→ SATELLITE EARTH OBSERVATIONS IN SUPPORT OF THE SUSTAINABLE DEVELOPMENT GOALS

Special 2018 Edition

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UN-GGIM Foreword

The integration of statistics, geospatial information, Earth observations, and other sources of Big Data, combined with new emerging technologies, analytics and processes, are becoming a fundamental requirement for countries to measure and monitor local to global sustainable development policies and programs. Today a large proportion of the global community have an entirely different set of Earth observations and geospatial information uses, needs and expectations than they did 10 years ago. But more is needed.

Adopted by the United Nations General Assembly in September 2015, the broad and transformative nature of the 2030 Agenda for Sustainable Development has ushered in a new era in thinking about global development. With 17 Sustainable Development Goals (SDGs), 169 targets and a global indicator framework, presently consisting of 232 indicators, the 2030 Agenda requires us to consider new and innovative means to curtail the many development challenges in order to 'leave no one behind', and with commensurate new and innovative data sources and methods. As the implementation of the 2030 Agenda gains momentum, Member States and the global community are now also beginning to understand the commensurate prospects for using Earth observations and geospatial information as fundamental inputs for realizing the 2030 Agenda.

The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) is advancing new approaches to data by implementing a global policy framework that will enable countries to better integrate geospatial and other key information into global development policies and into their own national plans. Established in 2011, UN-GGIM sets directions for the production and use of geospatial information within national and global policy frameworks, and for building and strengthening geospatial information capacity of nations, especially of developing countries. Through partnerships within the UN system and with organizations such as the World Bank, the Group on Earth Observations (GEO), the Committee on Earth Observations Satellites (CEOS), and other global actors, our combined ability to contribute towards an interconnected data ecosystem that will allow Member States to properly plan for and implement the SDGs, will be realized.

CEOS has a long and well recognized history for producing publications that promote the importance of satellite Earth observations in support of society's challenges. This latest Handbook continues that rich and valuable journey, and focusing on the contribution of satellite Earth observations in support of the Sustainable Development Goals, their targets and global indicator framework. The Handbook provides us with valuable global sustainable development and Earth observations context and guidance, and then captures the different dimensions and perspectives on the role and importance of Earth observations data, including specific examples, for supporting the implementation of the SDGs. Importantly, the Handbook recognizes and informs National Statistical Offices and the broader statistical community as to how geospatial information, Earth observations and other new data sources can reliably and consistently contribute to the 2030 Agenda for Sustainable Development.

The ways in which the aspirations of the 2030 Agenda have been embraced by the global community has been quite phenomenal and has generated great expectations for us to make real development progress. This Handbook is a significant and strategic contribution towards guiding the way in which countries collectively manage and transform the social, economic and environmental dimensions of people and the planet through to at least 2030.

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CEOS Message

The Committee on Earth Observation Satellites (CEOS) – established under the aegis of the G7 Economic Summit of Industrial Nations in 1984 – ensures international coordination of the civil Earth-observing programmes of more than 30 of the world's leading space agencies. These agencies are collectively investing billions of dollars in space infrastructure with the capability to provide precise, continuous and sustained observations of the entire planet. Recognising that no single country can satisfy all of the observational requirements necessary for monitoring of the Earth system, governments are taking steps through CEOS to harmonise and integrate their observing network.

The 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) represent a milestone in our progress towards a sustainable society, being the first data-driven international framework for development policies. The 2030 Agenda seeks to serve all countries, and effective reporting over the next 15 years will require significant effort in the utilisation of supporting data. In combination with the traditional statistical, socio-economic data used by countries, geospatial information and Earth observations, with modern data processing and big data analytics, offer unprecedented opportunities to make a quantum leap in the capacities of countries to efficiently track all facets of sustainable development and to make viable the prospect of a global indicator framework for the SDGs.

This report has been compiled to help develop a broader understanding of the fundamental, strategic importance of satellite Earth observation data to the 2030 Agenda. Satellites have a role to play in relation to most of the agreed Goals and have been shown to have the potential to support national reporting against a quarter of the associated targets, and to inform national development policies. Satellite data providers and enablers have already taken steps through CEOS and the Group on Earth Observations (GEO) to ensure coordination of their engagement with the 2030 Agenda. These efforts must be linked effectively to the work of the UN Agencies and other international partners, responsible as 'Custodian Agencies' for the development of workable and robust methodologies for the reporting by countries against the SDG Indicator Framework. National Statistical Offices must also be supported in understanding the opportunities and the challenges inherent in the application of large Earth observation datasets for the development of evidence. Individual countries are the most important players as the implementers of the SDGs and of the resulting development policies.

We are confident that this CEOS Report on SDGs can serve as a valuable reference source for a variety of readers from all sectors of society, including those engaged in the 2030 Agenda process, as well as decision-makers in political and socio-economic sectors. It is our firm belief that satellite Earth observations can support the realisation of the promise of the SDGs to ensure that no one is left behind.

Dr. Philippe Brunet

Director for Space Policy, Copernicus and Defence
Directorate-General Internal Market, Industry, Entrepreneurship and SMEs

European Commission CEOS Chairperson for 2018

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Part I

Satellite Data Supporting the SDGs

1

Introduction

The 2030 Agenda marks a milestone in the evolution of society's efforts to define and manage progress towards sustainable development in all its facets: social inclusion, economic growth and environmental sustainability. The definition of the Sustainable Development Goals (SDGs) and the associated Global Indicator Framework represent the first truly data-driven framework in which countries can engage with the aim of evidence-based decision-making and development policies. The Agenda recognises that *'if you can't measure it, you can't manage it'* and data is the enabler for the 2030 Agenda implementation.

