent. Landsat EO data has been used to estimate seasonal water demand against seasonal supply to achieve optimal irrigation practices for grape farmers. This information system has resulted in a US$80/acre cost savings in energy used for irrigation, a 30% to 60% reduction in the amount of water applied on grapevines, and an increase in grape quality between 30–35%.[80]
- An ESA EO4SD-Agriculture and Rural Development project supported the World Bank Sahel Irrigation Initiative Support Project (SIIP). This included an analysis of land that was most suitable for irrigation based on a number of EO products, including rainfall, topography, evapotranspiration and vegetation mapping. This supports SIIP to improve stakeholders' planning, investment and management capacity for irrigation services and increase irrigated areas across the region.[81]

EO supports the sustainable use of fertilisers and pesticides. It is widely accepted that fertilisers have dramatically increased food production worldwide. However, improper use of synthetic fertilisers has environmental costs, for example, nitrogen runoff can

79 Personal communication. Saravana Gurusamy. Rezatec. January 2020.
80 Publications Office of the European Union. 'Study to examine the socio-economic impact of Copernicus in the EU'. https://publications.europa.eu/en/publication-detail/-/publication/97a5cf70-aa5f-11e6-aab7-01aa75ed71a1/language-en/format-PDF/source-search. Accessed February 2020.
81 ESA. 'EO4SD Water Resources Management. Crop and water monitoring in the Sahel'. http://maps.eo4sd-water.net/siip/. Accessed February 2020.

contaminate surface and ground water. In Greece, Kenya, and France, EO data has been used to provide information on the quantity of fertiliser required for optimal yields resulting in time savings and precision in fertiliser and pesticide application.

- A 2017 study in Kenya demonstrated the potential to track yield response to fertiliser and improved seeds using a combination of high resolution EO data and intensive field sampling on thousands of fields over two years. The study showed that high resolution EO data can detect yield responses to fertiliser and hybrid seed inputs as accurately as more resource intensive ground-based surveys.[82]
- The Farmstar service uses a combination of weather, EO and in-situ data to advise farmers in France on fertiliser use—used by ~10,000 farmers over ~450,000 hectares. Farmers have reported saving up to 10 units of nitrogen per hectare of wheat and up to 20 units per hectare of rapeseed. [83]

EO provides powerful visualisations of ecosystem services at local, regional, and even national scales. Sustainable intensification uses an ecosystem approach, an internationally adopted strategy for the integrated management of land, water, and living resources that promotes conservation. [84] While nascent in terms of use case and impact evidence, EO can identify types of land cover, aspect, topography, infrastructure, and the land management systems in place – all key inputs for ecosystems services mapping.

- The UKSA IPP supported EO4cultivar project, led by Environment Systems, aim is to strengthen commercial agricultural supply chains operating between Colombia, Peru, Paraguay and the UK. The project includes case studies at landscape scale to provide 17 regional stakeholders organisations with EO derived information to support decision making to use nature-based solutions to deliver more sustainable land management of over 45,000 hectares of land.[85]
- ESA EO4SD-Agriculture and Rural Development project supported WB and IFAD in Burkina Faso. This included an analysis of the Habitat Quality of local ecosystems to better guide land management decisions in order to halt land degradation and safeguard natural resources.[86]

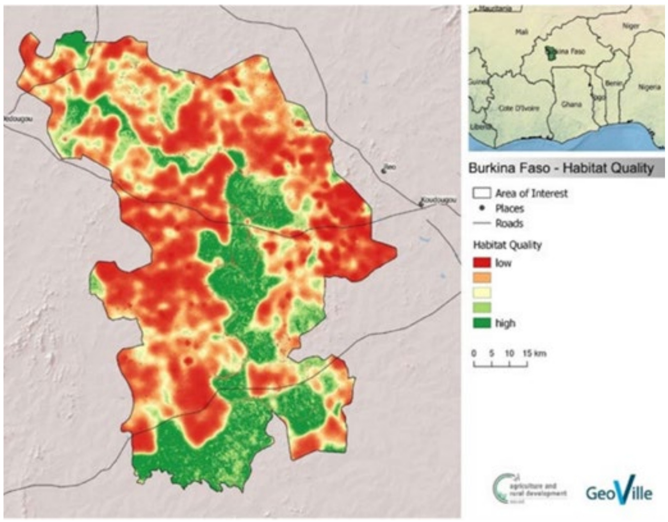


FIGURE 9: EO4SD-Agriculture Showing Habitat Quality Representing Threat to Habitat Health (Credit: ESA EO4SD Agriculture and Rural Development)

82 Burke, Marshall, and David P. Lobell. 'Satellite-based assessment of yield variation and its determinants in smallholder African systems'. PNAS 114 (2017): 2189-94. www.ncbi.nlm.nih.gov/pmc/articles/PMC5338538/. Accessed February 2020.

83 Publications Office of the European Union. 'Evaluation of socio-economic impacts from space activities in the EU'. https://op.europa.eu/en/publication-detail/-/publication/b3c64cf6-3caa-4f46-b6cc-a69c3b583cc5/language-en/format-PDF/source-search. Accessed February 2020.

84 Convention on Biological Diversity. 'Ecosystem Approach'. www.cbd.int/ecosystem/. Accessed February 2020.

85 Personal communication. Jacqueline Parker. Environment Systems. January 2020.

86 ESA. 'EO4SD – Earth Observation for Sustainable Development. Agriculture and Rural Development Cluster | Burkina Faso'. www.eo4idi.eu/sites/default/files/publications/eo4sd_agri_burkina_faso_en_2019.pdf. Accessed February 2020.

— *EO supports optimisation of supply chains to reduce losses and improve food security*

Food security remains an issue in developing countries, with 820 million people said to be hungry today.[87] Information on food shortages is vital to optimising supply chains. EO data has been incorporated into national food security monitoring and has improved government planning and decisions. While methodologies to optimise supply chains by reducing losses and improving traceability would have immense benefits, meeting this challenge requires the coordination of several actors and data sets. While there is limited public domain evidence of using EO for this challenge, it is a clear opportunity.

EO supports national food security information systems. Timely forecasts and estimates of production are critical for governments and agri-business to anticipate and respond to food shortages. EO data has been used in national food security information systems in developing countries to improve planning and early response.

- NASA's SERVIR programme worked with the Kenyan Department of Agriculture to release updated cropland maps to improve food security assessments. The completed cropland maps provide information on the locations of a variety of crops and their irrigation systems. This allows for rapid identification of changes in crop development, helping the Kenyan government improve planning of food assistance during droughts, flooding, and other food security crises.[88]
- In Nepal, the NASA SERVIR programme developed maps to highlight district-level crop anomalies based on a NDVI to inform the government's service delivery to food-insecure districts. These have been integrated into biannual crop monitoring missions conducted by Nepal's Food Security Monitoring Network and NDVI has been integrated into Nepal's quarterly food security bulletins.[89]
- An ESA EO4SD-Agriculture and Rural Development project provided an analysis of agricultural production (losses) in areas under conflict in Syria. Using EO they identified, for example, that productivity in some areas declined by 36% in winter and by 47% in summer.

This highlights that EO is useful for up-to-date and historical mapping of the impact of conflict on agriculture in terms of agricultural extent, productivity and irrigation performance.[90]

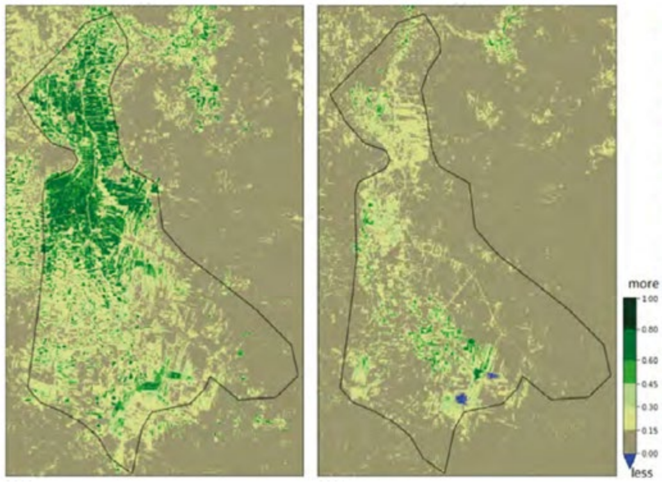


FIGURE 10: EO4SD-Agriculture Showing Productivity in Pre-conflict in 2011 (left) and Conflict Year 2016 (right) in Al Eis (Syria) (Credit: ESA EO4SD Agriculture and Rural Development)

EO supports the monitoring and forecasting of agricultural production to anticipate food security risks. The lack of accurate information around production volumes means it is difficult to anticipate shortages. EO provides an additional layer of transparency and enables the forecasting of production volumes to anticipate and respond to supply and demand needs as evidenced through examples in India, the Mekong basin and Africa.

- In India, the Ministry of Agriculture developed Forecasting Agricultural Output using Space Agro-meteorology and Land-based Observations (FASAL). Using EO as one of the data sources, FASAL captures the unforeseen impacts of unusually high temperatures during harvests, revises the forecast accordingly, and highlights areas of predicted shortfalls. For example, in the 2005/06 season, FASAL's timely insights enabled the country to take decision on importing 5.5 million tonnes of wheat to ensure food security after a predicted shortfall.[91]
- In 2016 an El Niño resulted in severe drought in the Mekong Basin. During this period the

87 Food and Agriculture Organisation (FAO). 'The State of Food Security and Nutrition in the World 2017'. www.fao.org/state-of-food-security-nutrition/en/. Accessed February 2020.

88 GEO. 'GEOGLAM strengthens global food security & early warning systems'. www.georeportonimpact.org/food-and-agriculture-impact-stories. Accessed February 2020.

89 USAID. 'SERVIR Performance Evaluation: Evaluation Question I Report'. https://files.globalwaters.org/water-links-files/SERVIR_Performance_Evaluation_0.pdf. Accessed February 2020.

90 ESA. 'EO4SD – Earth Observation for Sustainable Development. Agriculture and Rural Development Cluster – Syria'. https://www.eo4idi.eu/sites/default/files/publications/eo4sd_syria_final.pdf. Accessed February 2020.

91 Srivastava, 2011. 'Case Study: Harnessing new tools and techniques for making agricultural statistics more efficient and evidence based to support food security policy decisions in India'. https://bit.ly/2v2mMRa. Accessed February 2020.

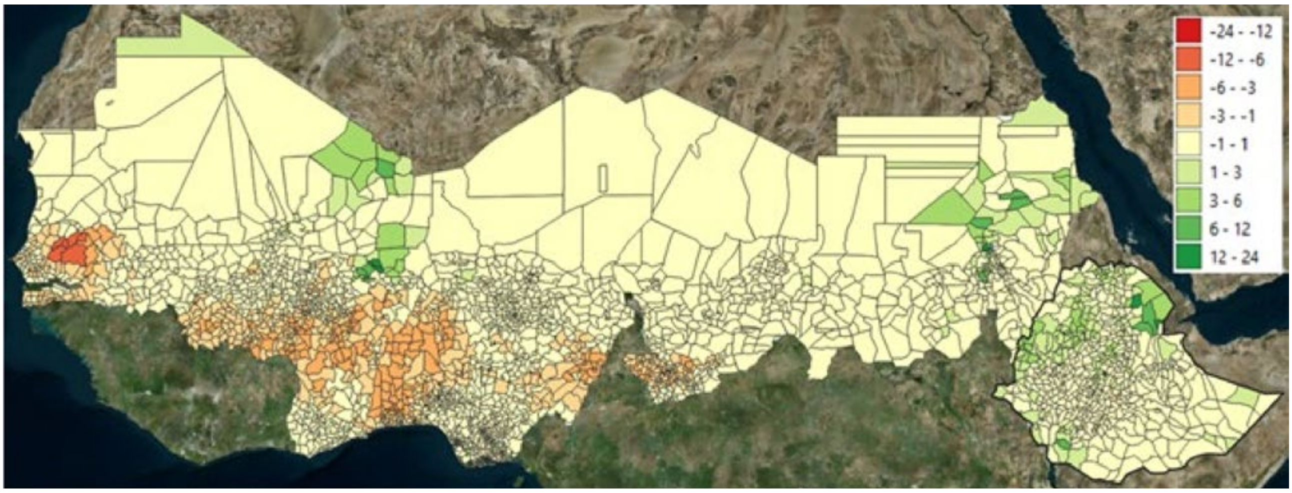


FIGURE 11: EO4SD-Agriculture Showing Multi-country Analysis of Trends in Above Ground Biomass Production (Credit: ESA EO4SD Agriculture and Rural Development)

GEOGLAM—GEORICE detected a 276,000 hectare (16.7%) decrease in rice production caused by water shortage and saline intrusion. Due to the effective demonstration of radar imagery to monitor rice production, there is now an effort to develop operational monitoring for the entire Mekong basin.[92]

- An ESA EO4SD-Agriculture and Rural Development project supported the WB and GEF Sahel and West Africa Program (SAWAP). It provided a multi-country system for monitoring land cover, land status, erosion potential, land productivity (vegetation cover and biomass production) and agriculture production. Having such indicators produced in a consistent way from EO across multiple countries provided the SAWAP programme with a concrete and operational contribution to the programme-level monitoring and evaluation (M&E) tools to allow evidence-based implementation of country-level projects. Ultimately this provides an improved multi-country assessment of land degradation to support better informed policy and investment outcomes.[93]

EO can support optimisation and traceability of agricultural supply chains to reduce losses. Of the food that we do grow, the United Nations estimates that 30% is lost in the production and delivery process.[94] In tandem with this, developed markets consumers are increasingly conscious of the potential negative impacts of intensive agriculture on local ecosystems and traceability of the supply chain is affecting buying decisions. Thus, information systems that trace food throughout the production process, from field to market, could both optimise supply chains and meet the consumer demand for environmentally conscious purchasing. While there is increasing demand for such systems, meeting this demand requires numerous supply chain actors and data sources acting in concert. As per examples of EO use in food production monitoring and ecosystem mapping, there is a potential use case but limited public domain evidence at present.

- The UKSA IPP supported EO4cultivar project, led by Environment Systems, aim is to strengthen commercial agricultural supply chains operating between Colombia, Peru, Paraguay and the UK. The Agri-track products help project partners develop a better understanding of how to increase production and improve margins through crop monitoring and forecasting for selected crops across varying scales from field to farm to regional to national. Agri-business partners are focussed on delivering a 3% increase in yield together with a 20% improvement in yield forecast for agricultural regions that extend over 800,000 hectares.

— *EO supports flood and drought early warning systems*

Many developing countries lack the ability to collect, process and distribute the data needed for accurate predictions of extreme weather patterns, leading to significant agricultural and economic losses. EO and meteorological satellites provide an added layer of detailed and accurate data to create effective early warning systems that give farmers and governments

92 GEO. 'Impact Stories'. http://earthobservations.org/geoglam.php?t=home&s1=impact_stories. Accessed February 2020.

93 ESA. 'EO4SD – Earth Observation for Sustainable Development. Agriculture and Rural Development Cluster – Great Green Wall Initiative'. www.eo4idi.eu/sites/default/files/publications/eo4sd_great_green_wall_en_2019.pdf. Accessed February 2020.

94 Thomson Reuters. 'How will we fill 9 billion bowls by 2050?' http://reports.thomsonreuters.com/9billionbowls/. Accessed February 2020.

FIGURE 12: Airbus Flood and Drought Resilience Showing Vegetation Health Index (VHI) for a Selected Farmland over a One-year Period (Credit: Airbus Defence and Space)[95]

advance notice on extreme weather and can proactively take the necessary actions to avoid loss.

EO improves farmer's resilience to climate change. Climate change has been devastating for developing countries where increasing temperatures and changing rainfall patterns have left many farmers vulnerable to frequent and severe pest outbreaks, floods, and drought events. More than ever, timely and accurate information is required. EO data applications in Ethiopia, Kenyan, and Vietnam showcase the potential of EO to improve farmer's resilience to climate change.

- The G4AW-supported GREENcoffee project is implementing an EO-based information service that supports coffee farmers in the Central Highlands of Vietnam. Due to climate change, coffee farmers have faced excessive rains and prolonged dry seasons causing widespread losses. 5,000 coffee farmers covering ~5,000 hectares have received information on weather, rain, and humidity forecasts, daily coffee prices and price forecasts, farming techniques, extreme weather conditions and risk of pests and disease.[96]
- UK Space Agency IPP supported a project with Airbus Defence and Space in Kenya and Ethiopia. This provides a flood and drought forecasting service based on climate change scenarios that has the potential to reduce the population at risk of hunger through increased adoption of insurance products.[97]

EO supports governments to anticipate and respond to drought. Drought is a slow onset disaster that EO can help forecast by providing enhanced data on land use and topology, meteorology, ground water, soil moisture, and crop health, which enables forecast models of drought in the target region and advanced planning at the government level. EO data has proven capabilities in estimating drought and improving government response in drought events.

- In 2017 the Office of the Prime Minister of Uganda used GEOGLAM satellite data to detect and forecast drought and initiate a proactive risk reduction and response plan three months earlier than they previously had. This early warning allowed them to establish mitigation programmes to offset losses improving the outcome for 150,000 people while

95 Caribou Space for UK Space Agency. 'Space Solutions for Development'. https://www.spacefordevelopment.org/library/space-solutions-for-development/. Accessed February 2020.

96 Geodata for Agriculture and Water (G4AW). 'GREENcoffee Vietnam: Information services for coffee farmers in Vietnam'. https://nso-g4aw.akvoapp.org/en/project/5312/#report. Accessed February 2020.

97 Caribou Space. 'Earth Observation for Flood and Drought Resilience (Airbus Defence and Space)'. www.spacefordevelopment.org/catalogue/earth-observation-for-flood-and-drought-resilience-airbus-defence-and-space/. Accessed February 2020.

saving an estimated US$2.6 million compared to what emergency response would have cost.[98]

- The Ministry of Agroindustry in Argentina relied on both EO and the capacity of the GEOGLAM network to produce a precise and robust mapping of areas impacted by a major drought in 2018. With this information, the government delayed tax payments for farmers, an important disaster relief mechanism.[99]

EO information help pastoralists locate water and feed in water-scare environments. For pastoralists, climate change affects the availability of grazing areas and access to water, which can lower animal productivity. EO data applications have provided pastoralists with information on the location of feed and water in Mali and Burkina Faso.

- The G4AW-supported Sustainable Technology Adaptation for Mali's Pastoralists (STAMP) project launched the 'Garbal' service in 2017 to enable herders to locate water sources. Previously herders would pay motorcyclists or camel drivers to check water levels. Garbal analyses a daily feed of images from Sentinel satellites to give herders up-to-date information on the location of water and feed. Herders call or send a text, and a technician will review a colour-coded satellite image and advise on the location of water or feed. The service has received 1,300 phone calls and 88,000 text messages from more than 50,000 users.[100]
- The Mobile Data for Moving Herd Management (MODHEM) project in Burkina Faso uses satellite data to inform pastoralists on the best locations for pastures and water areas via their mobile phones. Additionally, an early warning system will warn pastoralists of flooding, drought, and disease. Results so far show that 15,110 pastoralists are using the service.[101]

— *EO supports affordable credit for farming inputs and insurance for crop/livestock losses*

Globally, 1.7 billion adults, the vast majority of whom live in the developing world, remain unbanked—without an account at a financial institution.[102] Without access to financial services, credit, and insurance, farmers are vulnerable to economic shocks. There are many challenges to delivering accessible, affordable, and appropriate financial products to low-income customers in developing countries, but the ability to access information on farmers and their incomes is crucial. Several applications to deliver credit and insurance to farmers using EO data have been developed and they are timely, cost effective, and able to deliver financial support in times of need.

EO supports provision of affordable agricultural credit and monitoring of the loan portfolio. EO data—in combination with demographics, financial, agronomic, psychometric data, and other geospatial data—can provide sufficient detail on 'thin file' customers (those without traceable financial histories) to make lending decisions. Providers can generate credit scores using algorithms that rely on mobile phone data, alternative data and machine learning. EO data is now being used to create credit scores. Historical farm performance can be reviewed using a diverse set of information from EO, such as NDVI, soil moisture, water extents, and elevation, and so on.

- Apollo Agriculture helps small-scale farmers maximise their profits in Kenya by bundling credit for farm inputs with insurance. Apollo Agriculture uses machine learning, EO, and mobile phones to deliver credit, farm products, and customised advice to farmers efficiently and at scale. A 2018 survey of Apollo Agriculture customers found that 90% reported no better credit alternative to Apollo Agriculture, 84% of customers said their quality of life has improved, while 89% say their productivity has increased.[103]

EO supports provision of insurance for crop and livestock loss. To develop an insurance product and price the risk, insurance companies require data; but with insufficient data risk models are generalised and

98 GEO. 'Global Agricultural Monitoring Flagship Initiative (GEOGLAM) Implementation Plan for the GEO Work Programme 2020-2022'. http://earthobservations.org/documents/gwp20_22/geo_global_agricultural_monitoring_ip.pdf. Accessed February 2020.

99 As above.

100 McDonnell, Tim. 'How do cow herders spot water in the Sahara? With satellites, of course'. MIT Technology Review. www.technologyreview.com/s/613335/how-do-cow-herders-spot-water-in-the-sahara-with-satellites-of-course/. Accessed February 2020.

101 Geodata for Agriculture and Water (G4AW). 'MODHEM Burkina Faso: Mobile Data for Moving Herd Management and better incomes in Burkina Faso'. https://nso-g4aw.akvoapp.org/en/project/5309/#report. Accessed February 2020.

102 Demirgüç-Kunt, Asli, Leora Klapper, Dorothe Singer, Saniya Ansar, and Jake Hess. 'The Global Findex Database 2017: Measuring Financial Inclusion and the Fintech Revolution.' https://globalfindex.worldbank.org/sites/globalfindex/files/2018-04/2017%20Findex%20full%20report_0.pdf . Accessed February 2020.

103 Caribou Space. 'Space for Finance in Developing Countries'. www.spacefordevelopment.org/library/space-for-finance-in-developing-countries. Accessed February 2020.

premium prices are higher. Satellites collect large volumes of data that can be used for risk modelling by monitoring indices like soil moisture content, precipitation and vegetation health. When collected over time, the data can be used to forecast various risks and enable the cost-effective and timely provision of insurance products.

- NASA SERVIR and GEOGLAM researchers assisted the Kenyan government in developing a methodology for determining local harvest yield trends; it involves farmers insuring crops based on projected harvest with premiums calculated on production output in each region. The approach has resulted in more than a 70% cost reduction and reduced sampling time— increasing efficiency and reducing bias in sample selection.[104] The successful use of the method has created a demand to expand to 20 additional counties where the government crop insurance programme operates.[105]
- The Kenyan Livestock Insurance Programme (KLIP) is provided by the government to protect the most vulnerable pastoralists in Kenya. KLIP uses an algorithm that combines survey data on livestock mortality with EO data on vegetation cover to develop an index that predicts livestock mortality. During drought conditions and forage scarcity, the index predicts livestock loss. If this prediction is above a certain level of loss, it triggers an insurance pay-out. By early 2018, KLIP had made pay-outs of more than Kenyan shillings 700 million (US$7 million) to 32,000 pastoral households. An impact evaluation found that households under KLIP were less food insecure compared to the non-KLIP households.[106]

EO can increase the accuracy of insurance products. It is important for customers to trust that if they invest in an insurance product, they will receive a pay-out should they suffer losses. Through the integration of EO, index-based insurance can improve their accuracy, as demonstrated in Tanzania, Ethiopia, and India.

- A 2019 study in Tanzania found that when a satellite-derived index insurance product contained a clause allowing for an in-situ assessment when the index threshold was not triggered, demand for insurance rose from 22% to 36%.[107]
- In Ethiopia under the G4AW supported project, the Geodata for Innovative Agricultural Credit Insurance Schemes (GIACIS) project offers an EO-based vegetative index crop insurance product to farmers. The index was highly accurate—only 2% of farmers felt the index results did not match their experience.[108]

104 GEO. Coordinating Ocean Observations for the African Coasts'. www.georeportonimpact.org/impact-stories-afrigeo. Accessed February 2020.
105 As above.
106 Global Partnership for Sustainable Development Data. 'Agriculture Data Shaping Policy and Changing Lives in Kenya & Tanzania'. www.data4sdgs.org/sites/default/files/services_files/Ag%20Data%20Shaping%20Policy%20and%20Changing%20Lives_Case%20Study.pdf. Accessed February 2020.
107 Flatnes, Jon Einar, Michael R. Carter, and Ryan Mercovich. 2019. 'Improving the quality of index insurance with a satellite-based conditional audit contract'. University of California Davis. https://basis.ucdavis.edu/publication/paper-improving-quality-index-insurance-satellite-based-conditional-audit-contract. Accessed February 2020.
108 Impact Insurance: Emerging Insights. 'Creating a hybrid agriculture insurance product in Ethiopia'. https://mailchi.mp/ilo/ei152-en?e=6d1d53d3e8. Accessed February 2020.

Impact of Earth Observation in forestry

5. Impact of Earth Observation in forestry

Key points

- Forests in the developing world face a wide range of challenges. These include pressure for conversion to agricultural land, illegal deforestation, habitat and biodiversity loss, and deprivation of livelihoods for forest-dependent communities.
- EO provides benefits within forestry in four overarching areas:
  1. Supporting mapping and monitoring of deforestation and forest degradation,
  2. Supporting precision forestry,
  3. Providing resilience to natural disasters such as fires and floods in forests, and
  4. Aiding local forest populations.
- Several insights from public literature have contributed evidence to each of these areas:
  - EO has been used in global platforms for forest monitoring and as a data source for UN SDG 15 and Reducing Emissions from Deforestation and Forest Degradation (REDD+) reporting.
  - EO has been used to support forest governance, deter illegal logging, and conserve high-carbon forestry stocks.
  - EO has been applied as a cost-effective solution to optimise forest yield while also acting as an accountability tool for corporations to adhere to zero deforestation (ZD) commitments.
  - Numerous cases have demonstrated EO capabilities in detecting forest fires and improving emergency response.
  - Local forest populations have used EO to secure land rights and monitor and report illegal or harmful practices.

5.1 The value of forests

Forests are critical to human populations, terrestrial biodiversity, and mitigating climate change. 1.6 billion people depend on forests for their livelihoods and 500 million indigenous peoples have forests as their ancestral territories.[109] Forests are vital ecosystems, home to 80% of the world's terrestrial biodiversity—they also protect watersheds and reduce erosion.[110] Furthermore, because forests remove 30% of human carbon dioxide emissions from the atmosphere, they are instrumental in climate change mitigation.[111] Protecting, restoring, and promoting the sustainable use of the world's forests is essential for the planet's future.

Forests also provide an array of economic functions and benefits. Forests provide timber for a multitude of human uses including construction, energy, and paper. With approximately 300 million hectares of plantation forests and 900 million hectares of natural forests, together supplying two billion cubic metres of industrial wood, the financial value of the forestry industry is estimated at US$200 billion.[112]

109 Chao, S. 2012. 'Forest Peoples: Numbers across the world'. FPP, Moreton in Marsh. www.forestpeoples.org/sites/default/files/publication/2012/05/forest-peoples-numbers-across-world-final_0.pdf. Accessed February 2020.

110 WWF. 'The importance of forests cannot be underestimated'. https://wwf.panda.org/our_work/forests/importance_forests/. Accessed February 2020.

111 NASA. 'NASA Finds Good News on Forests and Carbon Dioxide'. www.nasa.gov/jpl/nasa-finds-good-news-on-forests-and-carbon-dioxide. Accessed February 2020.

112 Choudhry, Harsh, and Glen O'Kelly. 2018. 'Precision forestry: A revolution in the woods'. McKinsey and Company. www.mckinsey.com/industries/paper-forest-products-and-packaging/our-insights/precision-forestry-a-revolution-in-the-woods. Accessed February 2020.

5.2 Forestry challenges

Developing countries have some of the most valuable forests in terms of timber and ecosystems, but their sustainability is increasingly under threat. Rapidly growing human populations require more land for agriculture, while increased exposure to international markets for commodities like timber, soy, and palm oil are driving deforestation and degradation. These processes can be legal, but forestry is aggravated by illegal deforestation. These processes cause huge carbon emissions—around one-sixth of the emissions from all human sources—and are driving climate change. Additionally, the clearance of tropical forests is the largest driver of tropical biodiversity loss and deprives forest-dependent communities of their livelihoods.

5.3 EO's role in forestry

Monitoring forests is crucial and EO is the only cost-effective solution due to the vast and remote areas.

In some instances, human-led photography surveys, aircraft, or drones can be used. However, vast areas and remote locations can make this challenging, or impossible at times. For consistent, accurate, high-frequency monitoring of forests at national or international scales, EO is the only efficient and realistic mechanism, for use cases such as monitoring for REDD+.[113]

The UK Space Agency IPP has quantified satellite solutions for forestry as, on average, 12 times more cost effective than non-space alternatives (i.e., aerial photography, drones, human patrols) over the long term. This corresponds to an average cost of £12.84 per hectare of avoided deforestation.[114]

Figure 13 below highlights both the role and impact of EO data within the forestry sector. The following section forefronts how EO data has and is being used to solve the various challenges in the forestry sector.

Impact	EO products contribute to the achievement of UN SDG 15 "Life on Land"				
Outcomes	Reforestation and afforestation		Sustainable use of natural resources	Decreased risk from fire and flooding	Protected local populations
	Reduced degradation and deforestation	Reduced illegal logging, improved compliance and tax revenues	Uptake of precision forestry policies and practices	Reduced damage from forest fires and flooding	Improved rights for local populations
Outputs	EO supports the mapping and monitoring of deforestation and forest degradation		EO supports precision forestry and zero deforestation commitments	EO supports resilience to forest fires and floods	EO supports local forest populations
Forestry challenges	Deforestation and degradation		Unsustainable use of natural resources	Risk of fire and flooding	Vulnerable local populations
	Lack of data for forest mapping and monitoring				

FIGURE 13: Outcomes and Impacts of EO in Forestry

113 Lynch, Jim, Mark Maslin, Heiko Balzter, and Martin Sweeting. 'Choose satellites to monitor deforestation'. Nature 496 (2013): 293-94. www.geog.ucl.ac.uk/people/academic-staff/mark-maslin/files/Lynch%20et%20al%202013.pdf. Accessed February 2020.

114 Caribou Space and London Economics'. Economic evaluation of the International Partnership Programme (IPP): Cost-effectiveness Analysis'. www.spacefordevelopment.org/library/economic-evaluation-of-the-international-partnership-programme-ipp-cost-effectiveness-analysis/. Accessed February 2020.

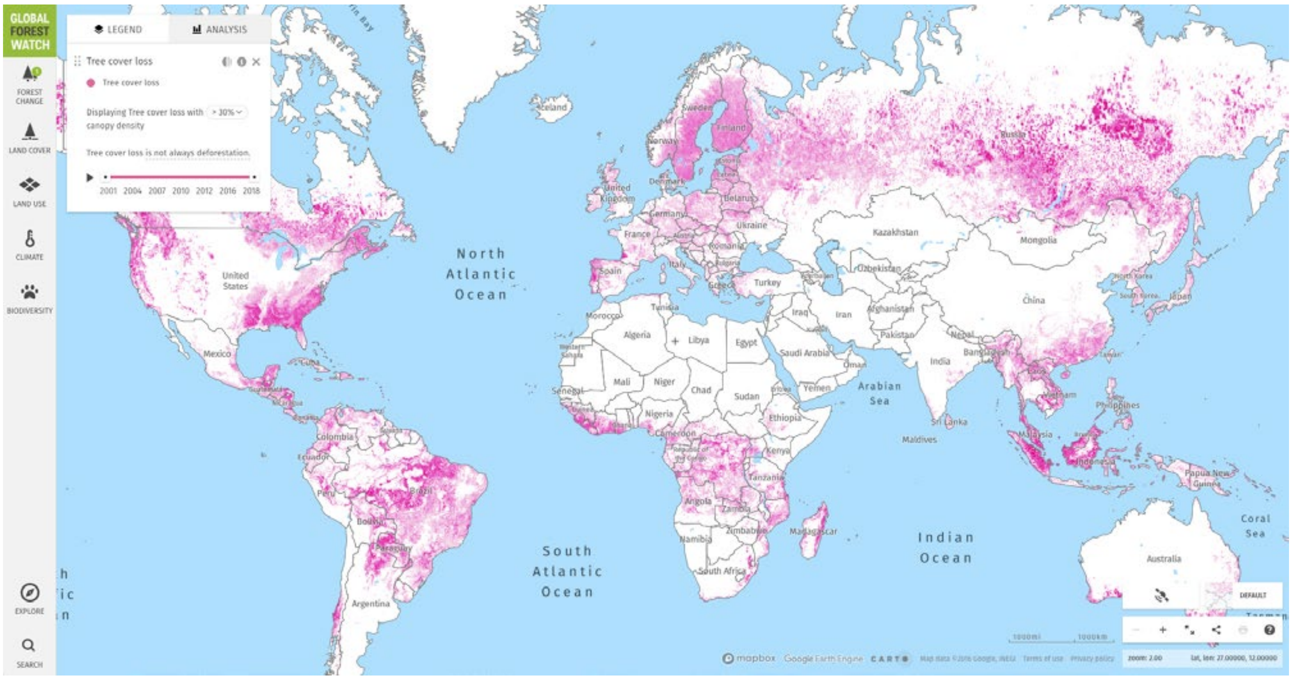


FIGURE 14: Global Forest Watch Platform Showing Areas of Tree Cover Loss (Credit: Global Forest Watch)

— *EO supports the mapping and monitoring of deforestation and forest degradation*

Due to the scale of the challenge, the importance of using EO data to quantify forest area and land use/ land cover change is clear. EO data applications have contributed to the development of global platforms for forest monitoring, data for UN SDG 15 reporting, and REDD+ reporting, which are being used by several developing countries. Additionally, EO data has been used to support forest governance, deter illegal logging, and protect areas of high-carbon stocks, such as peatland and mangrove forests.

EO enables the development of global platforms to map and monitor forest status. Deforestation is a global concern with global consequences requiring global actions. Several open EO-based platforms now support mapping and monitoring forests at a global scale.

- ESA's Forestry Thematic Exploitation Platform (Forestry TEP) allows users to efficiently access global EO based processing services and tools for forestry.[115] Forestry TEP was used to assess the carbon stocks of Mexico's extensive Chiapas forest. The Ministry of Environment and Natural History stated that comparable forest mapping would have taken three years to produce, while Forestry TEP allows new maps to be updated in a matter of weeks.[116]
- SEPAL (System for Earth Observation Data Access, Processing and Analysis for Land Monitoring) provides comprehensive image processing capabilities and enables the detection of small-scale changes in forests.[117] SEPAL has over 1,000 users representing 225 organisations in 85 countries. SEPAL was stated to have lowered costs, removed barriers, and improved forest monitoring for more than a dozen national governments and is contributing to the accuracy and transparency of reporting to international programmes and processes.[118]
- Global Forest Watch (GFW) is a free and open platform providing data and tools for monitoring forests using NASA Landsat data with over 3 million visitors.[119] In 2016, GFW developed the 'GLAD' alert system. The Amazon Conservation Association has used the GLAD deforestation alerts to detect illegal logging in protected areas. They stated they can now detect illegal logging "*within days*" and have "*seen government authorities acting within 24–48 hours of receiving an alert*".[120]

115 Forestry TEP. 'Home'. https://f-tep.com/. Accessed February 2020.

116 ESA. 'Chiapas forest land-cover map'. www.esa.int/ESA_Multimedia/Images/2016/11/Chiapas_forest_land-cover_map. Accessed February 2020.

117 SEPAL. 'System for earth observations, data access, processing & analysis for land monitoring'. https://sepal.io/. Accessed February 2020.

118 Food and Agriculture Organization of the United Nations. 'OPEN FORIS and SEPAL (System for Earth Observation Data Access, Processing and Analysis for Land Monitoring)'. www.fao.org/3/CA1085EN/ca1085en.pdf. Accessed February 2020.

119 Global Forest Watch. 'About'. www.globalforestwatch.org/about?map=eyJjZW50ZXIiOnsibGF0IjoyNywibG5nIjoxMnosImJlYXJpbmciOjAsInBpdGNoIjowLCJ6b29tIjoyfQ%3D%3D. Accessed February 2020.

120 Global Forest Watch. 'Home'. www.globalforestwatch.org/. Accessed February 2020.

At a national level, EO supports UN SDG 15 reporting. EO data is being used to support several countries in monitoring, tracking, and reporting on UN SDG indicators 15.1.1 (forest area as a proportion of total land area) and 15.2.1 (progress towards sustainable forest management). This is important in cases without a strong forest inventory.

- NASA and the University of Maryland have developed an EO-based methodology for tracking SDG 15 indicators—it has been implemented in Peru, Colombia, Republic of Congo, Bangladesh, Vietnam, Guatemala, Cameroon, and Nepal. Peru has adopted this method for official UN SDG reporting.[121]
- The Africa Regional Data Cube offers time series, free, and open EO data to address SDGs in five countries in Africa.[122] The Kenya Forest Service have used it to map over 200,000 hectares of forest cover. They stated that *"the Africa Regional Data Cube (ARDC) provides time series, cloud free mosaics and will help us in providing timely information for decision making"*.[123]

EO supports reporting to UN Reducing Emissions from Deforestation and Forest Degradation (REDD+). REDD+ is a UNFCCC mechanism that creates financial incentives for developing countries to reduce emissions from forested lands.[124] The Committee on Earth Observation Satellites (CEOS) has committed to providing global annual coverage of the world's forests to ensure that countries have the minimum data necessary to participate in REDD+.[125] Examples from Guyana and the Congo basin highlight how countries use EO data to establish baselines and report on REDD+.

- The Government of Guyana uses high-resolution EO data to map deforestation and forest degradation for its bilateral REDD+ deal. The government has mapped 18.4 million hectares of forest with a 96.8% accuracy.[126]
- In the Congo basin results from an analysis of forest cover change using Landsat data found a total forest loss of 2.3% between 2000 and 2010. Forest loss was concentrated in areas of dense population and mining. EO provided an important dataset in establishing baseline deforestation and forest carbon levels for REDD+.[127]

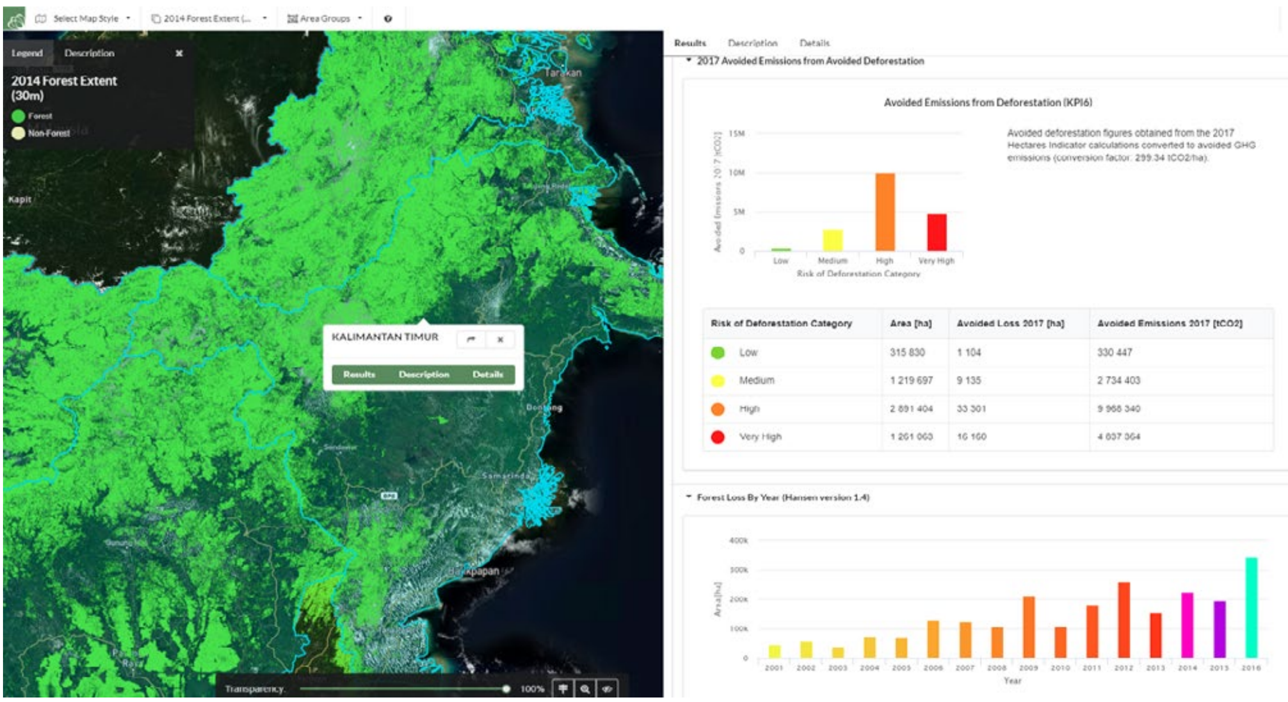


FIGURE 15: Ecometrica Forests 2020 Application (Credit: Ecometrica)

121 GEO. 'Earth Observations in support of the 2030 Agenda for Sustainable Development'. www.earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf. Accessed February 2020.

122 That is, Kenya, Senegal, Sierra Leone, Ghana, and Tanzania.

123 GEO. 'Coordinating Ocean Observations for the African Coasts'. www.georeportonimpact.org/impact-stories-afrigeo. Accessed February 2020.

124 UN-REDD. 'About'. www.unredd.net/about/what-is-redd-plus.html. Accessed February 2020.

125 Committee on Earth Observation Satellites. 'Forest Monitoring from Space: A Major Milestone'. http://ceos.org/home-2/2017-forest-monitoring-milestone/. Accessed February 2020.

126 Guyana Forestry Commission. 'Guyana REDD+ Monitoring Reporting & Verification System (MRVS) Interim Measure Report'. www.regjeringen.no/globalassets/upload/md/2011/vedlegg/klima/klima_skogprosjektet/guyana/guyanamrvs_interimmeasuresreport_year2.pdf. Accessed February 2020.

127 Global Forest Atlas. 'Forest Monitoring in the Congo Basin'. https://globalforestatlas.yale.edu/congo-forest/conservation-initiatives/forest-monitoring-congo-basin. Accessed February 2020.

EO supports forest governance, establishment of protected areas, and prevention of illegal logging. Governments manage forestry concessions – a contract between a forest owner and another party permitting the harvesting and/or managing of specified resources from a given forest area – and establish forest reserves to reduce deforestation rates. Traditionally, it is difficult to detect and intervene in illegal forest resource exploitation because of the scale of monitoring, but EO has proven capabilities in monitoring protected areas in numerous developing countries.

- Brazil's advanced satellite monitoring system DETER enables law enforcement officials from the environmental protection agency, IBAMA, to take quick action against illegal forest clearing. Coupled with increased law enforcement, DETER was responsible for nearly 60% of the ~100,000 km^2 drop in deforestation observed between 2007 and 2011.[128]
- Northern Thailand has almost 100 protected forest areas. The government uses EO to monitor the status of the protected areas. For example, an analysis of historical Landsat data showed a 7–19% reduction in deforestation.[129]
- The UK Space Agency-funded project Forests 2020, led by Ecometrica, uses EO to improve monitoring and management of forests in six developing countries (Indonesia, Brazil, Mexico, Colombia, Ghana, and Kenya), and aims to achieve improved forest governance across 300 million hectares of forest.[130]

EO supports monitoring high-carbon stock and high biodiversity ecosystems areas (e.g., High Conservation Value Forests, peatlands, and mangroves). Policymakers, businesses, and NGOs need to understand carbon and biodiversity distribution. Traditionally they use the forest inventory plot, but this method is limited by its small-scale mapping of forests, whereas EO data can cover very large areas as demonstrated through applications in peatland and mangrove monitoring.

- EO has also served as a powerful monitoring tool for the many coastal communities that rely on mangroves for food and forest products and as a natural coastline defence against storms.[131] Using Global Forest Watch (GFW) researchers found that the world lost 192,000 hectares of mangroves from 2001 to 2012. With continued data analysis, conservation, management, and restoration, the loss of the world's remaining mangrove forests can be halted and reversed.[132]
- Peatland is the world's most carbon-dense terrestrial ecosystem. Globally peatlands hold 30% of terrestrial carbon on just 3% of the land surface area. PASSES is a UKSA IPP project led by CGI developing a new satellite radar-enabled monitoring approach to provide routine, cost effective observations of peat surface motion on regional scales. Peat surface motion is a key indicator of peat condition. The PASSES approach aims to support restoration of almost 2.5 million hectares of peatland in Indonesia but has the potential to enable routine monitoring of the full 15 million hectares of Indonesian peatland.[133]

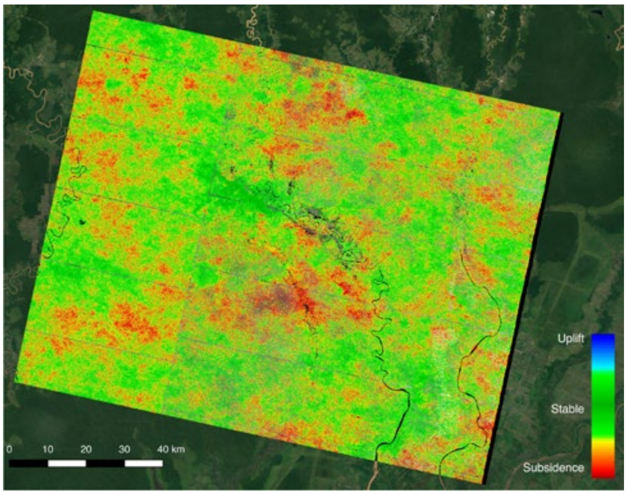


FIGURE 16: CGI Product Showing Land Uplift or Subsidence in Indonesia as an Indicator of Peatland Health (Credit: CGI)[134]

128 Mongabay. 'Brazil's satellite monitoring reduced Amazon deforestation by 60,000 sq km in 5 years'. https://news.mongabay.com/2013/05/brazils-satellite-monitoring-reduced-amazon-deforestation-by-60000-sq-km-in-5-years/. Accessed February 2020.

129 Inter-American Development Bank. 'Ex-post Evaluation of Forest Conservation Policies Using Remote Sensing Data: An Introduction and Practical Guide'. https://publications.iadb.org/en/ex-post-evaluation-forest-conservation-policies-using-remote-sensing-data-introduction-and. Accessed February 2020.

130 Ecometrica. 'Home'. https://ecometrica.com/space/forests2020. Accessed February 2020.

131 Wang, Le, Mingming Jia, Dameng Yin, and Jinyan Tian. 'A review of remote sensing for mangrove forests: 1956-2018'. Remote Sensing of Environment 231 (2019). www.sciencedirect.com/science/article/pii/S0034425719302421. Accessed February 2020.

132 Global Forest Watch. 'Satellite Data Reveals State of the World's Mangrove Forests'. (blog). https://blog.globalforestwatch.org/data-and-research/satellite-data-reveals-state-of-the-worlds-mangrove-forests. Accessed February 2020.

133 Personal communication. Andrew Groom. CGI. January 2020.

134 Caribou Space for UK Space Agency. 'Space Solutions for Development'. https://www.spacefordevelopment.org/library/space-solutions-for-development/. Accessed February 2020.

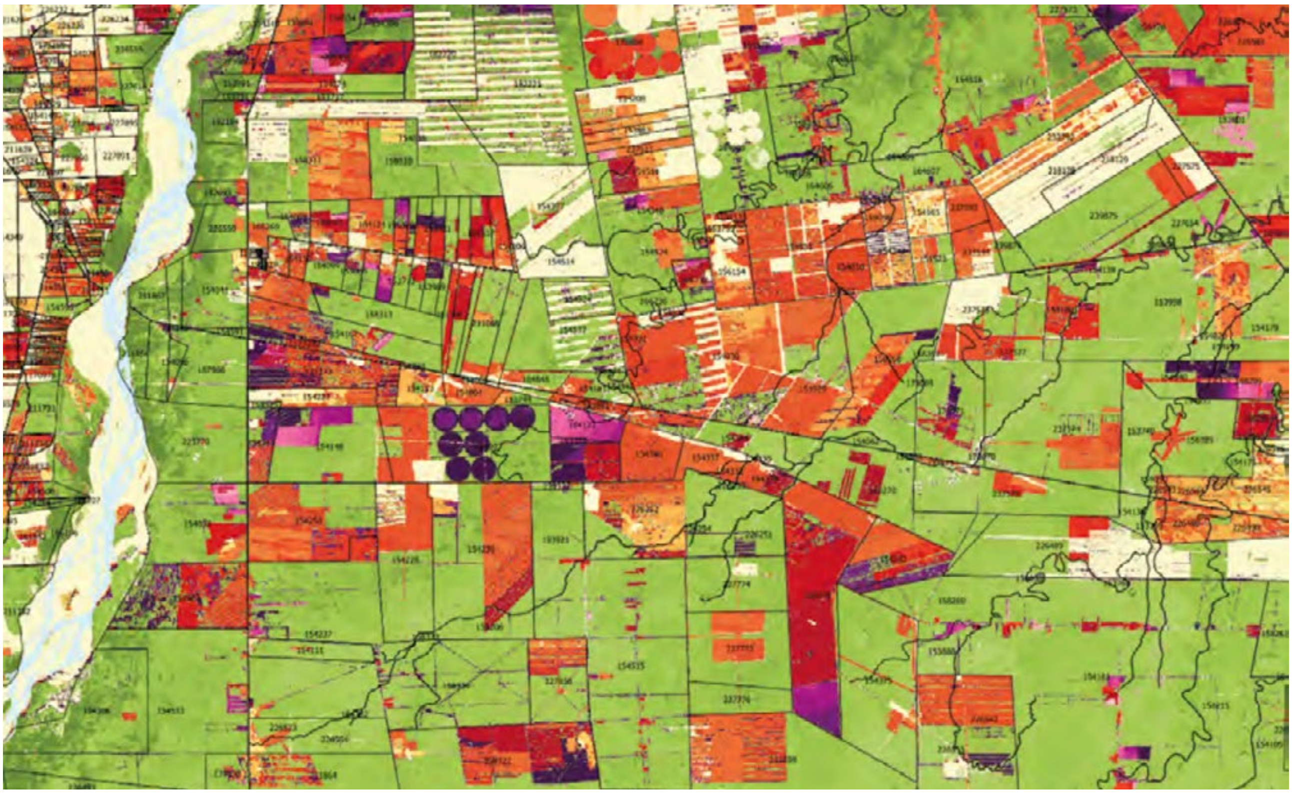


FIGURE 17: EO4SD-Agriculture Showing Deforested Areas (red and white) in Bolivia also showing Land Titles (black lines) (Credit: ESA EO4SD Agriculture and Rural Development)[139]

— *EO supports precision forestry and monitoring of agri-business zero deforestation (ZD) commitments*

With a finite amount of cultivable land, precision forestry practices are vital to improve forest yields and sustainability. EO has supported forest health and tree growth rate monitoring, storm damage mapping, land classification, and natural capital valuation—vital information for precision forestry.[135] In parallel, global commodities companies are pledging to cut deforestation from their supply chains by 2020, known collectively as zero deforestation (ZD) commitments. EO data has been used to provide monitoring on this commitment in Malaysia and Indonesia.