The 2030 Agenda aims to be relevant to all countries, rich and poor, leaving no one behind. The scope and scale of it is such that effective monitoring of progress towards Targets and reporting on Indicators by countries will require substantial modernisation of many national statistical and geospatial systems, as well as the integration and exploitation of many new data sets in pursuit of the monitoring of the hundreds of Targets and associated Indicators.

This report focuses on the role of Earth observations (EO) in making the reporting of countries against the Global Indicator Framework and the monitoring of national progress toward the SDG Targets a practical reality. Specifically we focus on the role of satellite EO and how the spatial and temporal coverage of their data can make the 2030 Agenda monitoring and reporting framework viable, technically and financially. EO satellite data have already proven their value across many sectors of society – supporting the science that underpins strategies for global decision-making – and for monitoring our progress on all geographical scales as we explore new development paths aimed at sustainable management of the planet.

Significant investment has already been made by national governments in the space-based infrastructure that is providing free and open, continuous and consistent EO satellite data streams. These governments and the space agencies that steward these satellites are actively engaged to ensure optimal return on the investment by maximising the societal benefit of the data.

This Handbook has been prepared for national agencies, UN bodies and other SDG stakeholders working towards a collective implementation of the 2030 Agenda and towards a cost-effective response of countries to the SDG monitoring and reporting challenges. It aims to explain how satellite EO are an essential tool in the development of the information and evidence required by many of the SDG Targets and Indicators. The Handbook seeks to improve understanding of readers from all sectors of society as to the role of satellite EO in support of a well-managed planet and society.

Part I explains the role of EO in support of the SDGs, Targets and Indicators. The satellite data characteristics are outlined and where these might best assist in achieving the Goals, monitoring progress towards the Targets and reporting on the Indicators. Institutional issues related to the Goals can be complex and these are addressed also. Guidance is provided on how to get access to EO data and help to use it.

Part II compiles a number of contributed articles (from EO data providers, national statistical institutions, UN Custodian Agencies, non-governmental organisations and other SDG stakeholders) aimed at inspiring prospective users as to the possibilities of using EO satellite data. This Part seeks to instruct by practical examples and showcases.

Part III focuses on five specific Goals highlighting the potential nature of the contribution from EO satellite data to the 2030 Agenda, with a number of best practice examples.