- Consumer goods companies such as Nestle and Unilever are under pressure to take responsibility for their impacts on forest areas, and over 500 companies have made zero deforestation commitments. The Airbus Starling service provides a reliable, near real-time monitoring tool in Indonesia and Malaysia to help companies across the food supply chain achieve their 'zero deforestation' commitments.[136]
- An ESA and EARSC study of EO data use in forest management in Sweden identified multiple benefits. Private forest owners benefited from the availability of EO data to perform replanting and thinning, while forest companies benefited from improved quantity and quality of timber. The combined economic return was estimated at up to €21.5 million per year.[137]
- The US Forest Service (USFS) uses an average of over 500 Landsat scenes per year to evaluate potential risks due to insects and disease on forest lands. The USFS uses this risk assessment to more efficiently allocate resources to mitigate the effects losses from insects and disease. Without Landsat, the increased cost to the US to improve forest yields is conservatively estimated at US$1.25 million annually due to higher imagery and analysis costs.[138]
- An ESA EO4SD-Agriculture and Rural Development project supported the IADB Rural Land Regularization and Titling Program, and the GEF Taking Deforestation out of Commodity Supply Chains programme. The Chaco forest region in the South of Bolivia and Eastern part of Paraguay is

135 Caribou Space for UK Space Agency. 'Space for Forestry in Developing Countries'. www.spacefordevelopment.org/wp-content/uploads/2018/11/6.4918_UKSA_Forestry-Report_WEB.pdf. Accessed February 2020.

136 Airbus. 'An eye deep in the forest'. www.airbus.com/newsroom/stories/starling.html. Accessed February 2020;

137 European Association of Remote Sensing Companies. 'What is the economic value of satellite Imagery? The case of forest management in Sweden'. http://earsc.org/news/what-is-the-economic-value-of-satellite-imagery-the-case-of-forest-management-in-sweden. Accessed February 2020.

138 National Geospatial Advisory Committee—Landsat Advisory Group. 'The Value Proposition for Landsat Applications—2014 Update'. www.fgdc.gov/ngac/meetings/december-2014/ngac-landsat-economic-value-paper-2014-update.pdf. Accessed February 2020.

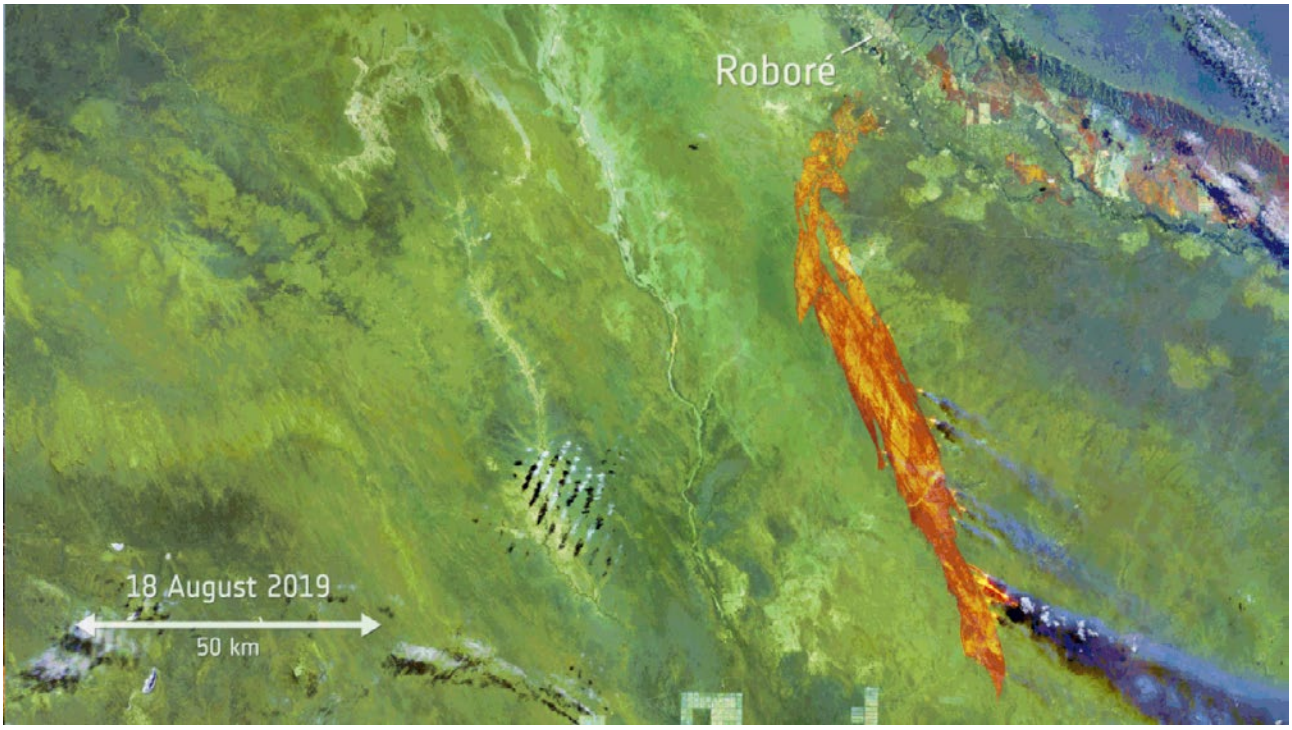


FIGURE 18: Wildfires on the Border between Bolivia, Paraguay, and Brazil from Copernicus Sentinel-2[141]

experiencing one of the highest deforestation rates in the world due to uncontrolled expansion of soy and livestock. The project provided EO-based forest, land cover/biodiversity and agriculture mapping and monitoring services to support the monitoring of the environmental impact of expansion of soy and livestock commodity production on Chaco dry forest.[139]

— *EO supports resilience to disasters such forest fires*

Forests and their local populations face risk from disasters including natural and man-made fires. EO data can provide information on risk factors, monitor current fires, and provide vital information for emergency response.

EO data provides compelling information for responding to forest fires and has been applied in numerous cases. Evidence has demonstrated EO capabilities in reporting fires, detecting previously hard-to-detect fires, and improving emergency response.

- Guatemala had no national geospatial management system to predict and manage forest fires until the NASA and USAID SERVIR programme developed the Geospatial Information System for Fire Management (SIGMA-1). First responders can now respond to fires that, previously, would have received no response due to non-detection. Also, SIGMA-1 has contributed to infrastructure development, where building fire roads and firebreaks has been based on needs assessments informed by the SIGMA-I fire management tools.[140]
- In 2019, the Brazilian Amazon had almost four times as many fires compared to the same period in 2018; Copernicus Sentinel-3 World Fires Atlas detected 4,000 fires between 1 and 24 August 2019. This imagery attracted the global media attention and led to pressure on the Brazilian government, for example, some European nations stated they would not ratify an EU trade deal unless Brazil did more to fight fires in the Amazon.[142]

139 ESA. 'EO4SD – Earth Observation for Sustainable Development. Agriculture and Rural Development | Bolivia and Paraguay'. www.eo4idi.eu/sites/default/files/publications/eo4sd_agri_bolivia_paraguay_2017.pdf. Accessed February 2020.

140 USAID. 'SERVIR Performance Evaluation: Evaluation Question 1 Report'. https://files.globalwaters.org/water-links-files/SERVIR_Performance_Evaluation_0.pdf. Accessed February 2020.

141 ESA. 'Wildfires on the border between Bolivia, Paraguay and Brazil from Copernicus Sentinel-2'. www.esa.int/ESA_Multimedia/Images/2019/08/Wildfires_on_the_border_between_Bolivia_Paraguay_and_Brazil_from_Copernicus_Sentinel-2. Accessed February 2020.

142 BBC News. 'Amazon fires: Brazil threatened over EU trade deal', August 2019. www.bbc.com/news/world-latin-america-49450495. Accessed February 2020.

— *EO supports local forest populations*

1.6 billion people depend on forests for their livelihoods and 500 million indigenous peoples have forest as their ancestral territory.[143] EO data has been applied to support local forest populations secure land rights, to monitor and report illegal practices and sustainably manage their agricultural activities in/near forested areas.

EO supports local populations to secure land ownership rights. Whilst indigenous peoples customarily own more than 50% of the world's lands, governments formally recognise only 10% of this ownership.[144] Policies that recognise land and forest rights ensure "*free, prior, and informed consent*" before outside groups undertake activities in indigenous-owned forests, increase investment in indigenous—and community-led initiatives, and end criminalisation of defence of these lands.[145] EO data has been used to support and bolster the claims of indigenous groups around the world.

- The Forest Peoples have supported mapping of Colombia using EO data which has led to proposals to establish a 1.4 million hectare conserved forest and dozens of inter-community agreements on actions to secure land rights, promote sustainable resource use, and enable self-determined community development.[146]
- Cadasta, a land rights organisation, has advanced land and property rights for 1.7 million people in 17 countries—including indigenous groups in Mozambique, Colombia, India, Kenya, and Nepal—using a mobile application incorporating EO data and land rights tools.[147]

EO data supports local populations to monitor and report harmful or illegal activities in their environment. EO data enables an improved understanding and ability to communicate potential and ongoing changes in the natural environment, such as deforestation, contamination, sedimentation of rivers, and infrastructure development. EO data has been used to halt destructive practices in the Peruvian Amazon.

- Rapid deforestation due to a large-scale cacao plantation in the northern Peruvian Amazon was halted. This was due to civil society groups exposing significant deforestation to the government using EO data as evidence.[148]

EO data helps local populations manage smallholder farms near forest areas. Forests are often bordered by the farmland of the local populations and EO data has been used to determine the appropriate legal titling and management of agricultural land and prevent unnecessary deforestation.

- A UK Space Agency IPP project in Peru with Vivid Economics has used EO to provide land titles to 14 smallholders, to provide them with their own land to farm, and they intend to use the tool to issue thousands more in the future.[149]

143 Chao, S. 2012. 'Forest Peoples: Numbers across the world'. FPP, Moreton in Marsh. www.forestpeoples.org/sites/default/files/publication/2012/05/forest-peoples-numbers-across-world-final_0.pdf. Accessed February 2020.

144 World Resources Institute (WRI). 'Land Matters: How Securing Community Land Rights Can Slow Climate Change and Accelerate the Sustainable Development Goals'. www.wri.org/news/land-matters-how-securing-community-land-rights-can-slow-climate-change-and-accelerate. Accessed February 2020.

145 As above.

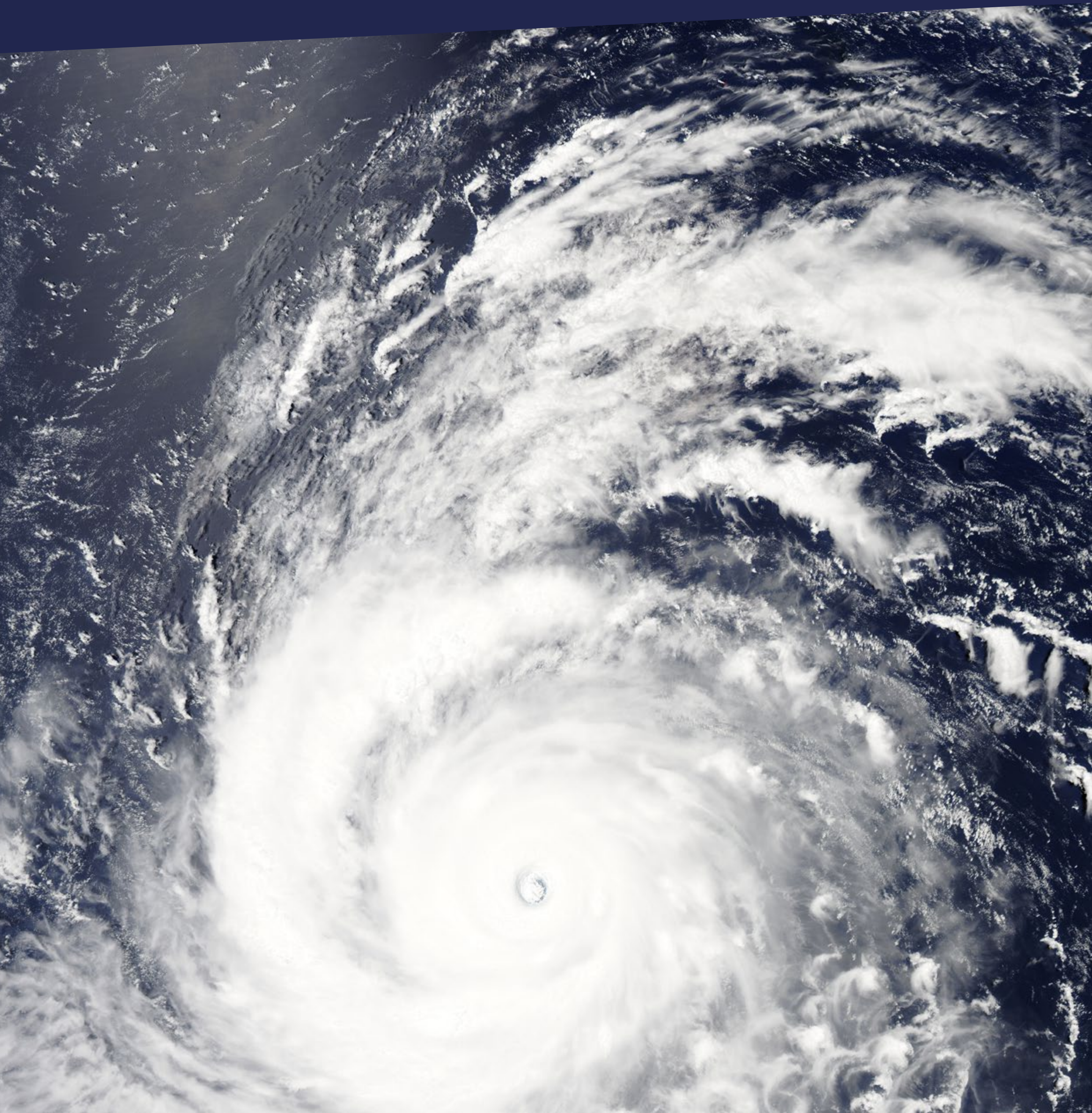
146 Forest Peoples Programme. 'Securing Forests Securing Rights: Report of the International Workshop on Deforestation and the Rights of Forest Peoples'. www.forestpeoples.org/sites/fpp/files/private/publication/2014/09/prreport.pdf. Accessed February 2020.

147 Cadasta. 'About Us'. https://cadasta.org/about-us/impact/. Accessed February 2020.

148 Monitoring of the Andean Amazon Project. 'MAAP #64: Good New Deforestation Stories (Peruvian Amazon)'. https://maaproject.org/2017/good_news/. Accessed February 2020.

149 Caribou Space for UK Space Agency. 'UK Space Agency International Partnership Programme: Three Year Review'. www.spacefordevelopment.org/library/uk-space-agency-international-partnership-programme-three-year-review/. Accessed February 2020.

Impact of Earth Observation in disaster resilience



6. Impact of Earth Observation in disaster resilience

Disaster resilience is a goal within three of the UN SDGs:

- **SDG 1: No Poverty**
  By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate related extreme events and other economic, social and environmental shocks and disasters.
- **SDG 11: Sustainable Cities and Communities**
  By 2030, significantly reduce the number of deaths and the number of people affected, and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters—including water-related disasters—with a focus on protecting the poor and people in vulnerable situations.
- **SDG 13: Climate Action**
  Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

Key points

- Developing countries are highly impacted by disasters. Infrastructure and buildings may not be as resilient, disaster response procedures may be less sophisticated; moreover, low-income populations are exposed to hazards more often, lose a higher share of wealth, and receive less support from financial systems and governments.
- EO provides benefits within disaster resilience in three overarching areas:
  1. Improving the accuracy and extent of disaster early warning systems,
  2. Supporting near real-time monitoring for better planning and prioritisation in disaster response, and
  3. Improving resilience via insurance through better risk calculation.
- Several insights from public literature have contributed evidence to each of these areas:
  - There is evidence of early warning systems becoming more effective using EO, particularly for weather related events. This allows for timely activation of emergency plans, which reduces the number of deaths and missing persons as well as economic losses.
  - EO use was shown to support a more coordinated and targeted disaster response, for floods, hurricanes, and earthquakes.
  - The use of EO has been demonstrated to enhance existing insurance schemes and support disaster-risk financing mechanisms. It is expected that this use case will grow, considering the urgent need to insure risk in the face of climate change.

6.1 The value of disaster resilience

The incidence of disasters has increased over the past 35 years and cost on average US$71.8 billion a year globally.[150] Developing countries are disproportionally impacted by disasters. The average annual damage from 1980 to 2015 was 1.5% of GDP in developing countries, compared to 0.3% of GDP in developed countries. The average share of affected populations over the same period was 3.0% in developing countries, compared to 0.4% in developed economies.[151]

Low income countries have dealt with fewer storm disasters than high and upper middle-income countries but had disproportionately more deaths. This is because infrastructure and buildings may be

150 Moody's Investor Services. 'Understanding the Impact of Natural Disasters: Exposure to Direct Damages Across Countries'. www.eenews.net/assets/2016/11/30/document_cw_01.pdf. Accessed February 2020.

151 As above.

as less resilient and disaster response procedures less sophisticated. Additionally, low-income populations are exposed to hazards more often, lose a greater share of their wealth when hit, and receive less support from their social networks, financial systems, and governments.[152] Moreover, people in developing countries often live in high-risk locations such as flood zones or urban slums—mainly to access economic opportunities at lower living costs. However, this proximity to hazards leads to potential deaths, displacement, and loss of assets. In addition to loss of human life, loss of housing, infrastructure, industry and agriculture causes economic damage. For example, in Kenya, the 1997-98 floods caused US$670 million worth of damage to transport infrastructure and US$270 million to the agriculture sector, highlighting how critical it is to strengthen countries' resilience against disasters.[153]

6.2 Disaster resilience challenges

To change these dire statistics, resources need to be dedicated to disaster resilience through mainstreaming disaster risk management into national and local laws, regulations and policies, and operational plans and protocols. This spans all stages of the disaster resilience: preparedness, response, recovery, and future mitigation. Information—on exposure to risk, forecasting disaster events, developing early warning systems, and, when a disaster hits, determining the location and extent of the damage—is foundational to establishing a coordinated and targeted response effort.

6.3 EO's role in disaster resilience

EO is well placed to contribute to the solution to these challenges in both developed and developing countries. EO provides global, repeatable, accurate, and scalable environmental information that provides high-value and cost-effective insights for disaster resilience. EO benefits include:

- Improving the accuracy and extent of disaster early warning systems,
- Near real-time monitoring for better planning and prioritisation in disaster response, and
- Improved resilience via insurance through better risk calculation.

The UK Space Agency IPP has quantified satellite solutions for disaster resilience as, on average, twice as cost-effective than non-space alternatives (i.e., aerial photography, drones, human patrols) over the long term.[154]

Figure 19 highlights both the role and impact of EO in disaster resilience. The following section forefronts how EO is being used to solve the various challenges in disaster resilience.

152 World Bank. 'Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters'. https://openknowledge.worldbank.org/handle/10986/25335. Accessed February 2020.

153 Mutemi, Joseph Nzau. 'Improving Seasonal Climate Forecasts over Various Regions of Africa Using the Multimodel Superensemble Approach'. Atmospheric and Climate Sciences 9 (2019). https://m.scirp.org/papers/95774. Accessed February 2020.

154 Caribou Space & London Economics. 'Economic evaluation of the International Partnership Programme (IPP): Cost-Effectiveness Analysis'. www.spacefordevelopment.org/library/economic-evaluation-of-the-international-partnership-programme-ipp-cost-effectiveness-analysis/. Accessed February 2020.

Impact	EO products contribute to the achievement of disaster related UN SDGs 1, 11 and 13		
Outcomes	**Improved disaster mitigation**	**Improved planning, prioritisation and coordination of disaster response**	**Increased resilience and recovery**
	Timely and appropriate response to reduce the human, environmental, and economic impact of disasters	Improved planning, prioritisation and coordination of disaster response	Increase in assets covered by insurance following a disaster
Outputs	EO improves the accuracy and extent of disaster early warning systems	EO supports near real-time monitoring and assessments for better planning and prioritisation during disaster response	EO supports resilience via insurance through improving risk calculations
Agricultural challenges	Limited data for forecasting disasters	Limited data reduces coordination with disaster response authorities	Difficulty obtaining data to quantify risk and assess vulnerability

FIGURE 19: Outcomes and Impacts of EO in Disaster Resilience

— *EO improves the accuracy and extent of disaster early warning systems*

Many developing countries lack the infrastructure to gather and process the data needed to estimate when and where disasters might occur and their potential impact. EO is used to support the identification and observation of hazards over time to enable and update risk analysis. When incorporated with ground-based data, such as weather stations and meteorological forecasting models, EO improves the accuracy of disaster forecasting, particularly for weather related events. This allows for timely activation of emergency plans, including flood defences and evacuation, that reduce the human deaths, missing persons, and economic losses.

EO supports improvements in the timeliness and accuracy of flood forecasting. An expanded forecasting window makes new adaptive strategies possible in flood-vulnerable areas, allowing local communities to adopt methods to mitigate the harmful impacts of major flooding. The cases below highlight EO's effectiveness in providing early warnings in Bangladesh and Sri Lanka.

- The Global Flood Awareness System (GloFAS) is a GEO Community Activity that provides flood warnings across country borders with forecasts beyond 15 days. During the August 2017 Bangladesh floods, the system provided an opportunity to evaluate the forecasting improvements. Initial estimates showed that a flood peak would occur between 13 and 22 August. The Bangladesh Flood Forecasting and Warning Centre used GloFAS information daily and coordinated with the Bangladesh Water Development Board. The field offices took charge of flood preparations and the system's extended range showed a marked improvement from the previous version.[155]
- The ESA EO4SD-Urban project supported Kolkata Municipal Council (KMC) and ADB to integrate EO data into the city's Flood Forecasting and Early Warning System (FFEWS). The FFEWS is designed to provide forecasts and real-time updates from sensor nodes installed in specific hotspots. Data is communicated to the KMC's control room and the real-time status of inundation is displayed on a flood monitoring dashboard. The Senior Climate and environmental advisor for DFID's Asia team stated that *"the Kolkata Flood Forecasting and Early Warning System will improve the resilience of vulnerable communities and of Kolkata's economy to current flooding risks and longer-term climate change"*.[156]

EO enables more accurate forecasting and monitoring of hurricane and cyclone movements. Hurricanes and cyclones are rapid-onset disasters. EO provides accurate status of current environmental conditions which is fundamental to forecasting the risk of disasters, and, in combination with ground-based meteorological data, EO improves the accuracy of disaster forecasting. This includes forecasting time and location of landfall, subsequent path over land and populated areas, and severity. As hurricanes and cyclones approach land, specific EO satellites are tasked to provide high resolution imagery of the areas at risk. EO has proven its capabilities in estimating hurricane intensity as highlighted in the case of Hurricane Katrina below.

155 Group on Earth Observations (GEO). 'GEO Blue Planet building a global platform for marine litter monitoring'. www.georeportonimpact.org/water-and-oceans-impact-stories. Accessed February 2020.

156 Asian Development Bank (ADB). 'Transforming Kolkata: A Partnership for a More Sustainable, Inclusive, and Resilient City'. www.adb.org/sites/default/files/publication/513696/transforming-kolkata.pdf. Accessed February 2020.