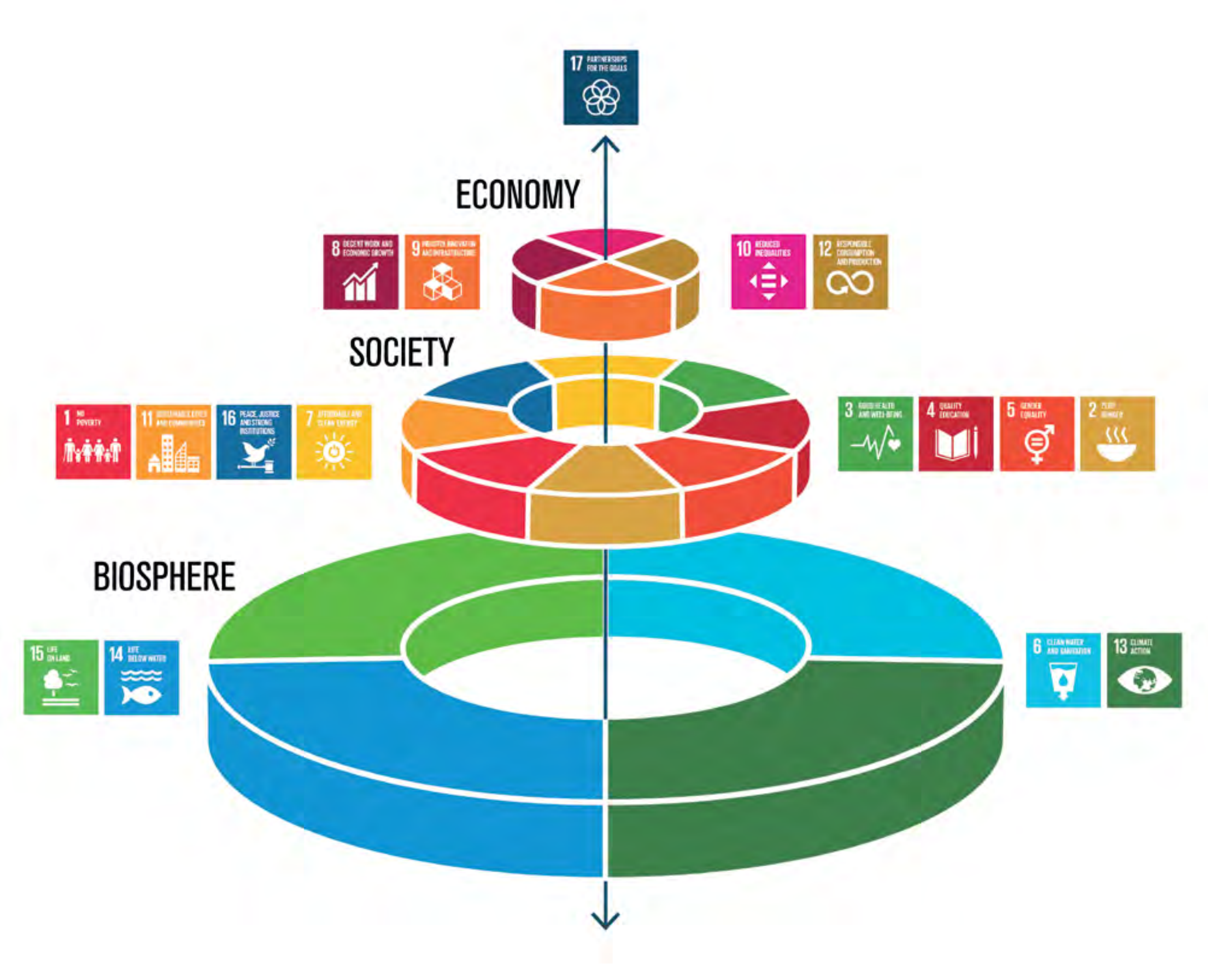

Figure 1: Relationship between the SDGs and the three main facets of the 2030 Agenda for Sustainable Development.
Credit: Azote Images for Stockholm Resilience Centre.

2 The Importance and Challenge of the SDGs

The SDGs represent a data-driven, evidence-based approach to sustainable development.

The Global Indicator Framework is the means by which national governments can practically monitor achievement on, and report progress toward, the Targets.

2.1 Historical context

Underlying the concept of sustainable development is the recognition that (1) planet Earth has finite resources; (2) that mankind is increasingly efficient at the extraction and conversion of those resources and (3) when combined with significant population growth and displacement over the last century, our development and consumption patterns are fundamentally becoming unsustainable, with increasingly significant environmental, social, economic, and political consequences.

The United Nations (UN) system has a long history of seeking to promote and address sustainable development across society and to establish governance frameworks to achieve it:

- **1972**: UN Conference on the Human Environment (Stockholm), the first major conference on environmental sustainability marking a political turning point;
- **1992**: UN Conference on Environment and Development (The Earth Summit, Rio de Janeiro) that included Agenda 21 calling for global action in all areas of sustainable development spanning social, economic and environmental issues, and initiation of the three Rio Conventions on sustainable development (UNFCCC – the UN Framework Convention on Climate Change; CBD – Convention on Biological Diversity; and UNCCD – the UN Convention to Combat Desertification);
- **2000**: The Millennium Declaration that sought to reduce poverty and set out targets for the year 2015 – known ultimately as the Millennium Development Goals (MDGs);
- **2002**: The World Summit on Sustainable Development (WSSD also known as 'Rio+10', Johannesburg);
- **2012**: The UN Conference on Sustainable Development ('Rio+20', Rio de Janeiro) that resulted in 'The Future We Want' political outcome document, with practical measures for implementation of sustainable development principles and a path to development of Sustainable Development Goals (SDGs).

2.2 The Sustainable Development Goals

The long heritage of efforts to characterise and address sustainable development culminated in the adoption by the UN General Assembly in September 2015 of what is known as the 2030 Agenda for Sustainable Development.

The 2030 Agenda (or Transforming our world: the 2030 Agenda for Sustainable Development) provides a framework to guide the way that countries should collectively manage and transform the social, economic and environmental dimensions of our society and planet over the next 15 years.

Whilst the MDGs of the previous 15 years (2000–2015) focused primarily on the needs of developing countries to tackle poverty, the 2030 Agenda is extremely broad and ambitious in scope and addresses well-being and sustainability in all countries and at all levels. It addresses the root causes of poverty and the universal needs for sustainable development, such as reduction of poverty and inequality, economic growth and job creation, as well as sustainable use of natural resources.

The 2030 Agenda for Sustainable Development aims to assist countries to measure, manage and monitor progress on economic, social and environmental sustainability, with the basic principle that no one is left behind. The aim is to integrate the principles of sustainable development into national policies and processes.

Although previous efforts expressed the importance of measurement and monitoring of progress towards sustainable development, insufficient attention was paid within the MDGs to the practicalities of clear targets and the data and evidence required in the measurement and monitoring of efforts to achieve them. The 2030 Agenda process sought to learn from this experience and has resulted in the definition of 17 SDGs and 169 Targets. These SDGs and Targets have been adopted by world leaders as the drivers for the 2030 Agenda and will be the foundation for sustainable development efforts for the next 15 years, for both the UN and its Member States.

The SDGs will inform the way in which countries and the international community will measure, manage, monitor progress and communicate on economic growth, social inclusion and environmental sustainability, as the pillars of sustainable development.

Just as the UN negotiations on climate (through the UNFCCC and its 21st Conference of Parties in Paris in late 2015) learned the importance of nationally determined contributions, so too has the sustainable development process, with the SDGs recognising the diversity in national circumstances and capacities. Each government defines its own targets guided by the global level of ambition but taking into account their national circumstances.

Figure 1: The 17 Sustainable Development Goals (SDGs) of the 2030 Agenda

- **Goal 1**. End poverty in all its forms everywhere.
- **Goal 2**. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
- **Goal 3**. Ensure healthy lives and promote well-being for all at all ages.
- **Goal 4**. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- **Goal 5**. Achieve gender equality and empower all women and girls.
- **Goal 6**. Ensure availability and sustainable management of water and sanitation for all.
- **Goal 7**. Ensure access to affordable, reliable, sustainable and modern energy for all.
- **Goal 8**. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
- **Goal 9**. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
- **Goal 10**. Reduce inequality within and among countries.
- **Goal 11**. Make cities and human settlements inclusive, safe, resilient and sustainable.
- **Goal 12**. Ensure sustainable consumption and production patterns.
- **Goal 13**. Take urgent action to combat climate change and its impacts.
- **Goal 14**. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
- **Goal 15**. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
- **Goal 16**. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
- **Goal 17**. Strengthen the means of implementation and revitalize the global partnership for sustainable development.

2.3 Measuring and Monitoring – the Global Indicator Framework for the SDGs

One the key lessons learned from the review of the MDGs and highlighted in the 2014 report *A World That Counts, Mobilizing The Data Revolution for Sustainable Development* was the recognition of the indispensable role of data in sustainable development and the importance for all stakeholders – governments, donors, UN Agencies, etc. – to be able to effectively track and monitor progress in a consistent and comparable way.

In support of the measurement and monitoring of progress towards the 17 SDGs, the UN has established a Global Indicator Framework, designed around 232 SDG Indicators. These Indicators represent the means by which national governments can practically monitor achievement on, and report progress toward, each of the 169 Targets of the 2030 Agenda. *Links to the full set of 17 SDGs, 169 Targets and 232 Indicators can be found at the end of this section.*

Sample Targets and Indicators for SDG #15 (Life on Land: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss) are shown in Figure 2 to illustrate the nature of the Targets and corresponding Indicators.

The scale and scope of the Indicator framework is daunting even to the most developed countries and there is a broad recognition that there will be substantial requirements for supporting data involved in the measuring and monitoring of so many Indicators at different scales.

Measurement of some of the Indicators is entirely achievable for many countries today, whilst tracking other Indicators will require further improvements in availability of underlying data and statistics, as well as corresponding availability of robust methodologies for National Statistical Offices (NSOs) and the relevant ministries responsible for the subject Indicators to be able to develop consistent and comparable information. In order to establish a sense of priority for implementation and of the scale of the task ahead in relation to the availability of new data and new methodologies, the Inter-Agency Expert Group on SDG Indicators (IAEG-SDGs) created by the UN Statistical Commission to develop and implement the SDG Global Indicator Framework, developed a tier classification system, based on the level of methodological development and overall data availability:

- Tier 1 for Indicators that are conceptually clear, have established methodologies, standards are available and data are regularly produced by countries (at least 50 per cent of countries and of the population in every region where the Indicator is relevant).
- Tier 2 for Indicators that are conceptually clear, have established methodologies, standards are available but data are not regularly produced by countries.
- Tier 3 for Indicators for which there are no established methodologies and standards or methodology/standards are being developed/tested.

As of 15 December 2017, the updated tier classification contains 93 Tier I Indicators, 66 Tier II Indicators and 68 Tier III Indicators. In addition to these, there are 5 Indicators that have multiple tiers (different components of the Indicator are classified into different tiers).

The Indicators will be refined annually by the IAEG-SDGs and reviewed comprehensively in 2020 and 2025. The tier classification is expected to change as methodologies are developed and data availability increases.

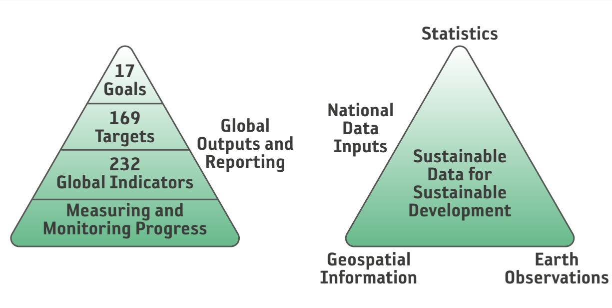

Figure 2: Reporting progress through the use of global Indicators, and key areas of national data inputs for the production of the SDG report on the global and regional progress toward the SDG Goals and Targets.

Recognising the scale of the challenge in ensuring appropriate methodologies, data availability and consistent and comparable reporting by countries, the UN has appointed specialised Agencies to play a coordinating role as Custodians of SDG Indicators relevant to their area of expertise. Each Indicator has one nominated Custodian and further partner Agencies. These Custodian Agencies have the mandate to compile monitoring guidelines for measuring and reporting on the Indicators, to support countries on their implementation and strengthen national statistical capacities, and to collect national data for the global reporting mechanism.

SUSTAINABLE DEVELOPMENT GOAL 15

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Targets	Indicators
15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements.	**15.1.1** Forest area as a proportion of total land area.
15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.	**15.1.2** Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type. **15.2.1** Progress towards sustainable forest management.
15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.	**15.3.1** Proportion of land that is degraded over total land area.
15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development.	**15.4.1** Coverage by protected areas of important sites for mountain biodiversity. **15.4.2** Mountain Green Cover Index.
15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.	**15.5.1** Red List Index.
15.6 Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed.	**15.6.1** Number of countries that have adopted legislative, administrative and policy frameworks to ensure fair and equitable sharing of benefits.
15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products.	**15.7.1** Proportion of traded wildlife that was poached or illicitly trafficked.
15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species.	**15.8.1** Proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of invasive alien species.
15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts.	**15.9.1** Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020.
15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems.	**15.a.1** Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems
15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation.	**15.b.1** Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems.
15.c Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities.	**15.c.1** Proportion of traded wildlife that was poached or illicitly trafficked.

Figure 3: Example Targets and Indicators for Goal 15 – Life on Land

As an illustration, examples of Tier 1, 2, and 3 Indicators and Custodians are:

- Tier 1: Indicator 15.1.1 – forest area as a proportion of total land area. The Food and Agriculture Organization (FAO) is the Custodian Agency for a total of 21 Indicators across SDGs 2, 5, 6, 12 and 14 that are mainly related to agriculture and forests, and is a contributing Agency for six more.
- Tier 2: Indicator 11.3.1 – ratio of land consumption rate to population growth date. UN-Habitat is the Custodian Agency as a part of a total of eight Indicators, and contributing agency for another five Goal 11 Indicators.
- Tier 3: Indicator 6.6.1 – change in the extent of water-related ecosystems over time. The UN Environment Programme (UN Environment) is the Custodian Agency (for a total of 30 Indicators, and Contributing Agency to 50 more).