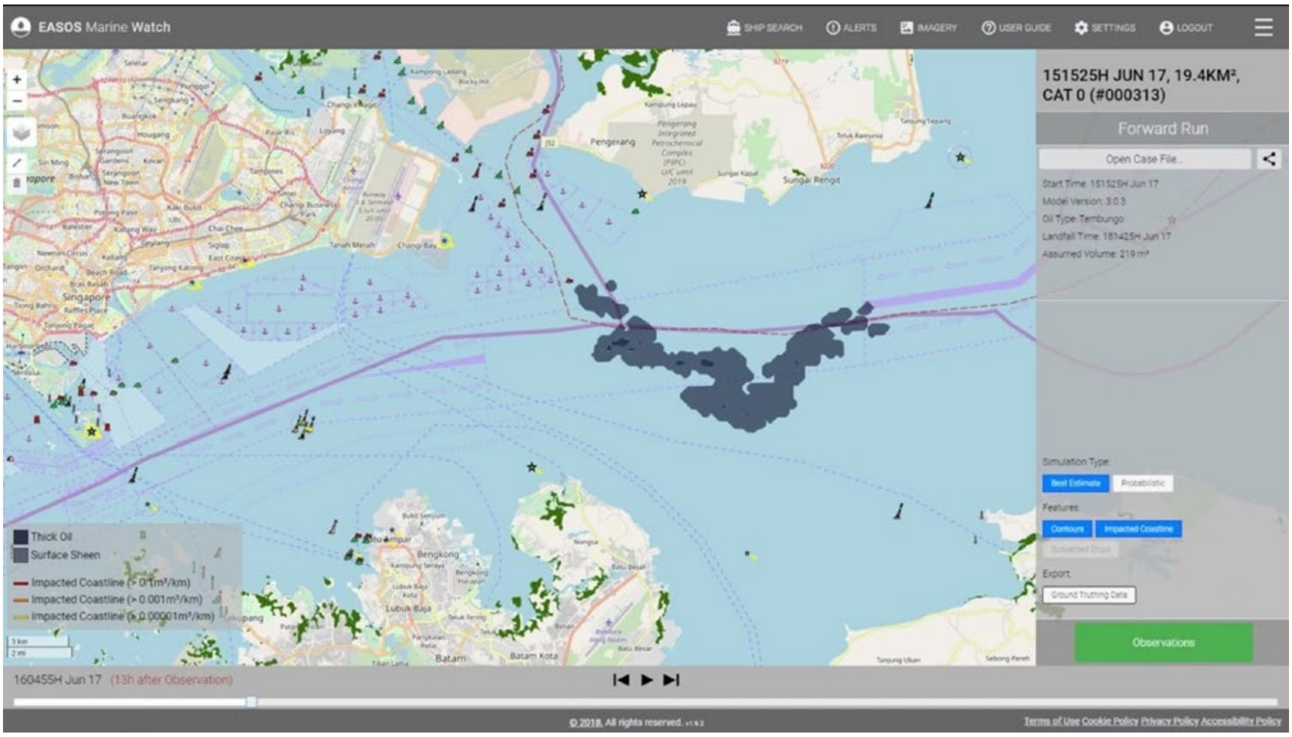


FIGURE 20: EASOS Marine Watch Showing Oil Pollution from Space (Credit: EASOS)[158]

- Hurricane Katrina was the most destructive tropical cyclone in recent years to strike the US. Less than a month later, hurricane Rita followed. Both storms were among the most well-forecast storms in US history. EO satellites had a major role in tracking the storms, response, recovery, and subsequent rebuilding efforts. Information derived from the US National Oceanic and Atmospheric Administration's (NOAA) satellites was used to estimate storm intensity with considerable accuracy. NASA contributed data from the TRMM satellite, which led to improved hurricane path and rainfall predictions.[157]

EO supports the identification of oil spills, seep, drift, and dispersion. Plans for protecting the environment, society, and the economy require reliable forecasts that predict where oil will spread in the event of a spill. Information on the direction and speed of oil movement, along with information on wind, currents, and waves, is required for predicting oil drift and dispersion. Monitoring the dynamics of an oil spill requires fast turn-around times and frequent updates; EO can provide this over wide areas. Applications have shown the accuracy of EO in identifying oil spills and the substantial economic impacts of these applications.

- Between April 2007 and January 2011, 72 authorised users in 24 coastal states have used EO data provided by the CleanSeaNet initiative of European Maritime Safety Agency (EMSA) for sea pollution operations. In this time, ~8,800 possible oil spills were detected, ~2,800 were checked on site, of which ~740 were confirmed. EO data enabled EMSA to monitor over 1000 million km² at an operational cost of approximately ~€2.7 million a year. That is 10 times less expensive than if aircraft-based remote sending was used, with a cost savings of more than €25 million a year.[159]
- The UKSA IPP supported EASOS Marine Watch, led by Satellite Applications Catapult, incorporating leading algorithms from Plymouth Marine Laboratories and Riskaware uses Sentinel Synthetic Aperture Radar (SAR) satellite imagery to automatically detect potential oil spills and model the expected propagation of the oil. In May 2019, EASOS automatically alerted to the presence of a 4.9km² slick off the east coast of Malaysia. The propagation models showed this slick would impact 13km of coastline. The Malaysian Maritime Department were able to scramble two vessels to intercept as well as contain the slick with the use of booms and dispersants.

157 Hertzfeld, Henry R, and Ray A. Williamson. 'The Social and Economic Impact of Earth Observing Satellites'. In Societal Impact of Spaceflight. Ed. Steven J. Dick, NASA SP (2007): 237-63. https://history.nasa.gov/sp4801-chapter13.pdf. Accessed February 2020.

158 EASOS. 'Propagation. Understand the propagation of the oil for the next 84 hours'. https://www.easos.org.uk/marine-watch?lightbox=dataItem-jrhshr1t2. Accessed February 2020.

159 Publications Office of the European Union. 'Evaluation of socio-economic impacts from space activities in the EU'. https://publications.europa.eu/en/publication-detail/-/publication/b3c64cf6-3caa-4f46-b6cc-a69c3b583cc5/language-en/format-PDF/source-search. Accessed February 2020.

It is estimated £1.6 million in clean-up costs were avoided from this one incident alone.[160]

EO supports volcano monitoring, including checking for seismic activity, small earthquakes, gas emission, and deformation. Volcanic eruptions can have significant human, environmental, and economic impacts. Recent research using satellite radar data found that 46% of volcanoes deform before eruption.[161] Measuring that deformation from space could make it possible to forecast when volcanic eruptions are likely, especially in difficult-to-access remote areas. This use case of EO was highlighted in the recent Kilauea volcano eruption.

- In 2018, Hawaii was impacted by a crisis at Kilauea volcano where a lava flow destroyed over 700 homes. Earlier in the year, the Kilauea caldera began to rapidly subside. High resolution Interferometric Synthetic-Aperture Radar (InSAR) EO monitoring provided unprecedented views of the collapse that were critical to understand the subsidence evolution. This data, alongside other data sources, was analysed by the Hawaiian Volcano Observatory to generate information that guided the emergency response.[162]

EO supports estimation of asset exposure and hazard identification. For countries to improve their disaster resilience, a clear understanding of risk is required. This comes from improved understanding of the different dimensions of vulnerability, exposure of persons and assets, hazard characteristics, and the environment. With an improved understanding of risk, investments in risk resilience can be made. The examples below show that EO applications in hazard risk identification has been demonstrated through measuring subsidence in Indonesia and through building and infrastructure exposure measurement in Indonesia, Nepal, Tanzania, and Timor Leste.

- Satellite radar and InSAR techniques have been used to accurately identify land movement trends in Jakarta in Indonesia with an unprecedented level of detail and accuracy. In Jakarta, pumping water from deep wells is causing the land to sink by approximately 10 cm a year. The information generated by the satellites has helped manage ground water extraction and supports regular monitoring of high-rise buildings and coastal defence infrastructure.[163]
- An ESA and WB collaboration used EO data to pinpoint parts of the Tunisian capital where land was sinking—undermining the city's ability to withstand storms, earthquakes, and extreme weather. Sameh Wahba, at the time was the manager of the Bank's Urban Development and Resilience unit, which spearheaded the programme and stated that "*The results from the satellite data were stunning…quick, cost-effective and technically sound. They gave us visually impressive products that easily communicated the magnitude of the problem to our counterparts in government*". Through this information, the Tunisian government has incorporated smart risk mitigation policies into the city's adaptation and resilience plans.[164]

— *EO supports near real-time monitoring and assessments for better planning and prioritisation during the disaster response*

In developing countries, there is limited information, visibility, and communication around post-disaster population movements and infrastructure damage. This leads to challenges in coordinating a response across government agencies, donors, NGOs, and the private sector. Near real-time disaster monitoring through EO enables improved planning and prioritisation of the response thereby reducing the human, environmental, and economic impact.

EO supports the provision of information on flood extent in disaster response. Information on flood extent is invaluable for emergency authorities involved in flood recovery and damage assessment. Prompt delivery of this information helps emergency authorities target their response activities. EO applications in several countries have highlighted that EO data increases response efficacy by decreasing the time and resources spent on identifying flood extent and helping to prioritise targeted actions to save lives and infrastructure.

- A 2019 study aimed to develop a methodology for rapid flood inundation and potential flood damaged area mapping using Sentinel and Landsat data. This was to support a rapid and effective response in

160 Personal communication. Alastair Lees. Satellite Applications Catapult. January 2020.

161 Lewis, Tanya. 'Satellite Images May Predict Volcanic Eruptions'. Live Science. www.livescience.com/44604-satellite-images-could-predict-volcanic-eruptions.html. Accessed February 2020.

162 Group on Earth Observation (GEO). 'UN Resolution on Geospatial Information & Services for Disasters'. www.georeportonimpact.org/disasters-impact-stories. Accessed February 2020.

163 World Bank. 'High Above Earth, Satellites Help Direct Ground-Breaking Development Work'. www.worldbank.org/en/news/feature/2013/08/20/earth-observation-for-development-success-stories. Accessed February 2020.

164 As above.

Bangladesh. The overall accuracy of flood inundation mapping was 96.4% and the accuracy of the land cover map was 87.5%. The flood inundation maps were distributed to the user community to support the response.[165]

- Malaysia used the UKSA-supported Earth and Sea Observation System's (EASOS) Flood Watch during the 2017-18 disaster season to predict and model floods. Following one instance of flooding, EASOS supported a clean-up and safe-return-home plan for 7,000 displaced people by providing street-level risk information.[166]

EO supports earthquake impact estimation and a more effective emergency response. Ground-based seismometers that measure seismic activity are mainstays in determining an earthquake's impact. But these instruments are not widespread, which can lead to incomplete information at critical times. EO applications have provided detailed information on earthquakes' locations in relation to population and infrastructure and scale of surface deformation just days after the earthquake, as shown in Indonesia and Chile.

- In 2018, a 7.5 magnitude earthquake struck the Minahasa peninsula in Indonesia and was quickly compounded by a localised tsunami. The event led to over 2,000 casualties, 10,000 injured, and more than 70,000 persons evacuated. The International Charter Space and Major Disasters was activated, and the first set of images were received within one day. The collection of images enabled the government and army to plan the rescue operations and provided a first estimate of the damage in the city (approximately 5,000 buildings). Based on the images received, an analysis of the state of critical infrastructures was conducted, enabling responders to identify alternative routes to damaged roads.[167]
- The EO4SD-Disaster Risk Reduction project supported Central Sulawesi, Indonesia, in the response to a 7.5 magnitude earthquake which combined with the ensuing tsunami left 2,256 people dead. ESA worked with the ADB and Government of Indonesia to provide EO products highlighting terrain motion, flood hazard, land use/land cover and night light change. These aided the drafting of a Master Plan that addresses the recovery of the affected areas and the application of mitigation measures.[168]

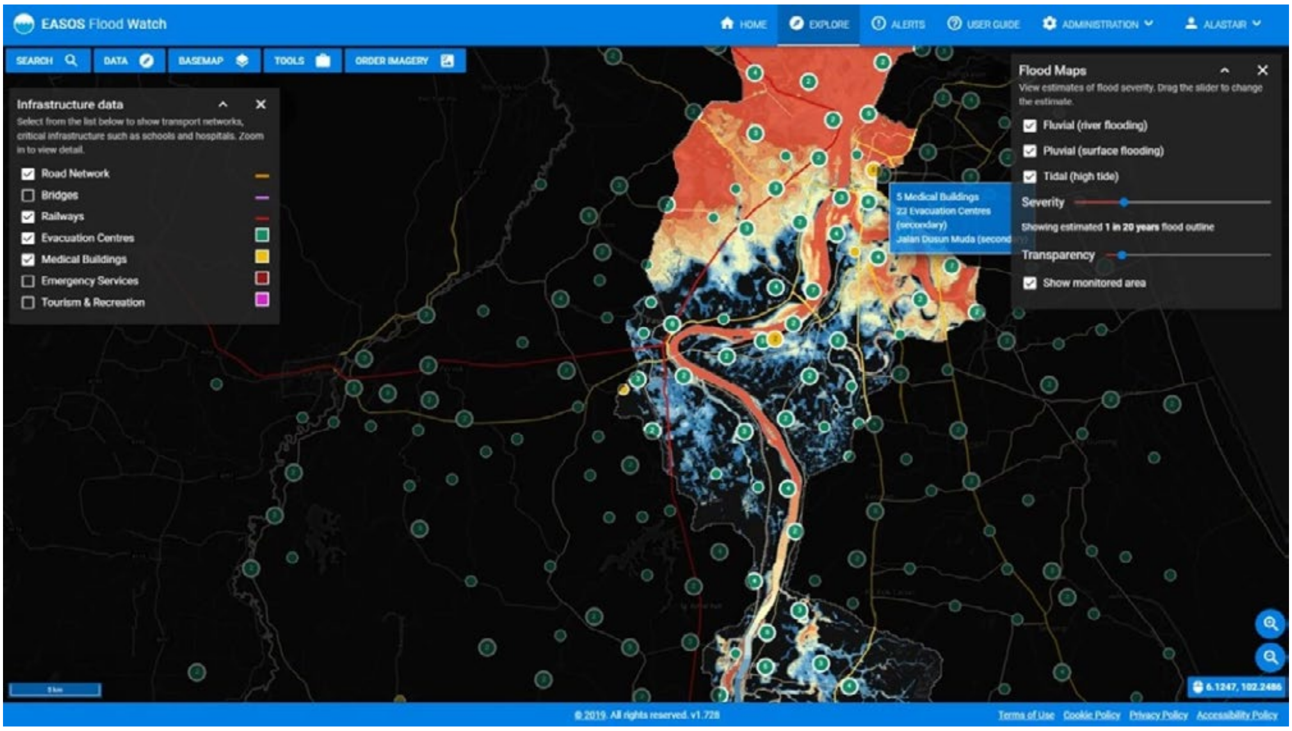


FIGURE 21: EASOS Flood Watch Showing Flood Severity Risk (Credit: EASOS)[169]

165 MDPI. 'Operational Flood Mapping Using Multi-Temporal Sentinel-1 SAR Images: A Case Study from Bangladesh'. www.mdpi.com/2072-4292/11/13/1581. Accessed February 2020.

166 Caribou Space for UK Space Agency. 'UK Space Agency International Partnership Programme: Three Year Review'. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/833424/UKSA_IPP_Three_Year_Review_Final_web.pdf. Accessed February 2020.

167 PwC for the European Commission. 'Copernicus: Market Report—February 2019'. www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf. Accessed February 2020.

168 ESA. 'EO4SD supports Central Sulawesi recovery'. www.eo4sd-drr.eu/news/eo4sd-supports-central-sulawesi-recovery. Accessed February 2020.

169 EASOS. 'Disaster Preparedness. Plan for 1 in 5 to 1 in 10,000 year flood events.' www.easos.org.uk/flood-watch?lightbox=dataItem-jrhscgcb5. Accessed February 2020.

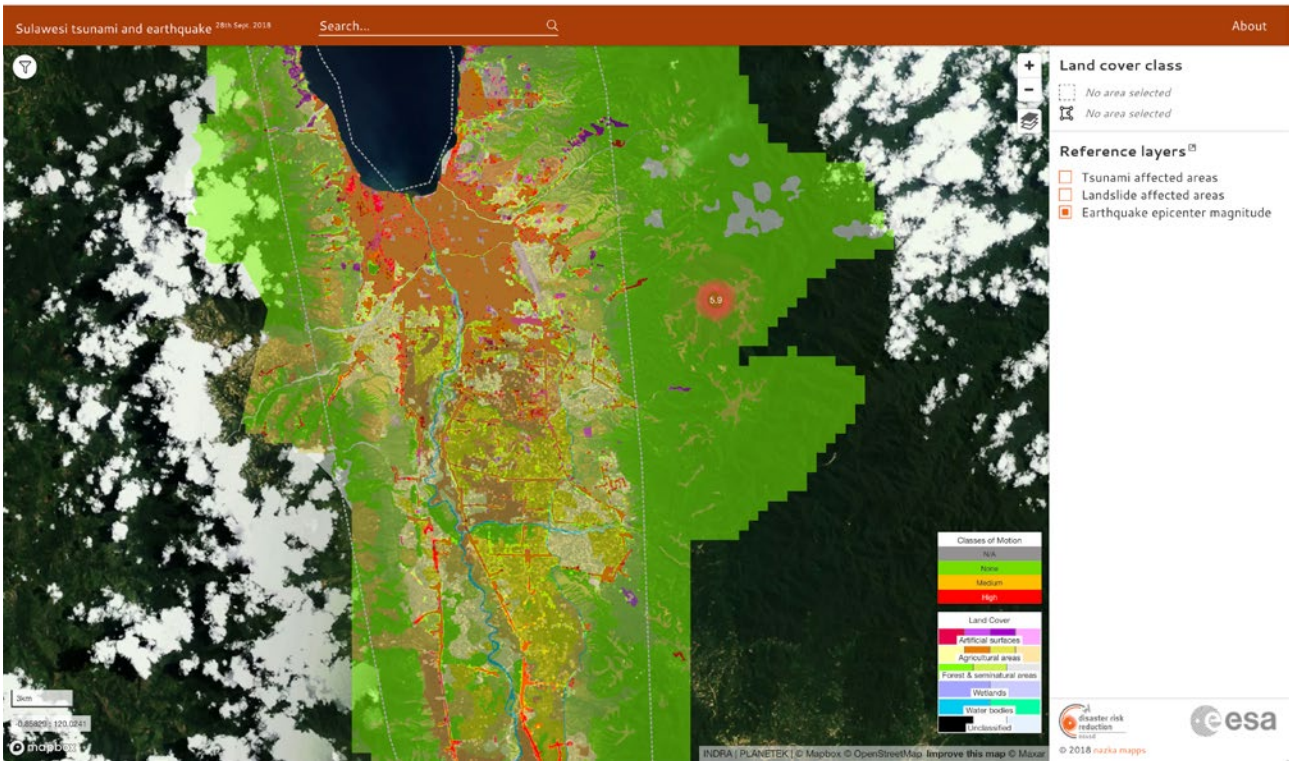


FIGURE 22: EO4SD-Disaster Risk Reduction Showing Post Sulawesi Earthquake Building Stabilty (Credit`: ESA EO4SD Disaster Risk Reduction)[170]

EO supports post hurricane and cyclone response and recovery by providing information on environmental conditions that are fundamental to forecasting and responding to the impact of hurricanes and cyclones. EO has proven its utility in supporting the response in the aftermath hurricanes in North and South America.

- In 2009, Hurricane Ida brought heavy rains that triggered flooding and mudslides in El Salvador, resulting in almost 200 deaths, leaving thousands homeless and causing more than US$150 million in damage. The satellite images provided by SERVIR mapped the mud flow and assisted officials in understanding the full extent of the damage and how it could be avoided in the event of future disasters.[171]
- The Copernicus Emergency Management Service (CEMS) has been activated for several seasonal hurricanes and typhoons in the Atlantic and Pacific Ocean, such as hurricane Harvey in the US (2017), hurricane Michael (2018), and hurricane Florence (2018). In total 54 post-event maps were delivered to the Federal Emergency Management Agency which helped coordinate the assessment of flooding and infrastructure damage. The US department of State noted that *"U.S. emergency managers have found great value in the near real-time, geospatial analytical products prepared by the Copernicus operation centres in Europe. As the 2018 hurricane season ends this month, U.S. emergency management agencies are grateful for Europe's full, free, and open data policy".*[172]

170 ESA. 'Sulawesi tsunami and earthquake'. http://eo4sd.dev.nazkamapps.com/. Accessed February 2020.

171 Washington Post. 'Daniel Irwin: Using NASA technology to solve disaster, environmental conditions'. www.washingtonpost.com/wp-dyn/content/article/2010/01/18/AR2010011802132.html. Accessed February 2020.

172 PwC for the European Commission. 'Copernicus: Market Report—February 2019'. www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf. Accessed February 2020.

— *EO supports a robust insurance market through improved calculation of risk*

Disasters can disrupt traditional risk avoidance and coping mechanisms, such as selling assets or financial relief from family and friends, who may also be affected. Many insurance schemes for disaster relief use information from ground observation to identify and value assets, which can be subject to delays and inconsistencies. This leads to inaccurate estimations of risk and insurance premiums, and therefore limited availability of affordable insurance coverage. EO can identify and estimate the value of assets such as buildings, infrastructure, livestock, or crops over wide areas with the precision required to price and offer insurance products.

EO has been demonstrated to enhance existing insurance schemes and support disaster risk financing mechanisms. In addition, it has been used to model and estimate the cost of disasters at a national scale as shown in the examples from Nepal and the Pacific island below:

- The Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) has developed catastrophe risk models specific to the Pacific Islands using the EO-based hazard and exposure databases. PCRAFI is now supporting the first set of applications using the PacRIS platform. These include the development of a risk financing and insurance pool for the Pacific, urban and infrastructure planning applications for selected locations, and a post-disaster loss assessment tool.[173]
- The UKSA IPP supported SIBELIUs project, led by eOsphere, aims to improve the dzud (deep winter) resilience of the Mongolian herding population by integrating EO into the Mongolian Index Based Linked Livestock Insurance (IBLI) scheme. This will improve the accuracy and regional sensitivity of the index. In a scenario where a region has not reached the livestock mortality threshold that triggers automatic payment, herders can make a claim which will be verified from satellite data. This would increase trust in the index and lead to a higher rate of insurance coverage. SIBELIUs aims to facilitate a 5% increase in insurance uptake by 2020 and by 40% in 2026.[174]

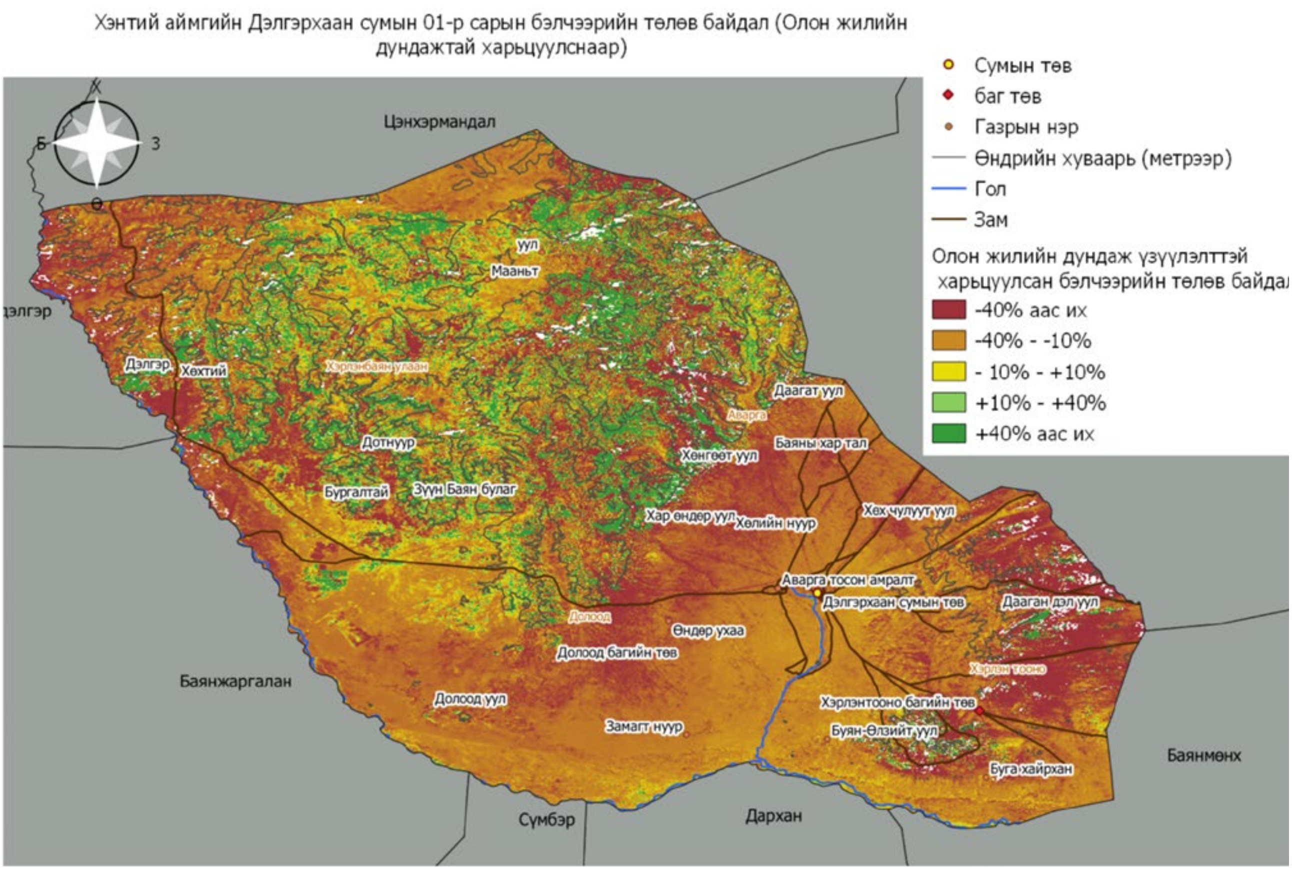


FIGURE 23: eOsphere Sibelius in Mongolian Script - Showing Pasture Condition Compared to the Long-Term Average in Mongolia for Pastoralists (Credit: eOsphere)

173 OECD. 'Disaster Risk Financing: A Global Survey of Practices and Challenges'. www.oecd.org/daf/fin/insurance/OECD-Disaster-Risk-Financing-a-global-survey-of-practices-and-challenges.pdf. Accessed February 2020.

174 Personal communication. Nick Walker. eOsphere. January 2020.

Impact of Earth Observation in urban development

7. Impact of Earth Observation in urban development

Key points

- Cities need evidence-based plans to understand the city fabric and prioritise investment. But obtaining relevant, scalable data is a significant challenge for many developing world cities.
- EO provides benefits within urban development in four overarching areas:
  1. Urban planning and monitoring,
  2. Transport planning and monitoring,
  3. Hazard assessment, early warning, and response coordination, and
  4. Monitoring of environmental issues.
- Several insights from public literature have contributed evidence to each of these areas:
  - There is evidence of EO being integrated into city plans, slums assessments, and innovations using EO to resource their development plans by improving tax revenue.
  - Examples of EO used in transportation planning and monitoring exist, primarily in developed countries, but also more recently from developing countries.
  - Evidence on the benefits of EO for disaster risk assessments and efficient response is plentiful. In addition, there are EO applications to assess urban building/infrastructure risk exposure (see Impact of Earth Observation in disaster resilience section, above).
  - Innovations in satellite sensors enable the measurement of air quality and surface temperature to provide cities with critical environmental information that can be used to support sustainable development interventions.

7.1 Value of urban development

With more than 80% of global GDP generated in cities, urbanisation contributes to sustainable growth—if managed well.[175] Well planned compact cities reduce transaction costs, make public spending on infrastructure and services economically viable, and facilitate generation and diffusion of knowledge, all of which are important for growth. When urbanisation is supported by forward looking plans, cities can elevate incomes and improve livelihood options. But the value of cities extends beyond economic opportunities; urban areas also offer greater access to education and health services, social mobilisation, and the potential for a higher quality of life. Over 4 billion people—more than half the global population—live in cities. This number is expected to increase; by 2050, 7 in 10 people are predicted to live in cities.[176] As the dominant habitat for the world's population, how cities evolve matters greatly.

175 World Bank. 'Urban Development: Overview'. www.worldbank.org/en/topic/urbandevelopment/overview. Accessed February 2020.
176 As above.

7.2 Urban development challenges

However, if the process of urbanisation is not well managed, the speed and the scale of urban growth can (and does) adversely affect social and economic equality, public health, and the natural environment. Some of the core challenges are:

- **Informal settlements:** Slum populations are expected to grow by 10% each year.[177] Slums marginalise low-income populations in peripheral parts of cities and limit their access to basic services. Shelters may be poorly constructed and are often located in areas vulnerable to hazards.
- **Transport:** Without a good transport network, city dwellers have few options to access socio-economic opportunities. In the absence of a robust public transport system there may be more vehicles on the road, compounding negative consequences for environmental and population health.
- **Disaster risk:** 90% of urban expansion takes place in developing countries, and much of it occurs near natural hazards, rivers, and coastlines.[178] This exacerbates the risk exposure of urban populations.
- **Environmental and human health:** The urban population's health is affected by several factors—hazards and pollution from waste sites leave urban residents susceptible to health repercussions while emissions from traffic, open fires, and industrial activities affect the air they breathe. Lastly, biodiverse ecosystems, which are vital to the effective functioning of city systems, are being removed; decreasing green areas impacts the overall population's health and well-being.

The first critical step in urban planning is to establish an understanding of current urban conditions to identify priorities for investment and understand the interconnections between city systems that can guide efficient use of resources.[179] Yet this fundamental point—obtaining relevant, scalable data—challenges many cities. Traditional sources of urban data, including population census and a multitude of public service company records, are housed in data silos which make it difficult to observe the interconnections vital for an integrated approach to work.

7.3 EO's role in urban development

EO helps address data limitations and support city planners and relevant authorities on sustainable urban development through:

- Information for urban planning by mapping land classes, urban extent, building footprints, and population density,
- Monitoring environmental issues by assessing public green spaces, waste sites, air quality, surface imperviousness, and urban temperatures,
- Mapping different transport classes, and
- Assessment of various hazards risks (flood, landslide, and subsidence) and facilitating early warnings and coordinated responses.

Figure 24 highlights both the role and the impact of using EO within urban development. The following section forefronts how EO has and is being used to solve the various challenges in the urban development sector.

177 UN Habitat. 'State of the World's Cities 2010-2011: Bridging the Urban Divide'. https://sustainabledevelopment.un.org/index.php?page=view&type=400&nr=1114&menu=35. Accessed February 2020.

178 World Bank. 'Urban Development: Overview'. www.worldbank.org/en/topic/urbandevelopment/overview. Accessed February 2020.

179 World Bank. 'Urban Sustainability Framework'. http://documents.worldbank.org/curated/en/339851517836894370/pdf/123149-Urban-Sustainability-Framework.pdf. Accessed February 2020.

Impact	EO products contribute to the achievement of UN SDG 11 "Sustainable Cities and Communities"			
Outcomes	Suitable housing	Improved transport	Greater disaster resilience	Improved environmental & human health conditions
	Compact city growth, adequate public services, and infrastructure for all inhabitants	Extensive, sustainable and affordable transport	Improved mitigation and recovery measures to reduce risk of natural and man-made disasters	Reduction in the environmental risks and conservation of natural ecosystems
	Improvements in sustainable urban planning via enhanced efficiencies in workflow and decision making processes			
IFI, donor and city outcomes	EO products provide accurate, robust, information on the status of urban sustainability to identify priorities for investment and to respond to/manage cities changing needs			
	IFIs, donors and city authorities have the incentives, skills, infrastructure and financial resources to use EO products			
Outputs	EO supports urban development planning and monitoring	EO supports transport planning and monitoring	EO supports the assessment of various hazards risks, early warnings and response coordination	EO supports monitoring of various environmental issues
Urban development challenges	Urban sprawl and informal settlements	Limited and inefficient transport	Vulnerability to disasters	Environmental degradation and population health concerns
	Data for sustainable urban planning			

FIGURE 24: Outcomes and Impacts of EO in Urban Development

— *EO supports urban planning and monitoring*

Urban settlement in developing countries is often informal and municipal records, when available, struggle to keep pace with rapid changes. EO can provide a spatially granular lens to improve cities' understanding of changes, needs, and priorities for investment. EO has been provided through free and open platforms for cities with limited information, there is also evidence of EO data being integrated into city plans, particularly for specific, nuanced needs of informal settlements. Furthermore, there have been interesting innovations using EO to enable cities to resource their development plans by improving their tax revenue.

There are now several EO-derived open and free base datasets and platforms that enable and support sustainable urban planning, specifically for countries that lack access to this data. Furthermore, by aggregating data in user-friendly platforms, non-EO experts can access and use EO in their urban work. Evidence highlights the value of core datasets to urban planning.

- The Global Human Settlement Layer (GHSL) is one of the core datasets in the GEO Human Planet Initiative and contributes to enabling city authorities to map built-up areas to monitor and plan infrastructure developments. GHSL is currently being used in South Africa to support several legislations.[180] [181]
- The Africapolis database is a unique database that uses census and EO data. The 2018 edition covers 51 countries and 7,500 urban agglomerations. The data and analyses generated by Africapolis aim to improve African policymakers' and researchers' capacity to better target resources and develop urban policies.[182]
- The ESA Urban-Thematic Exploitation Platform (U-TEP) provides access to EO information, processing tools, and computing resources. The WSF-2015 dataset—the world's first map that combines radar and EO data to provide a global overview of human settlements—has been integrated on U-TEP. The WSF-2015 development manager at DLR stated that, "*U-TEP will benefit from the new WSF-2015 data, particularly in view of services for more effective urban planning and service provision, enhanced risk analysis related to natural disasters, or improved assessment of human impact on ecosystems*".[183]

180 Including the Spatial Planning and Land Use Management Act, the National Human Settlements Land Inventory Act, the Statistics Act, the Municipal Demarcation Act, the Conservation of Agricultural Resources Act, and the Disaster Management Act and Electoral Act.

181 Mudau, Naledzani. 'Mappin & Monitoring of Settlements in South Africa'. Group on Earth Observations (blog). www.earthobservations.org/geo_blog_obs.php?id=209. Accessed February 2020.

182 OECD. 'The Space Economy in Figures: How Space Contributes to the Global Economy. Chapter 2. The socio-economic impacts of space investments'. 2019. www.oecd-ilibrary.org/science-and-technology/the-space-economy-in-figures_c5996201-en. Accessed February 2020.

183 Chaturvedi, Aditya. 'ESA combines radar and EO data to create world's first urban habitation map'. Geospatial World. www.geospatialworld.net/blogs/esa-maps-global-urban-habitation-patterns/. Accessed February 2020.

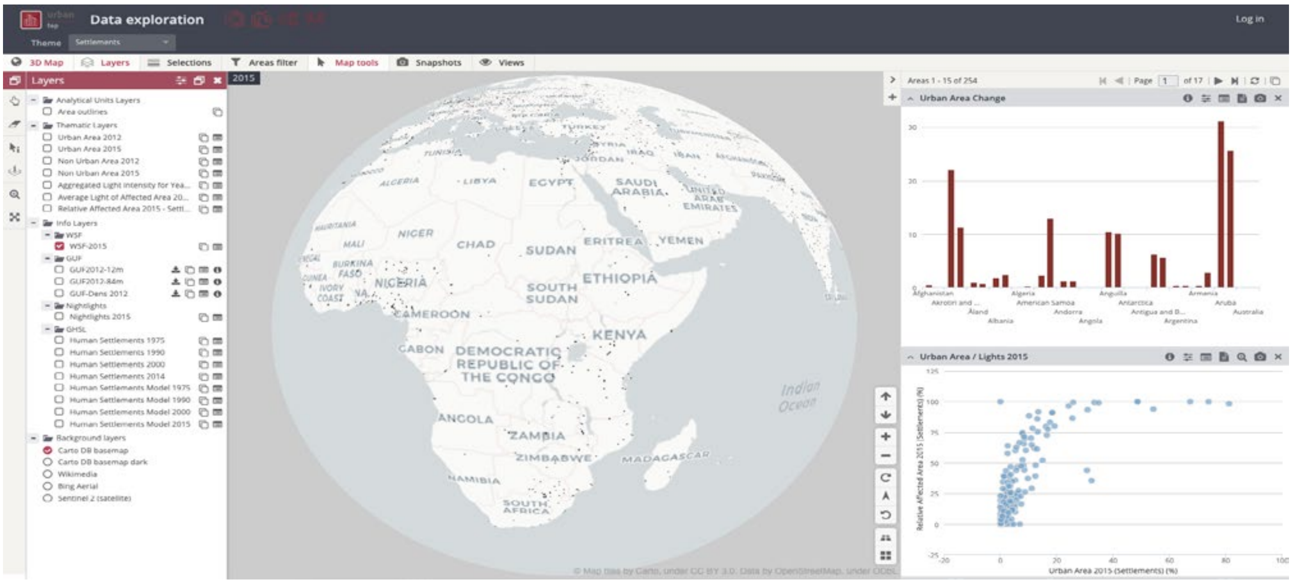


FIGURE 25: ESA Urban-Thematic Exploitation Platform[184]

EO is used to inform and monitor city plans. Evidence from a few African and Asian cities have highlighted the use of EO data for informing city plans and tracking urban development interventions, while new databases to provide African countries with EO derived data for their cities are being developed.

- The ESA EO4SD-Urban project supported WB, ADB, IADB and Global Platform for Sustainable Cities (GPSC) programmes across 31 unique cities (33 in total) across 15 countries. Across these IFI programmes the most commonly requested EO product from the consortium was a land use / land cover classification. The very high-resolution version provided 30 classes for the core city area whilst a high-resolution version provided 10 for primarily classifying the peri-urban areas. That provided urban planning teams within the IFIs and the cities with very accurate, up to date view of the current status of urban development.[185]

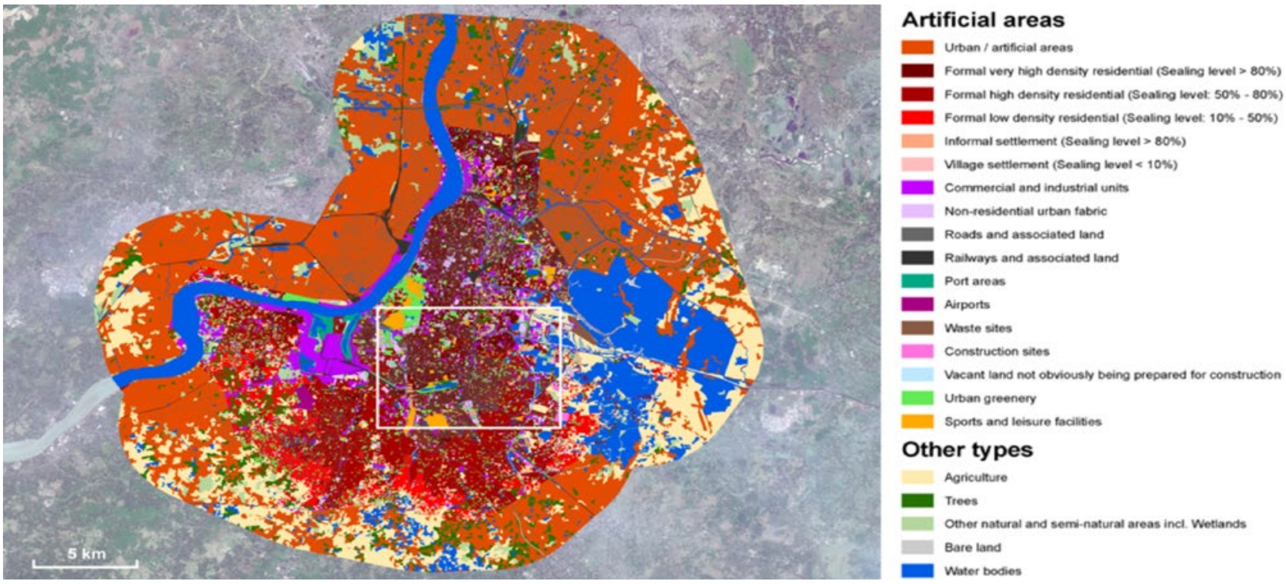


FIGURE 26: EO4SD-Urban Showing Land Use and Land Cover in Kolkata (February–March 2017) (Credit: SIRS)

184 Urban TEP. https://urban-tep.eu/. Accessed February 2020.

185 Caribou Space. 'Understanding the impact of Earth Observation for sustainable urban development'. April 2020.

- In 2016, the City of Johannesburg adopted its Spatial Development Framework 2040—an ambitious plan to transform the city into one that is spatially just, efficient, resilient, and sustainable. Johannesburg has used geospatial data for analysing inequality and poverty, job-housing mismatch, spatial disconnection, low walkability, and land-use defects. This data then informed city planning and helped officials prepare development scenario options for the future. The Director of City Transformation and Spatial Planning stated that, *"Satellite technology and geospatial information help track our urban footprint and understand the impact of our interventions"*.[186]
- Dhaka, the capital of Bangladesh, is expected to be one of the five most populated cities in the world by 2025. To understand Dhaka city growth dynamics and forecast its future expansion by the year 2030, a SLEUTH[187] model drawing on historical EO data was used. The model showed that an additional 20% of the metropolitan area will be converted into built-up land by 2030 and a clear spatial trend of sprawl towards the north and north-west. The interpretation of depicting the future scenario as demonstrated by EO will be of great value to urban planners and decision makers for the future planning of Dhaka.[188]

EO data has supported innovations in generating tax revenue for cities to fund urban investment. The technical complexity of ensuring that tax rolls are complete, and valuations are current is often perceived as a major barrier to bringing in property tax revenues in developing countries. Ensuring property taxes can be collected in fair, low-cost ways requires that automated property valuation methods based on routinely updated market values.

- The ESA EO4SD-Urban project supported the WB Development Economics Research Group (DECRG) to conduct a pilot study in Kigali, Rwanda to improve methods of land valuation using EO to simulate different property values. The pilot demonstrated that EO can reduce the cost of establishing and updating tax registers by allowing automated generation of building footprints, and based on building heights, an estimate of total built-up area. The pilot found that only 40% of the potential yield of US$4.9 million from current lease fees is collected, suggesting that more efficient collection could heighten returns. Furthermore, moving to a 1% value-based tax could increase revenue to about US$19.3 million—almost 10 times what is currently collected.[189]
- The UKSA IPP supported Dakar Change Monitoring project with Airbus Defence and Space uses GNSS-based field surveys and high-resolution EO to detect urban change. During the project 90,000 parcels of land were digitised. This data can support more effective property tax collection and ultimately the maintenance of city infrastructure and services. The EO-based methods were calculated to be able to generate additional revenues of £1.6m and at a cost-effectiveness ratio of £0.37 of cost per £1 of tax revenue collected.[190]

FIGURE 27: Geographic Information System Representation, by Colour and Vertical Extent, of the Property Values in Dakar (Credit: Airbus Defence and Space)[191]

EO has been used to provide the base information that enables authorities to address the specific needs and challenges of slums. Identifying slums and delineating their boundaries at the city scale without any base information is a challenge for any city, leading to public authorities under-estimating their needs in planning. Applications in Manilla and Dhaka demonstrate the cost-effective applications of EO for slum assessments.

186 Wang, Xueman. 'How geospatial technology can help cities plan for a sustainable future'. World Bank (blog). https://blogs.worldbank.org/sustainablecities/how-geospatial-technology-can-help-cities-plan-sustainable-future. Accessed February 2020.

187 That is, a self-modifying cellular automaton based on Slope, Land use, Exclusion, Urban extension, Transportation, and Hillshade.

188 Pramanik, Monjure Alam, and Demetris Stathakis. 'Forecasting urban sprawl in Dhaka city of Bangladesh'. Environment and Planning B: Planning and Design 0 (2015): 1-16. www.ncgia.ucsb.edu/projects/gig/Repository/references/Dhaka_Bangladesh/Environ-Plann-B-Plann-Des-2015-Pramanik-0265813515595406.pdf. Accessed February 2020.

189 Ali, Daniel Ayalew, Klaus W. Deininger, and Michael Wild. 2018. 'Using satellite imagery to revolutionize creation of tax maps and local revenue collection'. World Bank. Policy Research working paper WPS 8437. http://documents.worldbank.org/curated/en/347231526042692012/pdf/WPS8437.pdf. Accessed February 2020.

190 Caribou Space & London Economics. 'Economic evaluation of the International Partnership Programme (IPP): Cost-Effectiveness Analysis'. www.spacefordevelopment.org/wp-content/uploads/2019/10/UKSA-IPP-Cost-Effectiveness-Analysis-FINAL-for-web-1.pdf. Accessed February 2020.

191 Caribou Space for UK Space Agency. 'Space Solutions for Development'. https://www.spacefordevelopment.org/library/space-solutions-for-development/. Accessed February 2020.

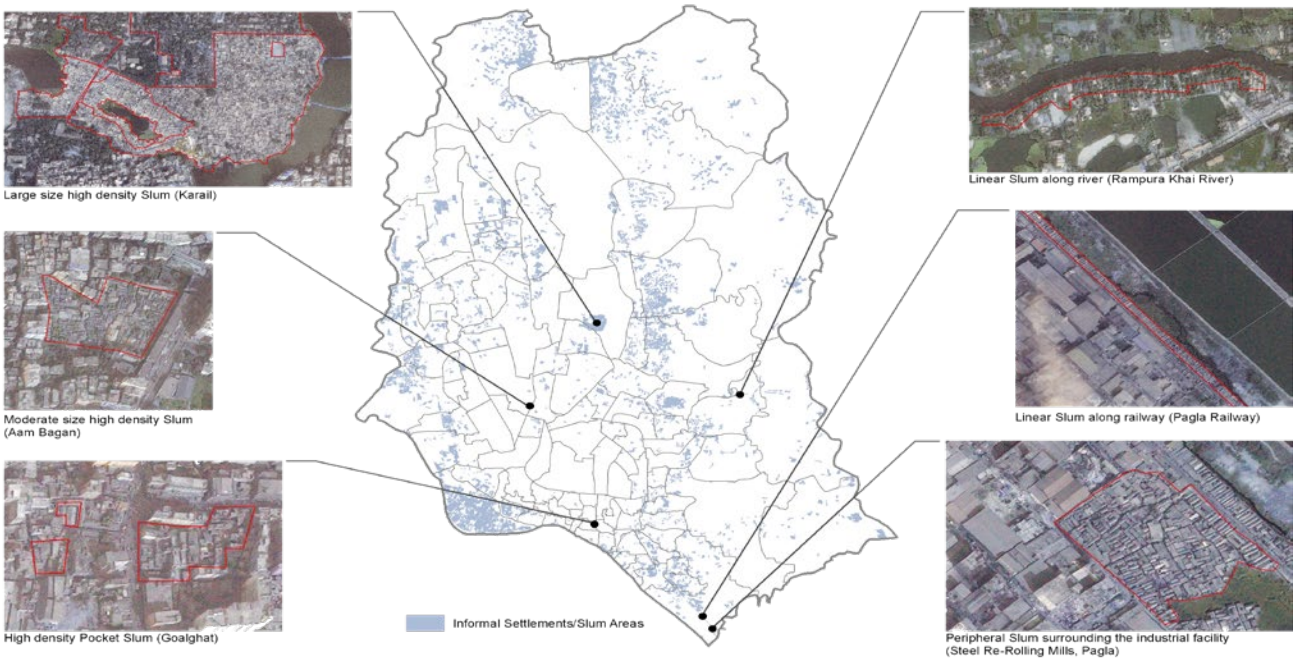


FIGURE 28: Slum Mapping and Characterisation in Dhaka, Bangladesh
(Credit: GISAT. Satellite imagery: Pleiades © (2017) CNES, Distribution AIRBUS DS)

- ESA supported WB with analysis of Metro Manilla's slums in 2014. At that time government records were found to be outdated and no comprehensive basis for developing a sample of slum dwellers was available. To address this challenge, ESA supported the application of very high resolution EO data to identify and delineate the slums at scale and in a short time frame. Because of this analysis, the first ever database of 2,500 slums of various shapes and sizes were developed for Metro Manila and was used to develop five distinct slum typologies.[192]
- ESA EO4SD-Urban supported WB Water Supply and Sanitation in Rapid Urbanization project in Dhaka, Bangladesh. They devised and tested a novel, predictive model that combines spatial characterisation analysis with statistical modelling to identify slum areas and characterise slum deprivation. Several EO-derived indicators (e.g., access to safe water and adequate sanitation) were incorporated into a Slum Severity Index (SSI). For national governments this methodology was stated to provide an efficient and cost-effective way to estimate household deprivation and demand for city services nationwide. Given that EO is available for entire nations simultaneously, there is less time lag between data acquisition and use in decision-making than traditional survey-based methods.[193]

192 Singh, Gayatri, and Gauri Gadgil. 'Navigating Informality: Perils and Prospects in Metro Manila's Slums'. World Bank. http://pubdocs.worldbank.org/en/564861506978931790/Navigating-Informality-Metro-Manila-7-26-17web.pdf. Accessed February 2020.

193 Mimmi, Luisa, and others. 2018. 'Predicting Deprivations in Housing and Basic Services from Space: A Pilot Study in Slums of Dhaka, Bangladesh'. www.researchgate.net/publication/325090468. Accessed February 2020.

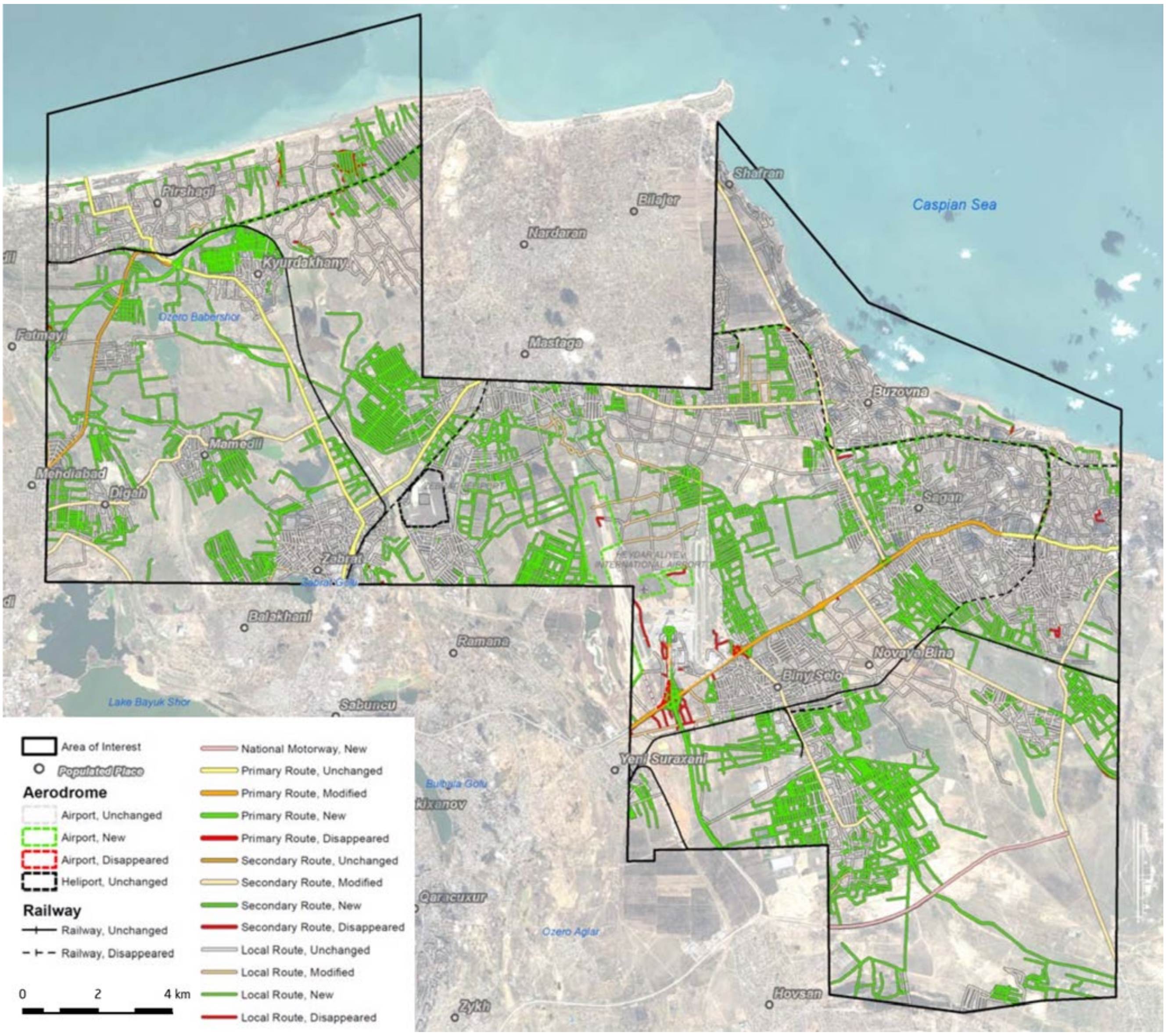


FIGURE 29: Change Detection in the Transport Infrastructure in Baku, Azerbaijan (Credit: ESA)

— *EO supports transport planning and monitoring*

There are numerous examples of demonstration projects supporting the development of sustainable rail and road transport. However, these were predominantly tested in developed countries. They range from gathering information on building railways resilient to disasters in Russia[194] to detecting subsidence on railways lines in the UK.[195] However, public domain evidence of use cases within developing countries is also emerging.