In addition, as Custodian Agencies, these organisations have the mandate to:

- support governments to set and report on national priorities and Targets;
- foster strong and coherent institutional and policy environments;
- support national statistical institutions to produce national Indicators and contribute to the Global Indicator Framework;
- support governments to report on challenges and results;
- contribute to mobilising resources, including data, in support of national efforts.

Such support is likely to be vital as countries – particularly developing countries or those without sophisticated national spatial data infrastructures – get to grips with the challenge around monitoring progress towards their Targets and reporting against the many metrics.

The Global Indicator Framework will be the basis for the routine annual reporting of progress towards the SDGs at the High Level Political Forum each year. The High Level Political Forum is the main UN platform on sustainable development and has a central role in the follow-up and review of the 2030 Agenda for Sustainable Development at global level. The Forum meets annually under the auspices of the Economic and Social Council (ECOSOC) and every four years at the level of Heads of State and Government under the auspices of the General Assembly.

Further information

UN Resolution on the 2030 Agenda for Sustainable Development:
sustainabledevelopment.un.org/post2015/transformingourworld

UN Sustainable Development Goals:
www.un.org/sustainabledevelopment/sustainable-development-goals

SDGs Knowledge Platform:
sustainabledevelopment.un.org/sdgs

Sustainable Development Goal Indicators Website:
https://unstats.un.org/sdgs

Rio+20, The Future We Want:
sustainabledevelopment.un.org/futurewewant.html

Data Revolution Report, A World That Counts:
undatarevolution.org/report

List of SDG Indicators:
https://unstats.un.org/sdgs/indicators/indicators-list

Tier Classification for Global SDG Indicators:
https://unstats.un.org/sdgs/iaeg-sdgs/tier-classification

UN High Level Political Forum on Sustainable Development:
sustainabledevelopment.un.org/hlpf

IAEG-SDGs:
unstats.un.org/sdgs/iaeg-sdgs

3

Role of EO Data in Support of the SDGs

Earth observations offer unprecedented opportunities to modernise national statistical systems and improve the capacities of countries to efficiently track all facets of sustainable development.

Satellite data has a role to play in relation to most of the 17 Goals and around a quarter of the Targets.

3.1 Data-driven development

The design of the 2030 Agenda, of its Goals, its Targets, and its Global Indicator Framework, is driven by the recognition that future sustainable development strategies must be evidence-based and data-driven. The Indicator Framework is predicated on the emergence of a data revolution, including within the NSOs that will be required to routinely report progress of countries towards the Targets. The UN Secretary General led calls to mobilise the data revolution for sustainable development, recognising that on-going measurement of progress towards the new goals and targets will require a sustainable flow of high quality, timely, authoritative and accessible data.

NSOs have long used a diversity of data sources and techniques to produce official statistics, such as censuses and household surveys, as well as administrative and transactional data. Traditional statistical methods have tended to dominate NSO's activities, even in today's data-rich and technologically driven society where citizens are exposed daily to geospatial datasets through mobile phone technology, GPS and internet mapping applications. But with the 2030 Agenda on Sustainable Development and the importance of high quality, timely and accessible data to inform the SDGs, there is a recognition that the full realisation of the 2030 Agenda at all levels (from local to global scales) will require the use of multiple types and new sources of data, including geospatial information and satellite EO, as well as advanced data processing and Big Data analytical techniques to extract the necessary information from all these data sets.

The first UN World Data Forum on Sustainable Development Data in early 2017 brought together NSOs, data scientists, data providers and users with academia, international organisations and civil society organisations to discuss challenges and opportunities for harnessing the power of data and monitoring to contribute to the SDGs. The resulting *Cape Town Global Action Plan for Sustainable Development Data* (see links section) stresses that the implementation of the SDGs requires the collection, processing, analysis and dissemination of an unprecedented amount of data and statistics, at multiple levels and by a large range of stakeholders.

The strategic areas identified for effort by the Plan include:

- strengthened national statistical systems and coordination of the NSOs;
- the application of new technologies and new data sources into mainstream statistical activities;
- integrating geospatial data into statistical production programmes at all levels;
- multi-stakeholder partnerships for sustainable development data.

The Global Action Plan proposes to leverage the efforts of the NSOs to modernise their national statistical systems, but also the efforts of international organisations and partnerships - such as those of the EO community to promote Earth observations in support of the SDG monitoring.

The use of geospatial data and technology is increasingly recognised as being fundamental to policy making and monitoring in relation to sustainable development. As societal pressures scale with growing populations and depleting resources, timely and comprehensive information on the state of the Earth will become increasingly important as the foundation for evidence-based decision-making for the 2030 Agenda.

The UN is working to ensure that the necessary data revolution, data supply, methodologies for application, and capacity for use, are all in place to support measuring and monitoring of the SDG Global Indicator Framework.