There is nascent evidence that EO has supported and positively contributed to providing users with inventories of transport infrastructure in developing countries. Transport infrastructure data availability and quality in developing countries often limits the development of sustainable transport policies, investment strategies, and models of future transport needs.

- An ESA project between 2014–16 supported the ADB Global Transport Intelligence—Transport Outlook Asia activity. EO contributed to the updated inventory of transport infrastructure, identification of existing gaps, giving the most up-to-date picture of transport infrastructure. The services delivered to ADB had beneficial effect as being highly relevant for future creation of harmonised transportation databases across multiple ADB member countries. According to the ADB Transport Specialist, *"For the same amount of money that we spent for planning previously, we can ask for more and better data* [using EO] *and deliver better services. That's especially important for public transport planning, like for corridors of Bus Rapid Transit systems or*

194 EARCS 'Railway line monitoring.' https://earsc-portal.eu/display/EOSTAN/Railway+Line+Monitoring. Accessed February 2020.

195 ESA. 'LiveLand: Predicting, monitoring and alerting of landslides and subsidence affecting transport infrastructure.' https://business.esa.int/projects/liveland. Accessed February 2020.

even when looking at informal transport". Another stated *"One of the major opportunities we had by using satellite imagery analysis is obtaining the data we needed without going into the field…It also allowed us to analyse the land use around the mass transit stations that we are planning. The outcome of the collaboration was very good"*. [196]

— *Assessment of various hazards risks and facilitating early warnings and a coordinated response*

Evidence on the use and benefits of EO for both assessing disaster risk and enabling a more efficient response to disasters in urban areas is plentiful. This may have its roots in a longer history of EO being used in disaster resilience. There is evidence on the use and impact of EO data in various natural disasters (earthquakes, hurricanes and landslides) in addition to clear applications to assess building and infrastructure exposure to disasters.

See the Disaster Resilience section for details on the following use cases where there is evidence of EO support on:

- Estimation of the impact of earthquakes and a more effective emergency response,
- Identification of landslides hazards and in the response to the aftermath of landslides,
- Development of flood early warning systems in cities, and
- Estimations of asset exposure and hazard identification.

— *EO supports monitoring of environmental variables in cities*

There were several insights on the application and use of EO in air quality monitoring and to a lesser extent, urban heat islands, waste management, and green and open spaces. Several EO products are available to identify and map urban green areas and waste disposal sites. Innovations in satellite sensors enable the measurement of air quality and surface temperature to provide cities with critical environmental information that can support sustainable development interventions.

EO supports the development of models to measure air quality in cities around the world. EO has been used to understand sources and volumes of air pollution and to communicate air quality to citizens.

- The Copernicus Atmosphere Monitoring Service (CAMS) is a GEO community activity that provides consistent and quality-controlled global information related to air pollution and health, solar energy, and greenhouse gases using EO and other sources. In 2017, CAMS helped expand the coverage of the Plumes Air Report—a smartphone application and website which prompts users to adapt their behaviour to air pollution levels—to every city in the world by providing forecasts of the key air quality pollutants. At the end of 2017, the Plume Air Report had been downloaded close to a half million times, with 73% of users saying it has helped them make changes to avoid smog spikes in their cities.[197]
- Research during haze episodes over Peninsular Malaysia assessed the value of using EO to provide new datasets to assist in the observation of air quality at urban scales. 3 km and 10 km MODIS aerosol products were used to provide an overview of the state of fine and coarse particulate matter. They concluded that EO analysis of atmospheric aerosols remain a great method for estimating haze distribution and can be further used to monitor the atmospheric environment in Malaysia.[198]

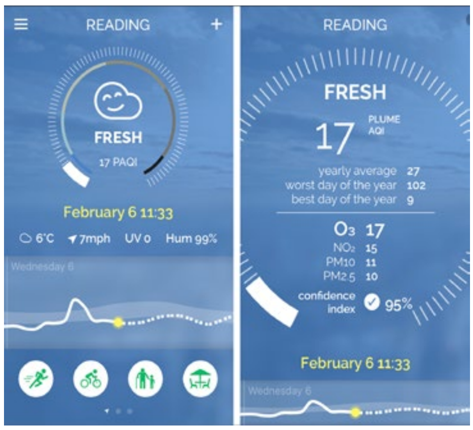


FIGURE 30: Plume Air Report via Mobile Application (Credit: Copernicus Atmosphere Monitoring Service)[199]

EO can support the assessment of urban heat islands in cities. In cities, temperatures can be several degrees higher than in surrounding rural areas. Prolonged periods of high temperatures increase the demand for

196 Asian Development Bank (ADB). 'Earth Observation for a Transforming Asia and Pacific'. www.adb.org/sites/default/files/publication/231486/earth-observation-asia-pacific.pdf. Accessed February 2020.

197 Group on Earth Observations (GEO). 'GEO Highlights: 2017-2018'. www.earthobservations.org/documents/publications/2018_geo_highlights_report.pdf. Accessed February 2020.

198 Khaled Ali Ahmed Ben Youssef and others. 2019. 'The development of Air Quality Indices using AOD-Retrieved Images during haze events in Peninsular Malaysia'. IOP Conf. Series. Earth and Environmental Science 373. https://iopscience.iop.org/article/10.1088/1755-1315/373/1/012027/pdf. Accessed February 2020.

199 Copernicus Atmosphere Monitoring Service. https://atmosphere.copernicus.eu/monitoring-air-pollution-across-europe. Accessed February 2020.

energy and water, trigger health issues, and increase air pollution. EO has enabled an improved understanding of this phenomenon which makes it possible to develop more efficient alert systems, helping decision- and policymakers adopt effective mitigation strategies and improve urban planning.

- Researchers investigated how to measure the urban heat island phenomena in Bangkok, Thailand. Maps of this phenomenon were developed using EO data from Landsat. The researchers stated that the proposed analysis can help determine if the land use plan requires targeted future actions for the urban heat island mitigation or if the maintenance of the current urban development model is in line with environmental sustainability.[200]
- A study in New Delhi India, again using EO data from Landsat to evaluate the correlation between urbanisation-induced rapid land use/land cover change and urban heat island intensity. The result showed that highly dense sub-districts, built-up areas, and industrial zones were more prone to urban heat island intensity. Overall the results can inform policy by highlighting the factors that contribute to reducing urban heat island intensity in cities.[201]

EO can enable the detection and mapping of illegal waste sites in cities and estimates of household waste generation. With 90% of waste openly dumped or burned in low-income countries[202] there is a need for adequate information on the location and status of waste sites so that authorities can mitigate illegal dumping practices. EO has supported use cases for the detection of illegal waste sites and the quantification of household waste in cities.

- A study assessed the quantity of household solid waste in the City of Da Nang, Vietnam. A combination of very-high-resolution EO data, field surveys, and solid waste measurements on the ground were used. The specific generation and composition of household waste correlated positively with the EO data on building type and the spatial location within the city. This assessment of household solid waste generation and composition by building type can help efficiently allocate resources to waste collection throughout the city and improve the rate of waste collection.[203]
- ESA supported the Wastemon project in Italy which provides waste monitoring to improve waste management practices and detect illegal landfills using EO. It was tested by the Environmental Protection Agency of Puglia region, Italy. Over 10 potential illegal waste sites were mapped in the area of interest and the verification results showed the services had an accuracy of 80%.[204]

EO can also support the mapping and assessment of a city's green and open spaces and support in the monitoring of restoring degraded ecosystems in urban areas. Use cases from Sri Lanka, Turkey and the USA have highlighted the EO can be an effective tool to map the status of green areas and to understand how and why green areas are changing.

- In a study, Colombo's green space areas were extracted from Thailand Earth Observation System (THEOS) and an environmental criticality map based on population density and percentage green spaces was constructed. The study revealed that 24% of the entire Colombo Municipal Council area consists of green spaces. This study also revealed that 34 of 55 divisions lack the minimum per capita green space recommended by World Health Organization. The research provided recommendations regarding areas where new green spaces should be established.[205]
- A recent study evaluated the 10-year change in the urban texture in the city of Nevsehir, Turkey, through the integration of very high resolution EO. The results showed a 23% decrease in urban open-green spaces. The results of the study are expected to be guide decision makers in restoring and maintaining green areas in Nevsehir city.[206]

200 Global Partnership for Sustainable Development Data. 'Landsat's Earth Observation Data Support Disease Prediction, Solutions to Pollution, and More'. https://static1.squarespace.com/static/5b4f63e14eddec374f416232/t/5bacd7f2b208fc8541817444/1538054151334/CaseStudy_Landsat_Sept2018.pdf. Accessed February 2020.

201 Pramanik, Suvamoy, and Milap Punia. 2019. 'Land use/land cover change and surface urban heat island intensity: source-sink landscape-based study in Delhi, India'. Environment, Development and Sustainability. https://link.springer.com/article/10.1007/s10668-019-00515-0. Accessed February 2020.

202 World Bank. 'What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050'. https://openknowledge.worldbank.org/handle/10986/30317. Accessed February 2020.

203 Vetter-Gindele, Jannik, and others. 'Assessment of Household Solid Waste Generation and Composition by Building Type in Da Nang, Vietnam'. Resources 8 (2019). www.mdpi.com/2079-9276/8/4/171. Accessed February 2020.

204 EARSC. 'Improving waste management practices'. https://earsc-portal.eu/display/EOSTAN/Improving+waste+management+practices. Accessed February 2020.

205 Senanayake, Indishe, Welivitiyage Don Dimuth Prasad, and Nadeeka Manage. 'Urban green spaces analysis for development planning in Colombo, Sri Lanka'. Urban Forestry & Urban Greening 12 (2013): 307-14. www.researchgate.net/publication/259163094_Urban_green_spaces_analysis_for_development_planning_in_Colombo_Sri_Lanka_utilizing_THEOS_satellite_imagery_-_A_remote_sensing_and_GIS_approach. Accessed February 2020.

206 Aklibasinda, Meliha, and Asli Ozdarici OK. 'Determination of the urbanization and changes in open-green spaces in Nevsehir city through remote sensing'. Environmental Monitoring and Assessment 191 (2019). www.researchgate.net/publication/337333144_Determination_of_the_urbanization_and_changes_in_open-green_spaces_in_Nevsehir_city_through_remote_sensing. Accessed February 2020.

Impact of Earth Observation in climate resilience

8. Impact of Earth Observation in climate resilience

Key points

- Climate change presents the single biggest threat to development, and its widespread, unprecedented impacts disproportionately burden the poorest and most vulnerable people in developing countries.
- EO can provide key inputs to understanding the potential relationships of previously un-modelled (and not intuitive) dependencies between physical climate change and social outcomes.
- EO provides benefits in these overarching areas:
  1. Measuring the state of the climate through Essential Climate Variables (ECVs),
  2. Providing indicators for climate change risk assessments,
  3. Monitoring and building resilience to slow-onset climate change events e.g. sea level rise, and
  4. Monitoring and building resilience to rapid-onset climate change events (i.e. extreme weather events).
- Several insights from public literature have contributed evidence to each of these areas, for example:
  – ECVs address public demands for transparency in environmental decision making and have helped many nations to make commitments to support systematic, sustained climate records. ESA uses EO to produce ECVs through its Climate Change Initiative programme.
  – There is evidence of EO being used to monitor slow-onset climate change events where the repeatable, historical time series of data allows the analysis of long-term trends – including numerous examples for assessing sea level rise and coastal flooding risk.
  – There is extensive evidence of use of EO for rapid-onset climate-related events such as tropical cyclones – see Impact of Earth Observation in disaster resilience section.

8.1 Value of climate resilience

Increasing greenhouse gas emissions are driving climate change. In 2017, greenhouse gas concentrations reached new highs, 146% of pre-industrial levels. Moving towards 2030 emission objectives compatible with the 2°C and 1.5°C pathways requires a peak to be achieved as soon as possible, followed by rapid reductions.[207] An analysis by the World Meteorological Organization shows that global temperature from 2015 to 2018 was the highest on record.[208]

The Paris Agreement of the UNFCCC Conference of the Parties (COP-21) saw important decisions taken by Parties to the Convention (i.e. national governments[209]) with significant commitments and related economic and social benefits to their countries. It came into force in 2016 and has a central aim to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C, which requires decisive and bold action.[210] However, much of the Paris Agreement, and the primary interest of many nations, regions and

207 Sustainable Development Goals Knowledge Platform. 'Sustainable Development Goal 13'. https://sustainabledevelopment.un.org/sdg13. Accessed February 2020.

208 World Meteorological Organization. 'WMO confirms past 4 years were warmest on record'. https://public.wmo.int/en/media/press-release/wmo-confirms-past-4-years-were-warmest-record. Accessed February 2020.

209 UNFCCC. 'List of Parties to the Convention'. https://unfccc.int/process/parties-non-party-stakeholders/parties-convention-and-observer-states. Accessed February 2020.

210 UNFCC. 'The Paris Agreement'. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. Accessed February 2020.

cities, lies in their capacity to adapt to unavoidable change and in how best to define their strategies for doing so.

Climate resilience is the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to the climate. Improving climate resilience involves assessing how climate change will create new, or alter current, climate-related risks, and taking actions to better cope with identified risks.[211]

8.2 Climate resilience challenges

Climate change presents the single biggest threat to development, and its widespread, unprecedented impacts disproportionately burden the poorest and most vulnerable.[212] Climate change is an acute threat to global development and efforts to end poverty. Without urgent action, climate change impacts could push an additional 100 million people into poverty by 2030.[213] By 2050, it could mean that as many as 143 million people across three developing regions will become climate migrants.[214] A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes, and can result in unprecedented extremes—there is evidence from observations gathered since 1950 of change in some extremes.[215]

Enacting climate resilience policies and interventions requires knowledge of both the changes in physical climate and local projections, but also of a range of factors which are less well defined and that cannot be integrated as part of a physical model, for example, socio-economic factors, demography and health statistics. Conversely, governments require appropriate indicators as evidence as to the effects of their climate resilience policies.

8.3 EO's role in climate resilience

To address these challenges, climate information services will require new approaches to define the probabilities of potential outcomes, including social and political factors, dependent on the predicted change in climate conditions. This requires knowledge not only of the likely trend of future physical parameters of climate but also of the behaviours of individuals, society and groups of varying size from cities to nations, involving complex interactions of social, health, economic, political, and other factors.

Here, EO can provide key inputs to understanding the potential relationships between previously un-modelled (and not obvious) dependencies between physical climate change and social outcomes. EO complements existing climate data and helps complete records in data-sparse regions. EO can provide a robust basis for decision making for IFIs, donors and developing countries by providing information about both natural hazards and the exposure of people and assets. Benefits of EO include supporting:

- Measuring the state of the climate through Essential Climate Variables (ECVs),
- Providing indicators for climate change risk assessments,
- Monitoring and building resilience to slow-onset climate change events e.g. sea level rise, and
- Monitoring and building resilience to rapid-onset climate change events (i.e. extreme weather events).

The Global Environment Facility (GEF) have published recommendations to increase the use of EO in their programmes, specifically "*Encouraging the agencies to continue to develop internal capacity to use Earth observation data and technologies throughout the project cycle, and to share Earth observation science and tools to provide opportunities for others to benefit from successes*".[216]

Figure 31 highlights both the role and the impact of using EO data within climate resilience. The following section forefronts how EO data has and is being used to solve the various challenges in climate resilience.

211 Center for Climate and Energy Solutions (C2ES). 'Climate Resilience Portal'. www.c2es.org/content/climate-resilience-overview/. Accessed February 2020.

212 United Nations Statistics Division. 'https://unstats.un.org/sdgs/report/2016/goal-13'. Accessed February 2020.

213 World Bank. 'Climate Change'. www.worldbank.org/en/topic/climatechange. Accessed February 2020.

214 World Bank. 'Climate Change: Overview'. www.worldbank.org/en/topic/climatechange/overview. Accessed February 2020.

215 Intergovernmental Panel on Climate Change (IPCC). 'Changes in Climate Extremes and their Impacts on the Natural Physical Environment'. www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap3_FINAL-1.pdf. Accessed February 2020.

216 Global Environment Facility. Earth Observation and the GEF. A STAP Document'. https://www.thegef.org/sites/default/files/council-meeting-documents/EN_GEF.STAP_.C.57.Inf_.06_Earth%20Observation%20and%20the%20GEF.pdf. Accessed February 2020.

Impact	EO products contribute to the achievement of UN SDG 13 "Climate Action"			
Outcomes	Measuring climate change	Measuring climate risks	Mitigating slow climate events	Mitigating rapid climate events
	Comprehensive, empirical assessment of the climate	Comprehensive, empirical assessment of climate risk for populations and assets	Improved mitigation measures for slow-onset climate change events	Improved resilience, response and recovery from rapid-onset climate change events
Outputs	EO provides Essential Climate Variables to assess the status of the climate	EO provides indicators for climate change risk assessments	EO supports monitoring and mitigating slow-onset climate events	EO supports monitoring and mitigating rapid-onset climate events
Climate resilience challenges	Limited data for monitoring the status of the climate	Limited data for monitoring climate risks	Limited disaster monitoring data	

FIGURE 31: Outcomes and Impacts of EO in Climate Resilience

— *EO measures the state of the climate through Essential Climate Variables*

Given the complexity of the climate system, empirical evidence is needed to understand and predict the evolution of climate. Such evidence is needed to guide mitigation and adaptation measures, to assess risks and enable attribution of climate events to the underlying causes.

The Global Climate Observing System (GCOS) provides vital and continuous support to the United Nations Framework Convention on Climate Change (UNFCCC) in the definition and specification of requirements for observations relevant to climate change.[217] GCOS specifies over 50 Essential Climate Variables (ECV)[218] that are physical, chemical, or biological variables or a group of linked variables that critically contributes to the characterisation of Earth's climate.

EO plays a key role in providing the ECVs and ESA has committed to producing 13 of them through its Climate Change Initiative (CCI) programme. The objective of the CCI programme is *'to realise the full potential of the long-term Earth Observation archives that ESA together with its member States have established over the last 40 years, as a significant contribution to the ECV databases required by the UNFCCC'.*[219] The programme focuses on the variables that it can best cover using ESA satellite data, as per Table 1.

Atmosphere	Aerosols Clouds Ozone Greenhouse Gases (carbon dioxide and methane)
Ocean	Sea Level Sea Surface Temperature Ocean Colour Sea Ice
Land	Land Cover Fire Soil Moisture Ice Sheets (Greenland and Antarctica) Glaciers

TABLE 1: 13 ECVs Produced through the ESA Climate Change Initiative[220]

- The ECVs address public demands for transparency in environmental decision making and have helped many nations to make commitments to support systematic, sustained climate records. The requirement for sustained observation of the climate—identified by the World Climate Research Programme (WCRP) and enabling the work of the Intergovernmental Panel on Climate Change (IPCC) are based on the ECVs.[221]

217 CEOS. 'CEOS EO Handbook—The Important Role of Earth Observations'. www.eohandbook.com/eohb2011/role_global.html. Accessed February 2020.

218 GCOS. 'Essential Climate Variables'. https://gcos.wmo.int/en/essential-climate-variables/table. Accessed February 2020.

219 European Space Agency (ESA). 'climate change initiative'. http://cci.esa.int/objective. Accessed April 2020.

220 European Space Agency (ESA). 'The Essential Climate Variables: What Do We Measure from Space'. http://cci.esa.int/sites/default/files/CCI_factsheetA5_150605_Part2.pdf. Accessed February 2020.

221 Bojinski, Stephan, and others. 'The Concept of Essential Climate Variables in Support of Climate Research, Applications, and Policy'. American Meteorological Society (2014). https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-13-00047.1. Accessed February 2020.

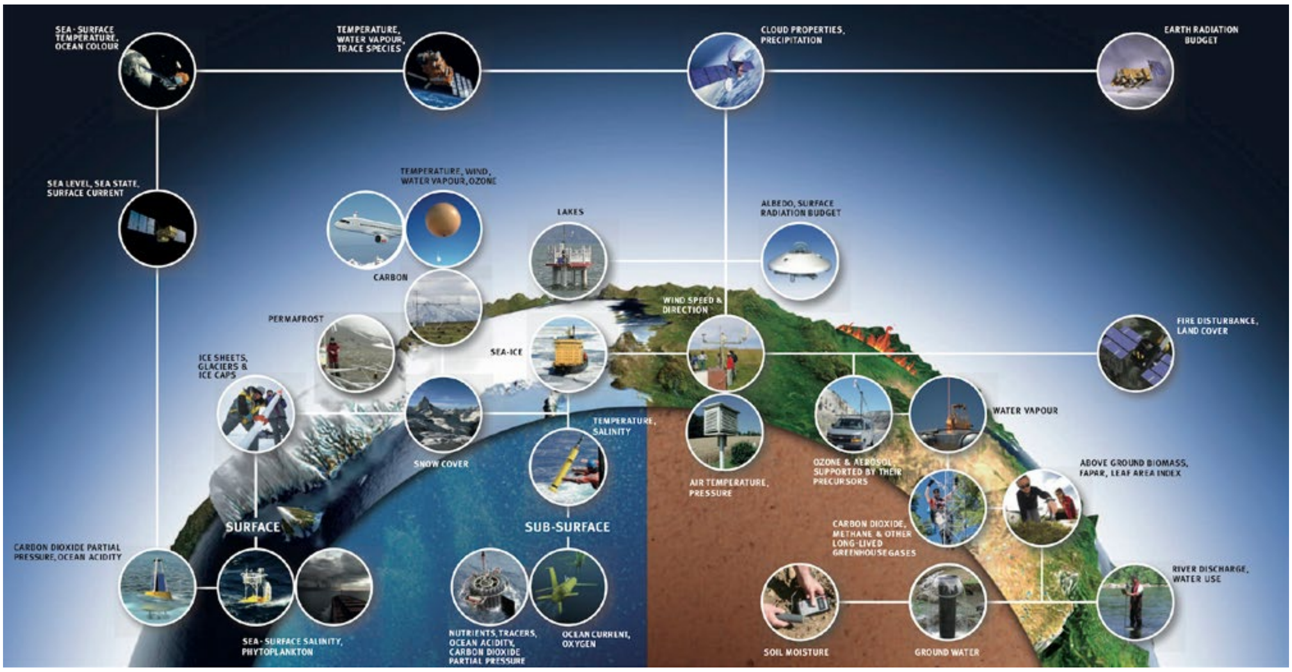


FIGURE 32: Essential Climate Variables (Credit GCOS)[222]

— *EO provides indicators for climate change risk assessments*

The IPCC places a focus for effective climate adaptation on a comprehensive understanding of climate change risk. Its risk concept brings climatic and socioeconomic processes together to capture the relevant dimensions of climate risk management. EO provides large quantities of timely and accurate environmental information, which, when combined with socioeconomic data can give unique insights into managing climate risks. EO data can help governments around the world not only prepare for climate change impacts and natural disasters, but also inform sustainable and climate resilient development planning to account for future climate risks.

- An ESA EO4SD-Climate Resilience project is supporting the African Risk Capacity's Africa RiskView (ARV) which combines EO data with population vulnerability data to provide an early-warning model that measures food insecurity and estimates response costs, enabling decision-makers to plan and respond quickly and efficiently to drought stresses. The project is providing new data to ARV allowing it to incorporate previously unavailable ECVs. This allows the identification and quantification of risk in an objective way, so this early warning tool helps countries to plan appropriate drought response actions and food security investments.[223]
- Also the ESA EO4SD-Climate Resilience project is providing a series of exposure and socioeconomic indicators for climate risk assessments in Bangladesh from EO. These include growing season length variability, number of extremely wet days, and flood extent indicators. The indicators when combined provide the Bangladesh stakeholders with a more comprehensive view of climate risks in a given location e.g. vulnerability of population and assets to flooding.[224]
- The UKSA IPP supported project 'CommonSensing' led by UNITAR's Operational Satellite Applications Programme (UNOSAT) in Fiji, Vanuatu and Solomon Islands, is focused on improving national resilience towards climate change. This is done by using EO to improve climate predictions, coupled with hazard mapping and food security analysis to provide countries capacity to better access climate funds and thus become more resilient to climate change. The project is targeting a 30% increase in financial support for Pacific Small Island Developing States (SIDS) for climate resilience.[225]

222 Global Climate Observing System (GCOS). 'Global Climate Observing System' (poster). http://ceos.org/wp-content/uploads/2015/10/GCOS_poster_FINAL.jpg. Accessed February 2020.

223 ESA. 'EO4SD climate cluster's support further improves Africa's leading drought and food security modelling tool'. http://eo4sd-climate.gmv.com/news/eo4sd-climate-clusters-support-further-improves-africa%E2%80%99s-leading-drought-and-food-security. Accessed February 2020.

224 ESA. 'EOS4D—Earth Observation for Sustainable Development: Climate Resilience Service Portfolio'. http://eo4sd-climate.gmv.com/sites/default/files/eo4sd_cr_service_portfolio.pdf. Accessed February 2020.