The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) aims to play a leading role in the development of global geospatial information and to promote its use to address key global challenges, such as the SDGs. UN-GGIM has characterised a general 'data flow' framework (Figure 1) for national information systems

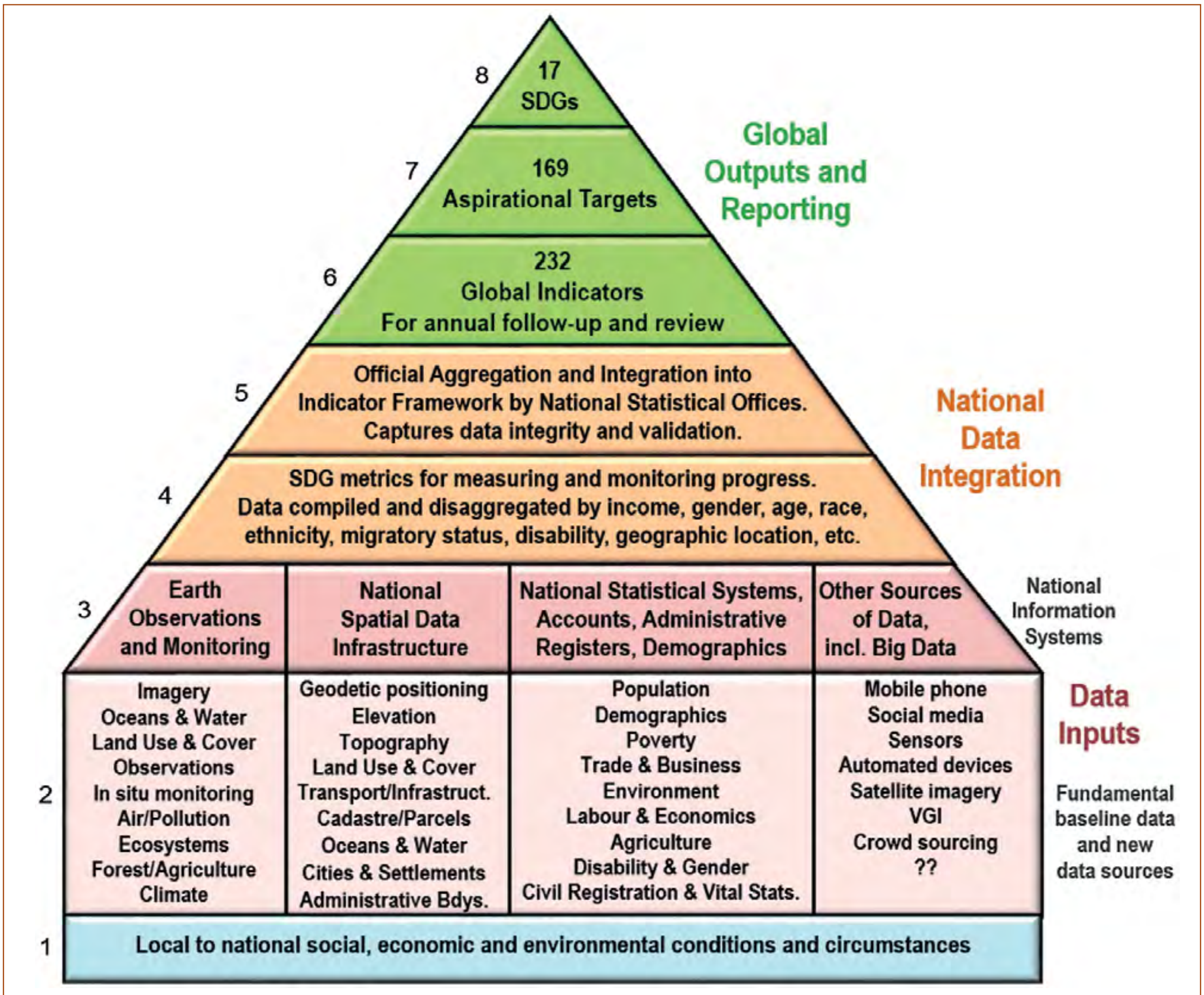

Figure 1: Model national information system with data inputs, data integration and reporting.

Credit: UN-GGIM

supporting the SDG Indicator Framework. This illustrates a typical mix of national data that provide the building blocks and processes for any given country to measure and monitor the SDGs from local real-world conditions, and allow global harmonised reporting through robust and reliable data inputs.

3.2 How satellite data can help

Geospatial information and EO, together with modern data processing and big data analytics, offer unprecedented opportunities to modernise national statistical systems and consequently to make a quantum leap in the capacities of countries to efficiently track all facets of sustainable development.

EO (from satellite, airborne and in-situ sensors) provide accurate and reliable information on the state of the atmosphere, oceans, coasts, rivers, soil, crops, forests, ecosystems, natural resources, ice, snow and built infrastructure, as well as their change over time. These observations are directly or indirectly necessary for all functions of government, all economic sectors and many day-to-day activities of society.

The benefits of satellite EO are already well understood across many areas of government, industry and science as a valuable information source in support of many sectors of society. As a consequence, satellite EO programmes represent the largest investment globally in relation to satellite applications by national governments, typically through their national space agencies. The Committee on Earth Observation Satellites (CEOS) reports that its member agencies are currently operating or planning more than 300 different satellite EO missions, carrying over 900 different instrument payloads. These systems span a diverse range of measurements of atmosphere, ocean, and land, supporting hundreds of applications related to matters that can affect the lives of citizens. In addition, privately funded EO missions, including large constellations of smaller satellites with the capability to provide frequent coverage or repeat measurements, are rapidly increasing in number in recent years.

Effective use of the information from satellite observations can have a transformational impact on many of humanity's most significant challenges, such as helping monitor and protect fragile ecosystems, ensure resilient infrastructure, manage climate risks and public health, enhance food security, build more resilient cities, reduce poverty, and improve governance, among others.