225 Personal communication. Einar Bjorgo. UNITAR. September 2018.

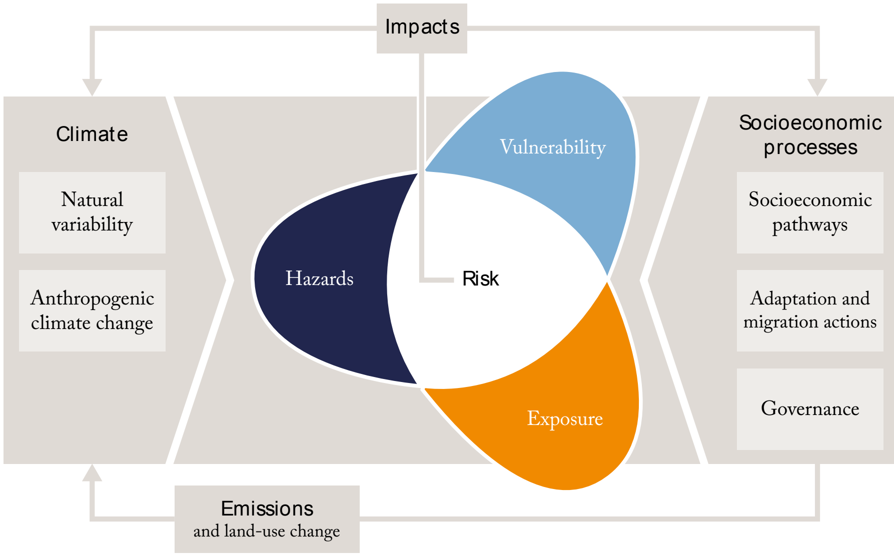


FIGURE 33: IPCC Risk Framework for Climate-related Impacts (Credit: IPCC)[226]

— *EO supports monitoring and improved resilience to slow-onset climate change events*

Climate-related slow-onset events are dangerous but can take decades to manifest—including desertification, glacial retreat, land and forest degradation, loss of biodiversity, ocean acidification, salinisation, increasing temperatures and sea level rise.[227] A 2012 UNFCCC technical paper stated that *"there are synergistic interactions between rapid-onset and slow-onset events that increase the risk of loss and damage"* highlighting the importance of addressing both in order to build climate resilience. EO is well suited to observing slow-onset events as they require a long-term time series of data showing the very subtle changes over time.[228]

EO supports responding to desertification by monitoring the status and change of degraded drylands. Desertification is a type of land degradation in drylands involving loss of biological productivity caused by natural processes or induced by human activities.[229] Such drylands cover 40% of the world's land surface and are the habitat and source of livelihood for more than one billion people.[230] EO data has been integrated into global efforts to monitor, halt and reverse land degradation.

- GEO's Land Degradation Neutrality (LDN) activity is designed to enhance national capacities to undertake quantitative assessments and corresponding mapping of degraded lands. GEO provides EO datasets, country support, capacity building and training, along with EO tools and platforms. The intended impact is the halting and reversing land degradation trends will help deliver multiple SDGs, climate action in terms of enhanced carbon sequestration and reduced emissions, and increased resilience to slow onset disasters.[231]

EO supports the monitoring and communication of glacier retreat. Higher temperatures and less snowfall have been causing many glaciers around the world to retreat recently. Glacial retreat is perhaps the most visible and striking sign that Earth's climate is warming. EO data has been critical in monitoring and showcasing the impact of glacial retreat.

- UK's Centre for Polar Observation and Modelling used EO data to assess Antarctica's glacial retreat. They state that "*as well as being able to routinely monitor the polar ice sheets as a whole, these results show the ability of satellites to pinpoint how individual glaciers are responding to environmental change. The next steps are to refine our calculations of ice loss and sea level rise from the Antarctic ice sheet as a whole, and, in turn, improve our models of what might happen in the future*".[232]

226 IPCC. 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation'. https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf. Accessed February 2020.

227 ESA. 'EOS4D—Earth Observation for Sustainable Development: Climate Resilience Service Portfolio'. http://eo4sd-climate.gmv.com/sites/default/files/eo4sd_cr_service_portfolio.pdf. Accessed February 2020.

228 As above.

229 Wikipedia. 'Desertification'. https://en.wikipedia.org/wiki/Desertification. Accessed February 2020.

230 ESA. 'Tracking desertification with satellites highlighted at UNCCD COP'. https://www.esa.int/Applications/Observing_the_Earth/Tracking_desertification_with_satellites_highlighted_at_UNCCD_COP. Accessed February 2020.

231 Group on Earth Observation (GEO). 'GEO Initiative on Land Degradation Neutrality "GEO LDN Initiative"'. www.earthobservations.org/uploads/event_se/678_ldn_initiative_overview.pdf. Accessed February 2020.

232 ESA. 'Satellites track variations in Antarctica's glacial retreat'. www.esa.int/Applications/Observing_the_Earth/CryoSat/Satellites_track_variations_in_Antarctica_s_glacial_retreat. Accessed February 2020.

EO supports monitoring and minimising biodiversity loss due to climate change. Climate change will have significant impacts on biodiversity. These impacts include effects on ecosystems, on their component species and genetic diversity within species, and on ecological interactions. The implications of these impacts are significant for the long-term stability of the natural world and for the many benefits and services that humans derive from it.[233] Cases in Côte d'Ivoire and South Africa highlight EO data being used to monitor and plan for reversing biodiversity loss.

- In Côte d'Ivoire, a UKSA IPP supported project led by Vivid Economics uses EO to identify areas of forest with the highest levels of biodiversity and carbon stocks. This allows improved land use policy by highlighting regions most suitable for reforestation.[234]
- The South African National Biodiversity Institute (SANBI) uses EO data for tracking biodiversity indicators including terrestrial ecosystem threat status, climate change stability in biomes and biodiversity priority areas. This supports South Africa to monitor and manage the condition of terrestrial ecosystems, rivers, wetlands and estuaries.[235]

EO supports measurement, forecasting and resilience to sea level rise. Global sea levels have risen by about 20 cm since reliable record keeping began in 1880 and are projected to rise an additional 30 to 120 cm by 2100.[236] Coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion due to relative sea level rise.[237]

- The UKSA IPP Coastal Risk Information Service (C-RISe) project led by Satellite Oceanographic Consultants (SatOC), is supporting Mozambique, Madagascar and South Africa for governance and management of coastal hazards via increasing accuracy of coastal sea level measurements. The objective is to use C-RISe derived sea level data in at climate adaption strategies/management plans in each country.[238]
- CoastalDEM improves the accuracy of digital elevation model (DEM) used to assess global and national population exposure to extreme coastal water levels, compared to previous estimates by the NASA Shuttle Radar Topography Mission.[239] Based on the estimates, 190 million people currently occupy global land below projected high tide lines for 2100 – in a low carbon emissions scenario. That is three times more people than indicated by previous models and this increased accuracy will support governments with populated coastlines in climate resilience planning.[240]
- An ESA EO4SD-Climate Resilience project supported WB Monrovia Integrated Development Project (MIDP) in Liberia. Since 2013, sea level rise and coastal erosion has displaced more than 6,500 people and destroyed 800 houses in Monrovia. WB provided several EO products including modelling sea level rise and its impacts on coastal population and coastal shoreline erosion. This supported WB decisions as to where best make investments and identify hotspot areas that need immediate attention.[241]

FIGURE 34: EO4SD-Climate Resilience Showing Flood Risk Analysis in Monrovia (Risk Severity Depicted by Red Colour Gradient) (Credit: ESA EO4SD Climate Resilience)[242]

233 UN Environment Programme. 'Impacts of Climate Change on Biodiversity: A review of the recent scientific literature'. www.unenvironment.org/resources/report/impacts-climate-change-biodiversity-review-recent-scientific-literature. Accessed February 2020.

234 Caribou Space for UK Space Agency. 'Space for Forestry in Developing Countries'. www.spacefordevelopment.org/wp-content/uploads/2018/11/6.4918_UKSA_Forestry-Report_WEB.pdf. Accessed February 2020.

235 Secretariat of the Convention on Biological Diversity. 'Earth Observation for Biodiversity Monitoring'. CBD Technical Series 72. www.cbd.int/doc/publications/cbd-ts-72-en.pdf. Accessed February 2020.

236 NASA. 'The Effects of Climate Change'. https://climate.nasa.gov/effects/. Accessed February 2020.

237 Intergovernmental Panel on Climate Change (IPCC). 'Coastal Systems and Low-Lying Areas'. www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap5_FINAL.pdf. Accessed February 2020.

238 Personal communication. David Cotton. Satellite Oceanographic Consultants. January 2020.

239 Nasa Jet Propulsion Laboratory. 'Shuttle Radar Topography Mission. U.S. Releases Enhanced Shuttle Land Elevation Data'. www2.jpl.nasa.gov/srtm/. Accessed February 2020.

240 Kulp, Scott A., and Benjamin H. Strauss. 'New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding'. Nature Communications. 10 (2019). www.nature.com/articles/s41467-019-12808-z. Accessed February 2020.

241 ESA. 'ESA's EO4SD climate resilience cluster collaborates with World Bank in Liberia'. http://eo4sd-climate.gmv.com/news/esa%E2%80%99s-eo4sd-climate-resilience-cluster-collaborates-world-bank-liberia. Accessed February 2020.

242 Same as above

— *EO supports monitoring and resilience to rapid-onset climate change events*

As opposed to slow-onset events, rapid-onset climate-related events have dramatic and sudden impacts including heatwaves, extreme rainfall, tropical cyclones, droughts, floods, and wildfires. This topic is addressed in the **Impact of EO in disaster resilience** section.

Earth Observation uptake and barriers for donors and IFIs

9. Earth Observation uptake and barriers for donors and IFIs

Key points

- Donors particularly in Europe, have been flagbearers for the adoption of EO in sustainable development.
- In parallel, ESA has supported IFIs adoption of EO since 2010.
- The main barriers to expanding the wider use of EO in sustainable development are referred to as the 'five As':
  - The (1) Availability and (2) Accessibility barriers are currently being addressed by existing European programmes, including the Copernicus space component and the Copernicus Data and Information Access Services (DIAS).
  - The (3) Awareness, (4) Acceptance, and (5) Adoption barriers will be addressed by a new joint initiative between ESA, WB and ADB—Space in Support of International Development Assistance (Space for IDA).

This section highlights how EO is being utilised by donors and IFIs and the remaining barriers for further uptake.

9.1 Uptake by donors and IFIs

Donors particularly in Europe have been flagbearers for the adoption of EO in sustainable development. The **UK Space Agency IPP** funded with £150 million of ODA has 33 projects in 44 countries addressing 10 UN SDGs.[243] In the Netherlands, the Dutch Ministry of Foreign Affairs have commissioned the Netherlands Space Office (NSO) to execute the **G4AW programme**, delivering 23 projects in 14 countries with 120 organisations.[244] The **German donor BMZ** has over 130 projects using EO or related technologies[245] largely focused on environmental protection and water & sanitation. **Germany's GIZ** is the implementing agency for development cooperation/assistance, has 100 projects across all regions, with a concentration in 'forestry and biodiversity' (35%) and 'rural development and agriculture' (18%) and 'climate change' (13%). In late 2017, GIZ signed a cooperation agreement with the German Aerospace Centre (DLR), and also founded the Forum on Earth Observation at GIZ.[246] **AFD in France,** have a number of multi-million euro projects focused on forest/land use and ocean/fishery monitoring and being implemented in Central/West Africa and Asia.[247]

Other European donors are also piloting the use of EO in their programmes. Sweden's SIDA have a handful of projects using EO but seem to have a growing interest in building this capacity within their organisations. Norway also has a limited number of related projects with a focus on using EO in forestry including supporting GFW and also a US$6 million for the FAO's forest monitoring platform, SEPAL.[248] Denmark have funded World Resources Institute

243 Caribou Space for UK Space Agency. 'UK Space Agency International Partnership Programme—Three Year Review'. https://www.spacefordevelopment.org/wp-content/uploads/2019/10/UKSA_IPP_Three_Year_Review_Final_web.pdf. Accessed February 2020.

244 Geodata for Agriculture and Water (G4AW). 'Space for Food Security'. https://g4aw.spaceoffice.nl/files/files/G4AW/Threefold%20leaflet%20G4AW%20July%202018%20LR.pdf. Accessed February 2020.

245 Identified from BMZ's reporting to OECD DAC Creditor Reporting System, including remote sensing, GIS, satellite, geospatial, and Earth Observation.

246 GIZ. 'DLR and GIZ sign a cooperation agreement'. www.giz.de/en/press/60498.html. Accessed February 2020.

247 AFD. 'Current experiences in the use of satellite information in Development Aid activities'. http://eo4sd.esa.int/files/2018/01/AFD-presentation-at-ESA-Esrin-16-01-2018.pdf. Accessed February 2020.

248 Food and Agriculture Organization of the United Nations (FAO). 'Norway and FAO will scale up innovative forest monitoring tool'. www.fao.org/news/story/en/item/1142131/icode/. Accessed February 2020.

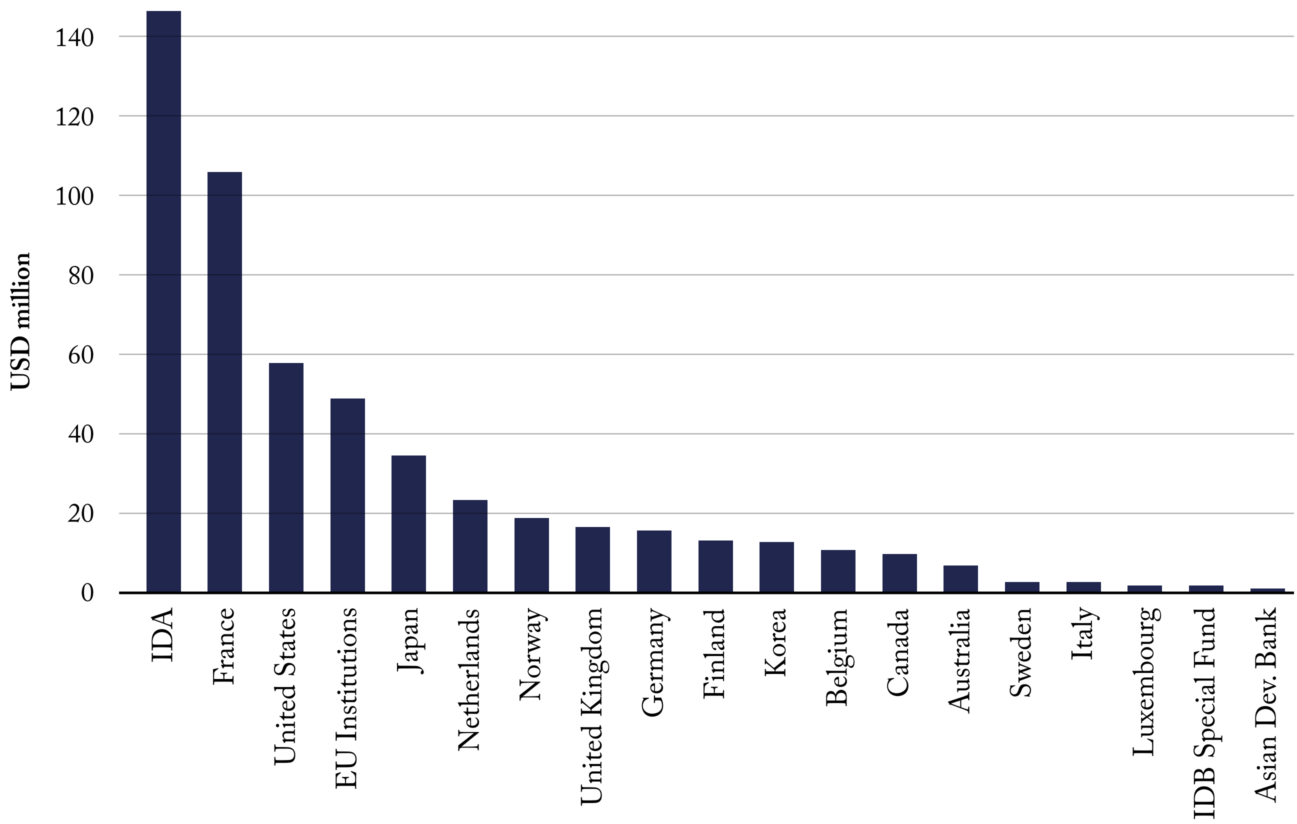


FIGURE 35: Disbursements for Space-related Official Development Assistance by Donor, 2002-16 (Credit: OECD)[249]

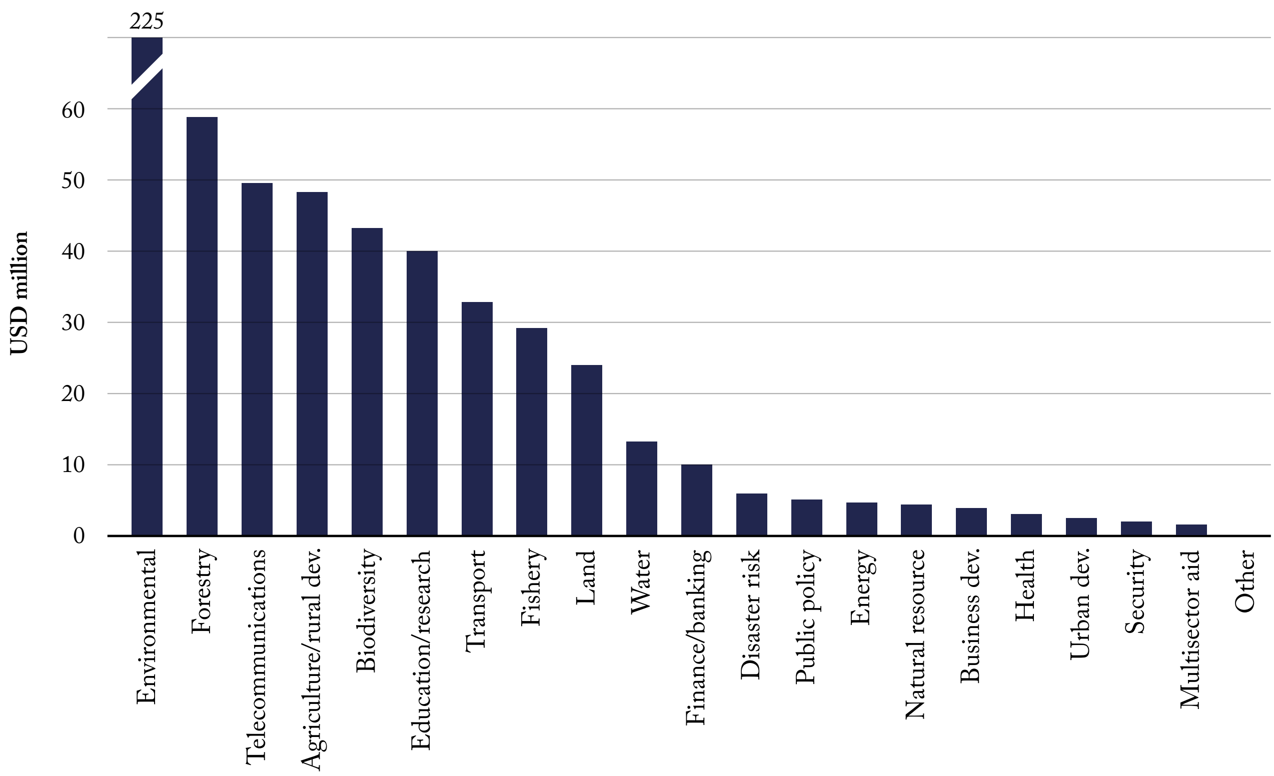


FIGURE 36: Space-related Official Development Assistance Commitments by Project Purpose, 2000-16 (Credit: OECD)[250]

249 OECD. 'The Space Economy in Figures: How Space Contributes to the Global Economy. Chapter 2. The socio-economic impacts of space investments'. 2019. www.oecd-ilibrary.org/sites/c5996201-en/1/2/2/index.html?itemId=/content/publication/c5996201-en&_csp_=ffe5a6bbc1382ae4f0ead9dd2da73ff4&itemIGO=oecd&itemContentType=book. Accessed February 2020.

250 As above.

(WRI) to develop Resource Watch which includes EO and domain specific data layers with the Planet Pulse application.[251]

Outside of Europe, SERVIR is a joint venture between NASA and USAID to provide state-of-the-art EO data, geospatial information and tools to help national, regional and local governments, forecasters and scientists to track environmental changes, evaluate ecological threats and rapidly respond to natural disasters.[252] 50 countries are directly served by SERVIR's 42 products, applications or trainings, with 6600 people in 390 institutions trained on these tools.[253]

France and United States are the donors with highest levels of space-related ODA—as per Figure 35 (N.B. IDA is the part of the World Bank that helps the world's poorest countries). However, the 2002-2016 data source will not account for the more recent donor investments such as UK Space Agency IPP. The dominant sectors are environmental management (US$225 million) followed by forestry (~US$58 million)—as per Figure 36.

ESA has supported IFIs adoption of EO since 2010 via the Directorate of Earth Observation Programmes (EOP). From 2010 to 2016 with a programme called eoworld and from 2016 with Earth Observation for Sustainable Development (EO4SD).[254] EO4SD's objective is to start the integration of satellite information products & services, as 'best-practice' environmental information, in the planning and implementation of the development projects, programmes and activities of the IFIs, together with their respective developing country partners. EO4SD has activities with WB, ADB, EIB, IADB, IFAD and GEF.

IFIs adoption of EO is growing steadily. The WB in particular, have been increasing their use of EO as represented in Figure 37 showing the cumulative number of project procurements with specific budget for satellite imagery & services. This trend indicates the increasing interest of IFIs in the value of EO for development assistance.

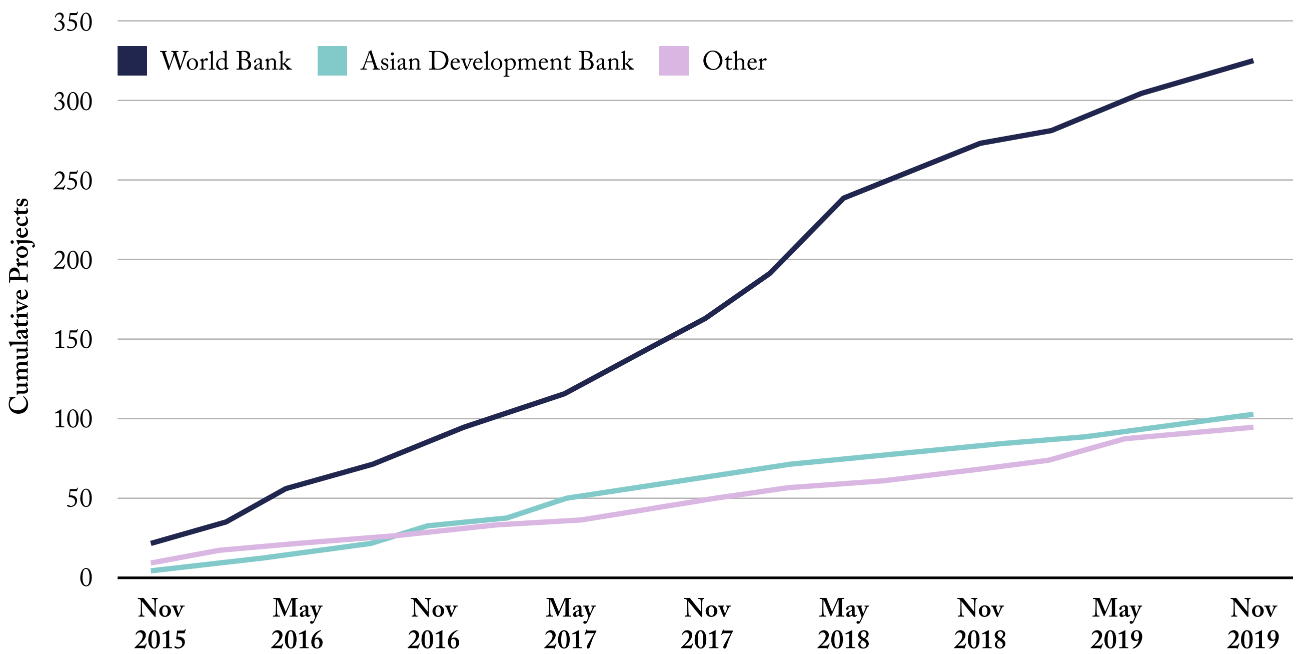


FIGURE 37: Cumulative number of IFI Projects from November 2015 to December 2019 with Specific Financial Amounts for Satellite Imagery & Services[255]

251 Resource Watch. 'Resource Watch Partner'. https://resourcewatch.org/about/partners/3. Accessed February 2020.

252 SERVIR GLOBAL. 'SERVIR connects space to village…'. www.servirglobal.net/. Accessed February 2020.

253 SERVIR. 'SERVIR' (poster). www.servirglobal.net/Portals/0/Images/multimedia-images/infographics/dowloads/G-466717_SERVIRByTheNumbers_9x20_2018.pdf. Accessed February 2020.

254 ESA. 'Earth Observation for Sustainable Development'. http://eo4sd.esa.int/. Accessed February 2020.

255 Caribou Space analysis of data from ABD International Ltd. February 2020.

In addition to this project-based information, it is also worth noting that there is an increasing focus on developing internal capacity at the IFIs. For example, WB has established the Geospatial Operations Support Team to advise how geospatial data can help solve specific problems, purchasing support for data and EO imagery, and direct technical assistance for internal stakeholders, to help make the WB a sophisticated consumer of geospatial analytics.[256] Also, there are a number of strategic planning and policy technical reports in which satellite technology is now being referred to. A few recent examples include:

- World Bank—The Changing Wealth of Nations 2018: Building a Sustainable Future (January 2018),[257]
- Asian Development Bank—Strategy 2030 (July 2018),[258]
- Asian Development Bank—Work Program & Budget Framework, 2018-2020 (Dec 2017),[259]
- Earth Observation and the Global Environment Facility.[260]

9.2 Barriers to uptake

The main barriers to expanding the wider use of EO in sustainable development are referred to as the 'five A's':

1. ***Availability:*** **a lack of EO at sufficient temporal, spatial and spectral resolution, and at appropriate cost, to address challenges in developing countries.**
2. ***Accessibility:*** **complexity of accessing, storing and manipulating EO for non-experts, due to the technical skills and computing infrastructure required.**

The Availability and Accessibility barriers are currently being addressed by existing European programmes, including the Copernicus space component, and the Copernicus Data and Information Access Services (DIAS).