Key benefits of satellite Earth observation data for the SDGs and for the NSOs reporting against the indicators are:

- **Satellite Earth observation data makes the prospect of a Global Indicator Framework for the SDGs viable.** For many Indicators, the coverage and frequency of measurements from which the Indicators are derived would simply not be feasible, technically or financially if satellite observations are not used;
- **the potential to allow more timely statistical outputs**, to reduce the frequency of surveys, to reduce respondent burden and other costs and to provide data at a more disaggregated level for informed decision making;
- **improved accuracy in reporting by ensuring that data are more spatially-explicit** and directly contribute to informing the Targets and Indicators, helping to augment statistical data, validating national statistics, and providing disaggregation and granularity of the indicators (where relevant, by income, sex, age, race, ethnicity, migratory status, disability and geographic location, in support of the principle of leaving no one behind). Satellite data can support the evolution from traditional statistical approaches to more measurement-based solutions as some challenges, including in relation to the environment and human populations, become more pressing, and with the need for more accurate, spatially explicit, and frequently updated evidence.

3.3 Satellite data characteristics

There being many different EO satellites in operation, the data characteristics can vary significantly from one to another depending on the purpose and application. But a number of characteristics are common to many satellite datasets that are of interest to NSOs seeking to integrate such data into their national information systems:

Free and open: not all nations are able to develop and launch their own EO satellites, with a relatively small (but growing) number having the capacity to do so. Hence the availability of the data from these missions, for all nations, is of fundamental importance to their uptake and global impact. This has been advocated for strongly by the Group on Earth Observations (GEO) for many years.

US government mission data has long been freely available, and with the free and open data policy of the European Union's Copernicus programme, the prospects for access to the EO data required by developing countries have improved considerably. Copernicus also provides free access to added-value services in the fields of land, marine and atmosphere monitoring, climate change and emergency management.

Scale and coverage: first and foremost, satellites are unrivalled in their ability to make global measurements and to provide data on all scales from local to national, regional and even global. Indeed, they are likely the only source of global information for many parameters; satellites can observe all points of the globe including areas that are remote or difficult to reach;

Consistency and comparability: satellites provide the means for the effective comparison of results among different countries, which may otherwise suffer from lack of standardisation in measurements or methods, impeding attempts to derive meaningful comparisons or regional/ global statistics; consistency over time and space is an important feature of a credible Indicator Framework;

Continuity and time-series: investment in national systems and processes to integrate new sources of data such as EO satellite data, requires a degree of confidence in the continued availability of supply of that data; this has been recognised by the world's largest space agencies and guaranteed continuity is a factor in their planning; some EO satellite mission series date back to the 1970s and others are now planned up to 2030 and beyond, providing governments with unique evidence with which to track progress, including the establishment of baselines for the determination of future trends, for monitoring and compliance of agreements, for improved predictions, and for management and mitigation; these characteristics will be invaluable over the 15-year span of the 2030 Agenda;

Complementarity with traditional statistical methods: while EO datasets can be used to monitor directly some specific Indicators of SDGs, they can also offer a unique and complementary source of information to cross-check the validity of in-situ data measurements (such as survey and inventory data) and to communicate and visualise the geographic dimensions and context of the Indicators as needed.

Diverse measurements: technological advances in instrumentation and measurements covering both science and applications have resulted in an increasingly diverse array of EO satellite missions with dozens of geophysical parameters being measured on a regular basis from a range of different satellite orbits. In the field of climate change alone, CEOS has identified that more than half of the approximately 55 Essential Climate Variables (ECVs) benefit from a major contribution from satellite observations or simply would not be feasible without satellites (such as polar ice extent and global sea level).

The CEOS Database of EO Satellite Missions, Instruments, and Measurements identifies hundreds of different missions and sensors that provide a multitude of different measurements of land, sea, ice and atmosphere. Some instruments make passive measurements of observed radiation, whilst others (like imaging radars or lasers) actively emit signals to remotely sense target properties. Many different parts of the electromagnetic spectrum are employed by these sensors. Most common are simple optical cameras, which may image in the visible part of the light spectrum and may include infra-red sensing. Microwave instruments feature increasingly and provide all-weather, day-night capabilities.

Spatial resolutions vary tremendously too, with some land surface imaging sensors capable of resolving objects just tens of centimetres in size (typically these very high resolution missions are commercially operated). The most commonly applied government-funded satellite missions of Europe and the US typically provide optical and microwave data of 10–30m resolution with free and open data policies. Some sensors focused on more global applications, such as those for climate observations, might be designed to measure at resolutions of hundreds of metres or even kilometres.

3.4 Status of support to the SDGs

A number of analyses have been undertaken by different organisations seeking to establish a clear understanding of where EO data currently support the SDG Targets and Indicators and where they might have future potential to do so. While these analyses may vary slightly in their conclusions, they agree broadly with regards to the type of Goals, Targets and Indicators that can be supported by information extracted from EO data. As an illustration, Figure 2 below summarises the main conclusions of the analysis by GEO and CEOS.

This table provides a comprehensive list of Targets and Indicators that can be directly or significantly supported by EO. It gives a steer to countries seeking to understand the potential of these data sources and where they might best be applied.

The GEO/CEOS study suggests that EO data has a role to play in relation to most of the 17 SDGs. More specifically, around 40 of the 169 Targets (representing about a quarter) and around 30 of the 232 Indicators (about an eighth) are supported.

It is particularly telling that of these approximately 30 Indicators, only 12 are identified as being Tier I Indicators (with established methodologies and regular data production by countries) where we might reasonably assume significant exploitation of EO data currently. This means there remains significant unrealised potential for EO data to contribute to the Indicator Framework, with only a third of its potential routinely being exploited today.