3. ***Awareness:*** **a lack of understanding of *what* types of EO can be produced and what are the benefits of its use.**
4. ***Acceptance:*** **a lack of experience of *how* to use this source of information and a 'champion' to promote its use.**
5. ***Adoption:*** **a lack of the capabilities existing locally in the developing countries to *produce & deliver* these types of information operationally from EO, and support users in its uptake.**

The Awareness, Acceptance, and Adoption barriers are recommended to be addressed through a new dedicated joint initiative between ESA, WB and ADB—Space in Support of International Development Assistance (Space for IDA).

256 World Bank. 'Geospatial Operations Support Team at the World Bank'. www.worldbank.org/en/research/brief/geospatial-operations-support-team-at-the-world-bank. Accessed February 2020.

257 World Bank. 'The Changing Wealth of Nations 2018: Building a Sustainable Future'. https://openknowledge.worldbank.org/handle/10986/29001. Accessed February 2020.

258 Asian Development Bank (ADB). 'Strategy 2030'. www.adb.org/sites/default/files/institutional-document/435391/strategy-2030-main-document.pdf. Accessed February 2020.

259 Asian Development Bank (ADB). 'Work Program and Budget Framework, 2018–2020'. www.adb.org/documents/work-program-and-budget-framework-2018-2020. Accessed February 2020.

260 Global Environment Facility. Earth Observation and the GEF. A STAP Document'. https://www.thegef.org/sites/default/files/council-meeting-documents/EN_GEF.STAP_.C.57.Inf_.06_Earth%20Observation%20and%20the%20GEF.pdf. Accessed February 2020.

"The main bottleneck is going to be within the [IFI] *institution, within our teams, as there are maybe two or three people within each team that have a level of know how to pick up on what you* [ESA EO4SD-Urban project] *are offering."*

Niels Holm-Nielse, Global Lead Resilience and Disaster Risk Management, World Bank[261]

"I think a main barrier is the translation from what is desired to do by an Earth Observation specialist to what is actually necessary in sustainable development. There is a need to translate in simple enough terms for people who are not well versed in the Earth Observation itself. You don't have to be car mechanic to drive a car".

Pieter Waalewijn, Global Lead Water in Agriculture, WB[262]

"There is a lack of knowledge of what's out there [regarding EO]. *I mean, we shouldn't assume that people* [in partner developing countries] *know, right? And even if they know it all and are happy, they're still a bit conservative – how are we going to access this data? Can we get it? Do we have to pay for it upfront? Can we do some trials of this data?"*

Erick Fernandes, Global Lead Technology, Innovation & Climate Smart Agriculture, WB[263]

"To be fully adopted at the operational level [in IFIs and developing countries], *we need to remove the scepticism behind how can we trust this data? We need to change the mindset of how this data can be used. For instance, in some sectors/applications not to replace existing data, but to complement it".*

"Also, often the processing and analysis for certain applications requires a certain level of technical expertise to use these [EO] *products. Sometimes these can get very complex and there can be a sense of scepticism of them being a black box. The clients* [in developing countries] *want to understand how the processes work underneath to be able to appropriate the use of* [EO] *products; to continue to upgrade and expand them".*

Andrea Juarez-Lucas, Water Resources Management Specialist, The World Bank

261 ESA and World Bank workshop. Jan 21st 2020.

262 Caribou Space interview with Pieter Waalewijn on 23rd January 2020

263 Caribou Space interview with Erick Fernandes on 23rd January 2020

Recommendations

10. Recommendation one: Close impact evidence gaps with robust monitoring & evaluation

Key points

- Across multiple sectors and within various EO use cases, encouraging and positive evidence on benefits of EO within sustainable development have been highlighted.
- Some sectors have a longer history with using EO and therefore have more mature evidence bases. However, this is use case specific.
- New use cases for EO are emerging more quickly than the publication of corresponding impact evaluations. Both time and commitment of resources are needed for measuring the impact of EO.
- In programmes that are integrating EO as a core data source, a robust M&E system that both articulates and can evaluate the impact of EO within the sustainable development sector should be established at the start of the programme.
- Impact evaluations should communicate and quantify the benefits of EO—using language and statistics that the development community are familiar with.
- It is recommended that impact evidence be widely shared so that others can benefit from these lessons and results.

Through the review of more than 200 sources of public domain literature a clearer understanding of the abundance of impact evidence for the EO use cases is forming – as summarised in Figure 38.[264]

KEY: Nascent evidence base · Emerging evidence base · Maturing evidence base

Agriculture	Accurate agricultural decision support tools	Accuracy of flood and drought warning systems	Affordable credit and insurance	Sustainable management of environmental resources	Optimising supply chains
Climate resilience	Status and change of the Earth's climate	Monitoring and resilience to slow-onset climate events	Monitoring and resilience to rapid-onset climate events	Indicators for climate change risk assessments	
Forestry	Monitoring of deforestation and forest degradation	Resilience to forests fires and floods	Precision forestry	Supporting local forest populations	
Urban	Hazard assessment, early warning and response	Urban planning and monitoring	Transport planning and monitoring	Monitoring of environmental issues	
Disaster resilience	Accuracy and extent of disaster early warning systems	Monitoring and assessments disaster response	Resilience via insurance		

FIGURE 38: Qualitative Review of Impact Evidence in Developing Countries by Use Case and Sector

264 Caribou Space. February 2020. There are sub-use cases within each main use case, thus this is intended to be illustrative and based on the qualitative review of the evidence. Note that this report does not feature all the literature highlighting any given impact.

EO has proven benefits across sectors and within sector use cases. As showcased in this report, there is encouraging and positive evidence of the value of EO in agriculture, forestry, disaster resilience, urban development, and climate resilience in developing countries.

New use cases for EO are emerging more quickly than the publication of corresponding impact evaluations. Some sectors, such as disaster resilience, have been using EO for a longer period and thus have a more mature evidence base. However, this is dependent on the specific use cases, such as the use of EO in agricultural supply chain optimisation and transport planning that are being implemented but are yet un-evaluated. Measuring the impact of EO-based services is a matter of both time and commitment of resources.

More investment in impact measurement is required to close the evidence gaps and keep pace with emerging use cases. In both EO demonstration projects and in programmes that are integrating EO as a core data source or service, a robust M&E system should be established. This is essential if the impact of EO is to be measured and the learnings communicated. The M&E system should be tailored to the specific needs, set-up, and goals of the demonstration project or programme and be sufficiently resourced.

An M&E system should contain the following as minimum:

- Clearly articulate the impact that is expected from the use of EO data using the Theory of Change approach.
- Establish robust indicators to both monitor progress towards impact and evaluate the final impact.
- Develop clear guidance on methodologies to collect and report on the indicators.
- Establish a clear baseline on the status prior to the intervention to assess impact post intervention.
- Measure the anticipated impact *after* the use of EO.
- Be set up to measure long term impact. If, for example, a city did implement tailored flood mitigation plans, it would be beneficial to understand the follow-on long-term impact on the city inhabitants.

Impact evaluations should communicate and quantify the benefits of EO—using language and social and economic statistics that the development community are familiar with. Equally, when communicating with the development community members of the EO community should ensure their language is understandable for non-experts.

Document and share findings on the impact of EO. The sustainable development community advances its effectiveness through the sharing of knowledge. It is recommended that impact evidence should be widely shared so that others can benefit from any lessons and so that the impact evidence of EO in sustainable development can continue to grow.

The evidence base within this report is a move toward a consolidation of the understanding of the variety of impacts of EO within sustainable development.

11. Recommendation two: Need for the Space for IDA initiative to transfer and mainstream EO into development assistance

Key points

- The primary objective of Space for IDA will be to "*Realise the full potential impact of environmental information from satellites in addressing core development challenges through transfer and mainstreaming into development assistance operations, activities and financing*". The initiative will have three activities designed directly to address the barriers identified above:
  - **Activity 1: Knowledge Development (ESA-led)**: Co-develop demonstration materials and do risk-reduction technical developments for less well-established EO product types.
  - **Activity 2: Capacity Building (IFI-led)**: For IFIs, donors, private foundations, and developing countries in the use of EO in operations; co-design and develop methodologies and guidelines.
  - **Activity 3: Skills/Knowledge Transfer (IFI-led)**: Expertise and capability transfer programme for EO production and analytics in developing countries.
- The initiative will be implemented in a joint, coordinated programme of work between ESA and newly established Trust Funds at WB and ADB.
- The estimated budget will be between US$80-100 million for the WB and ADB led components.
- 13 ESA member states have provided initial financial commitments of €30 million and the objective to initiate implementation from 2020 to 2025.

This report has highlighted that across sectors and within various EO use cases, encouraging and positive evidence on benefits of EO within sustainable development exists. ESA's Space for IDA programme will complement the existing national programmes using space within sustainable development. It will bring together a broad group of donors from across Europe to partner with the WB and ADB to ensure developing countries benefit from the transfer and mainstreaming of EO in development assistance.

11.1 Vision and activities

Overcoming the remaining barriers (Awareness, Acceptance & Adoption), will require a sustained effort and resources through a joint initiative between ESA, WB and ADB—'Space in Support of International Development Assistance (Space for IDA)'. The main objective will be to:

> *"Realise the full potential impact of environmental information from satellites in addressing core development challenges through transfer and mainstreaming into development assistance operations, activities and financing"*

Here, 'mainstream' is to be understood as the systematic use of EO as best-practice source of environmental information, planned and provisioned in the financial resources and operational working practices for all phases and activities of all development assistance projects & activities.[265] This

265 Including long-term planning via Systematic Country Diagnostic & Country Partnership Framework (CPF) and project identification, preparation, appraisal, negotiation, implementation, completion, and evaluation phases.

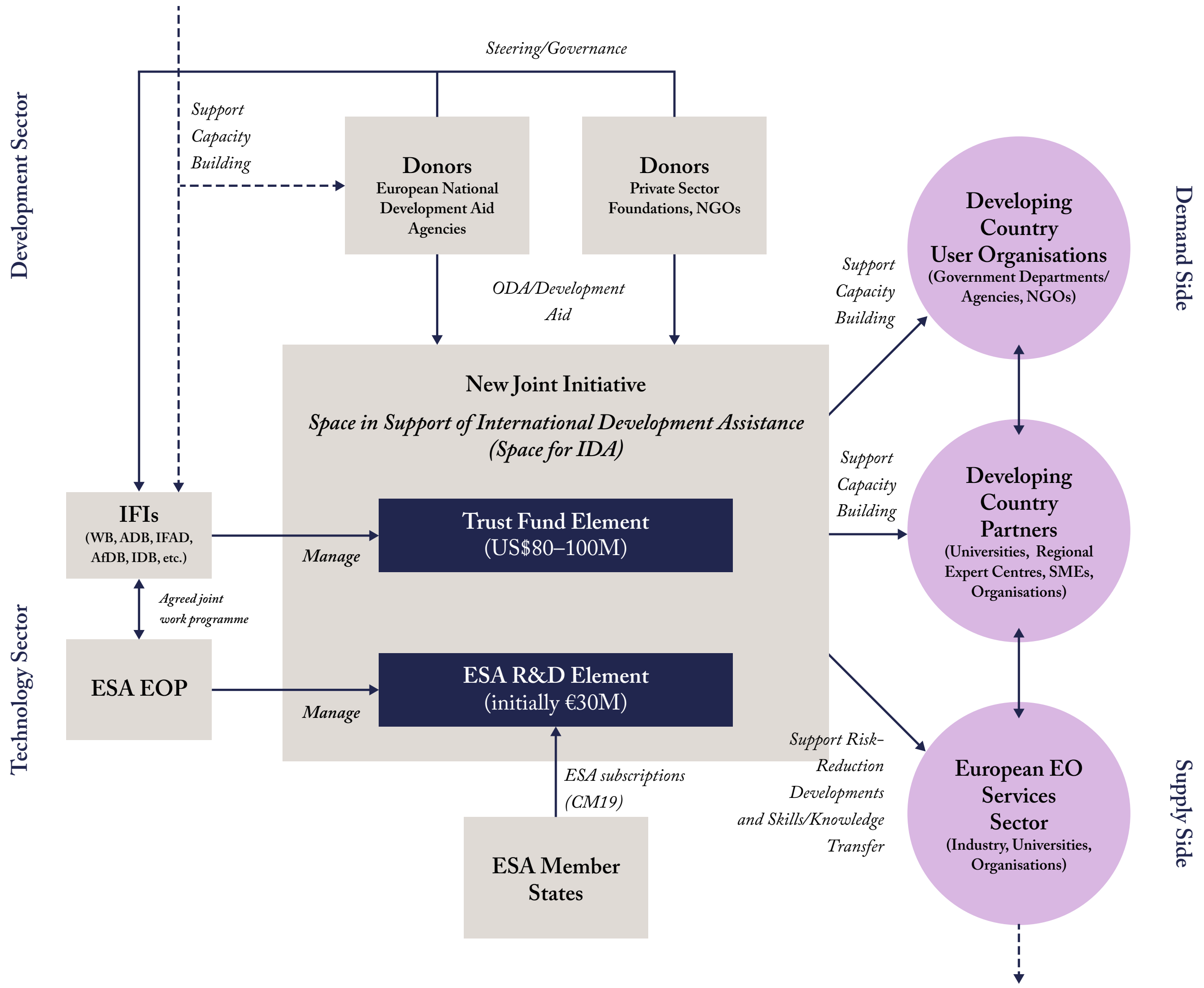


FIGURE 39: Overall Schema for Space in Support of International Development Assistance (Credit: ESA & Caribou Space)

is an ambitious and far-reaching vision as it will require change (for improvement) and evolution in all aspects of the functioning of development assistance (e.g., technical assistance, loan operations, policy formulation, planning, and analysis).

Adopting a new technology and way of working will require time and dedicated effort, and it is for this reason that a specific program of work is proposed for the timeframe 2020-25. This new initiative is designed from the outset to achieve sustainable transfer and systematic use of EO and should be implemented in partnership with the development assistance stakeholders.

The three primary activities that are directly addressing the three remaining barriers to the uptake of EO in sustainable development (as stated above) are:

- Activity 1: Knowledge Development (ESA led): Co-develop demonstration materials and do risk-reduction developments for higher risk, less well-established EO product types,
- Activity 2: Capacity Building (IFI led): for IFIs, donors, private foundations and developing countries in the use of EO in operations; co-design and development of methodologies and guidelines,
- Activity 3: Skills/Knowledge Transfer (IFI led): Expertise and capability transfer programme for EO production & analytics in developing countries.

11.2 Initiative structure

The initiative will be implemented in a joint, coordinated programme of work between ESA and newly established WB and ADB Trust Funds.

Activity 1 (Knowledge Development) is more in line with the normal technical R&D actions undertaken by ESA and is therefore to be financed through conventional space funding sources – with initial committed resources of €30 million.

Activity 2 (Capacity Building) and Activity 3 (Skills/ Knowledge Transfer) are associated with the bulk of the work to be carried out financial resources (estimated > 70% of resources). Both of these are typically the types of activities associated with growth and development and therefore are to be financed through Official Development Assistance (ODA) sources. This would be via the WB and ADB Trust Funds, with a proposed target budget of US$80-100 million. In addition, it is expected that these two activities are largely both IFI-executed and recipient-executed.

11.3 Initiative timeline

The initial strategy and design for the initiative was published in September 2018 in a co-authored ESA & Caribou Space report called 'Satellite Environmental Information and Development Assistance: An Analysis of Longer Term-Prospects'.[266]

A multi-stakeholder workshop in Frascati, Rome (September 2018) allowed the European space agencies, donors and IFIs to provide feedback and input. During 2019 further activities included a Caribou Space led evaluation of the existing EO4SD programme to identify key lessons.[267] Also in 2019 were bilateral meetings between ESA and the European space agencies and donors to solicit support. In November 2019, 13 ESA member states have given their backing via financial commitments and the objective is to initiate implementation from 2020 to 2025. In parallel, the WB and ADB have initiated the setup of their respective Trust Funds.

Further multi-stakeholder workshops and knowledge events are being considered during 2020 to raise awareness of this new initiative, but the unprecedented effects of COVID-19 are having a major impact on these plans. In addition, the pandemic is having an enormous impact on ODA financing (for both donor countries and IFIs), where major re-planning is now in progress to deal with the economic response efforts. Given this, both WB and ADB are investigating (in addition to the Trust Funds) the use of existing ODA financing sources as a first route to get the "Space for IDA" joint initiative started during 2020.

266 As above.

267 Caribou Space. 'Evaluation of the Earth Observation for Sustainable Development'. www.spacefordevelopment.org/library/evaluation-of-earth-observation-for-sustainable-development/. Accessed February 2020.

11.4 Longer term evolution of the Space for IDA initiative

The long-term goal (and an exit condition for continued ESA involvement) is that ODA financing is used for the procurement of satellite-derived environmental information from the EO services sector systematically in development assistance activities (planning programmes, implementation and monitoring & evaluation).

This could occur either via the loan operations of the IFIs, and/or the operational bi-lateral initiatives of the European (national) Aid Agencies/Ministries, and/or (as is the case for Copernicus Services) via a dedicated initiative of the EU as a 'Public Good' investment available to the development assistance community to improve development operations (e.g. a combination of DG-DEFIS and DG-DEVCO financing). These different possibilities will proceed on different timescales.

The IFIs and National Agencies/Ministries are already showing interest and using initial levels of financing now, which could be increased in the short-term (i.e. over the next few years).

A new EU initiative is likely to be a long-term (i.e. at least decadal) undertaking. But this is indeed a highly opportune time for such a discussion to take place. In the broader picture, the EU and its Member States have recently (October 2019) commissioned an independent report by the High-Level Group of Wise Persons on the future of the European financial architecture for development. Both climate change and engagement in Africa are key issues to be addressed in the longer-term, together with tackling the overlaps, gaps and inefficiencies (sectorial and geographical) that arise from the multiplicity of actors at EU and national levels in the complex European development finance architecture (see **https://www.consilium.europa.eu/media/40967/efad-report_final.pdf**).

This report concludes that the new European institutional cycle and the current multi-annual financial framework (MFF) negotiations present a significant window of opportunity. It is a matter of political urgency for Europe to be able to ensure that external financial instruments for development are used strategically and that they contribute the wider political aims; to enhance Europe's leadership and reinforce its influence in the world.

However, there is a strong recognition that public finance alone will not be able to allow low and lower/middle income economies to achieve the UN SDGs by 2030 (for which an estimated additional US$2.5 trillion per year are now needed). Any solution to this problem thus depends on the mobilisation of additional private capital. EU institutions and the Member States agree that, in order to incentivise private capital to venture into high-risk environments, existing blending mechanisms and EU guarantees need to be scaled up.

Annexes

Annex A: Glossary

Committee on Earth Observation Satellites (CEOS): CEOS ensures international coordination of civil, space-based Earth Observation programs and promotes exchange of data to optimise societal benefit and inform decision making for securing a prosperous and sustainable future for humankind.

Copernicus: The European Union's Earth Observation programme, looking at our planet and its environment for the ultimate benefit of all European citizens. It offers information services based on satellite Earth Observation and in situ (non-space) data. The programme is coordinated and managed by the European Commission. It is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies, and Mercator Océan.[1]

Cost-effectiveness Analysis (CEA): A 'value-for-money' analysis. It compares the relative cost of achieving the same impact using alternative approaches and can be used to assess whether a given solution is the least costly method.

Development Assistance Community: Those stakeholders involved in the provision of development assistance, including IFIs, donors, and private foundations.

Earth Observation (EO): The gathering of information about the physical, chemical, and biological systems of the planet via remote-sensing technologies. EO is used to monitor and assess the status of, and changes, in natural and built environments.

Earth Observation for Sustainable Development (EO4SD): An ESA initiative to support the uptake of EO-derived information in sustainable development.

Essential Climate Variables (ECV): Physical, chemical, or biological variables or a group of linked variables that critically contributes to the characterisation of Earth's climate.

European Space Agency (ESA): An intergovernmental organisation of 22-member states whose mission is to *"shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world"*.

Geodata for Agriculture and Water (G4AW): A programme that improves food security in developing countries by using satellite data. Netherlands Space Office (NSO) is executing this programme, commissioned by the Dutch Ministry of Foreign Affairs.

Global Climate Observing System (GCOS): A co-sponsored programme which regularly assesses the status of global climate observations and produces guidance for its improvement.

1 Copernicus. 'What is Copernicus'. www.copernicus.eu/en/about-copernicus. Accessed February 2020.

Global Navigation Satellite System (GNSS): A constellation of satellites providing signals from space that transmit positioning and timing data to ground receivers. The receivers then use this data to determine location.

Group on Earth Observations (GEO): An intergovernmental organisation working to improve the availability, access, and use of Earth observations for the benefit of society.

Interferometric Synthetic Aperture Radar (InSAR): A method that uses two or more synthetic aperture radar (SAR) images to generate maps of surface deformation or digital elevation, using differences in the phase of the waves returning to the satellite.

International Financial Institutions (IFIs): Institutions created by a group of countries that provide financing and professional advising for the purpose of development. Examples include World Bank, Asian Development Bank, and International Fund for Agricultural Development.

International Partnership Programme (IPP): A UK Space Agency programme that uses the UK space sector's research and innovation strengths to deliver a sustainable, economic or societal benefit to undeveloped nations and developing economies.

Landsat: Landsat is an Earth Observation programme led by United States Geological Survey (USGS) and NASA.

Monitoring & Evaluation (M&E): An objective process of understanding how a project was implemented, what effects it had, for whom, how, and why.

Normalised Difference Vegetation Index (NDVI): A simple graphical indicator that can be used to analyse remote sensing measurements, often from a satellite, assessing whether or not the target being observed contains live green vegetation.

Official Development Assistance (ODA): Government aid designed to promote the economic development and welfare of developing countries.

Organisation for Economic Co-operation and Development (OECD): An intergovernmental economic organisation with 37-member countries, founded in 1961 to stimulate economic progress and world trade.

Private Foundation: Philanthropic organisations providing funding in international development including Bill and Melinda Gates Foundation, Mastercard Foundation, Rockefeller Foundation, and Omidyar Network.

Reducing Emissions from Deforestation and Forest Degradation (REDD+): The international framework, negotiated under the UNFCCC in 2005, with the objective of mitigating climate change by reducing net emissions of greenhouse gases through enhanced forest management in developing countries.

Satellite Communications (SatComms): Artificial satellites that relay signals from an earth station and then retransmit the signal to other earth stations.
Sentinel: Family of Earth Observation satellites for the operational needs of the Copernicus programme.

SERVIR: A joint venture between NASA and USAID to provide state-of-the-art, EO data and tools to help improve environmental decision-making among developing nations.

Stakeholders: This refers to the body of users closely involved in the planning and implementation of international development activities.

Synthetic Aperture Radar (SAR): A form of radar that is used to create two-dimensional images or three-dimensional reconstructions of objects, such as landscapes.

United Nations Framework Convention on Climate Change (UNFCCC): An international environmental treaty adopted in 1992.

United Nations Sustainable Development Goals (UN SDG): 17 Global Goals adopted by the world leaders and ratified by the UN General Assembly in 2015.

Unmanned Aerial Vehicle (UAV): Commonly known as a drone, an aircraft without a human pilot aboard.

Zero Deforestation (ZD): Commitments made by global commodities companies to cut deforestation from their supply chains.

Annex B: Literature review limitations

The limitations in the methodology of the literature review used in this report are:

- **Scope**: It should be noted that this was a rapid review and thus cannot claim to have captured the field of knowledge on the impact of EO in sustainable development comprehensively. However, over 200 publications—research reports, academic literature, blogs, and product websites—were reviewed.
- **Isolating the impact of EO**: The use of EO is just one of many sources of information used in sustainable development. Additional information beyond EO is typically integrated into various models and maps, making it difficult to isolate the precise effects of the use of EO. Impact studies, when conducted, are rarely engineered to provide detail of whether, or to what degree, the EO component contributed to an identified impact.
- **Geography**: Evidence on EO use cases and impact were prioritised for developing countries. However, in some areas limited information was located and thus some examples from developed countries were used.

Caribou Space supports organisations to bridge the space and sustainable development worlds by working with governments, space agencies, development agencies, and private sector space companies. Caribou Space provides:

- **Official Development Assistance (ODA) fund and programme strategy**: Strategic recommendations for the design and delivery of ODA programmes.
- **Fund management**: Large scale ODA funds (£100 million plus), and seed stage funds (£4 million plus).
- **Monitoring and Evaluation (M&E)**: Design of M&E systems, delivery of process and impact evaluations, and M&E training.
- **Research, communications, and knowledge sharing**: Conducting research on market opportunities, user needs, use cases, and impact of space solutions, and publicly sharing knowledge of what works, doesn't work, and why. Using diverse communications channels including press and media, publications, social media, conferences and workshops.
- **Programme management**: Delivery of complex, multi-country, multi-million-pound programmes in developing countries.
- **Product strategy**: Supporting strategy for the sustainability and commercialisation of space solutions for developing countries.
- **Economic evaluation**: Quantification of the economic case and impacts of space technology.

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