Goal	Supported Targets	Supported Indicators	Tier
1 NO POVERTY	**1.4** By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	**1.4.2** Proportion of total adult population with secure tenure rights to land, with legally recognized documentation and who perceive their rights to land as secure, by sex and by type of tenure	2
	1.5 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		
2 ZERO HUNGER	**2.3** By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment		
	2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	**2.4.1** Proportion of agricultural area under productive and sustainable agriculture	3
	2.c Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility		
3 GOOD HEALTH AND WELL-BEING	**3.3** By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases		
	3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being		
	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	**3.9.1** Mortality rate attributed to household and ambient air pollution	1
	3.d Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks		
4 QUALITY EDUCATION			

Goal	Supported Targets	Supported Indicators	Tier
5 GENDER EQUALITY	**5.a** Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws	**5.a.1** (a) Proportion of total agricultural population with ownership or secure rights over agricultural land, by sex; and (b) share of women among owners or rights-bearers of agricultural land, by type of tenure	2
6 CLEAN WATER AND SANITATION	**6.1** By 2030, achieve universal and equitable access to safe and affordable drinking water for all		
	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	**6.3.1** Proportion of wastewater safely treated	2
		6.3.2 Proportion of bodies of water with good ambient water quality	3
	6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	**6.4.2** Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	1
	6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	**6.5.1** Degree of integrated water resources management implementation (0-100)	1
	6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	**6.6.1** Change in the extent of water-related ecosystems over time	3
	6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies		
	6.b Support and strengthen the participation of local communities in improving water and sanitation management		
7 AFFORDABLE AND CLEAN ENERGY	**7.2** By 2030, increase substantially the share of renewable energy in the global energy mix	**7.1.1** Proportion of population with access to electricity	1
	7.3 By 2030, double the global rate of improvement in energy efficiency		
	7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology		
	7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support		

Goal	Supported Targets	Supported Indicators	Tier
	8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead		
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	**9.1** Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all	**9.1.1** Proportion of the rural population who live within 2 km of an all-season road	3
	9.2 Promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and gross domestic product, in line with national circumstances, and double its share in least developed countries		
	9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets		
	9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	**9.4.1** CO_2 emission per unit of value added	1
	9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending		
	9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States		
10 REDUCED INEQUALITIES	**10.6** Ensure enhanced representation and voice for developing countries in decision-making in global international economic and financial institutions in order to deliver more effective, credible, accountable and legitimate institutions		
	10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies		
	10.a Implement the principle of special and differential treatment for developing countries, in particular least developed countries, in accordance with World Trade Organization agreements		

Goal	Supported Targets	Supported Indicators	Tier
11 SUSTAINABLE CITIES AND COMMUNITIES	**11.1** By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	**11.1.1** Proportion of urban population living in slums, informal settlements or inadequate housing	1
		11.2.1 Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities	2
	11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	**11.3.1** Ratio of land consumption rate to population growth rate	2
	11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage		
	11.5 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		
	11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	**11.6.2** Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)	1
	11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	**11.7.1** Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities	3
	11.b By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels		
	11.c Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials		
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	**12.2** By 2030, achieve the sustainable management and efficient use of natural resources		
	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment		
	12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature		
	12.a Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production	**12.a.1** Amount of support to developing countries on research and development for sustainable consumption and production and environmentally sound technologies	3
	12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products		

Goal	Supported Targets	Supported Indicators	Tier
13 CLIMATE ACTION	**13.1** Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	**13.1.1** Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population	2
	13.2 Integrate climate change measures into national policies, strategies and planning		
	13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning		
	13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities		
14 LIFE BELOW WATER	**14.1** By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution		
	14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans		
	14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	**14.3.1** Average marine acidity (pH) measured at agreed suite of representative sampling stations	3
	14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	**14.4.1** Proportion of fish stocks within biologically sustainable levels	1
	14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiationb	**14.5.1** Coverage of protected areas in relation to marine areas	1
	14.7 By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism		
	14.a Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries		

Goal	Supported Targets	Supported Indicators	Tier
15 LIFE ON LAND	**15.1** By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	**15.1.1** Forest area as a proportion of total land area	1
	15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	**15.2.1** Progress towards sustainable forest management	1
	15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	**15.3.1** Proportion of land that is degraded over total land area	2
	15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	**15.4.1** Coverage by protected areas of important sites for mountain biodiversity	1
		15.4.2 Mountain Green Cover Index	1
	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species		
	15.7 Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products		
	15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species		
	15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts		
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	**16.8** Broaden and strengthen the participation of developing countries in the institutions of global governance		
17 PARTNERSHIPS FOR THE GOALS	**17.2** Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of gross national income for official development assistance (ODA/GNI) to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries		
	17.3 Mobilize additional financial resources for developing countries from multiple sources		

Goal	Supported Targets	Supported Indicators	Tier
	17.6 Enhance North-South, South-South and triangular regional and international cooperation on and access to science, technology and innovation and enhance knowledge-sharing on mutually agreed terms, including through improved coordination among existing mechanisms, in particular at the United Nations level, and through a global technology facilitation mechanism	**17.6.1** Number of science and/or technology cooperation agreements and programmes between countries, by type of cooperation	3
	17.7 Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed		
	17.8 Fully operationalize the technology bank and science, technology and innovation capacity-building mechanism for least developed countries by 2017 and enhance the use of enabling technology, in particular information and communications technology		
	17.9 Enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the Sustainable Development Goals, including through North-South, South-South and triangular cooperation		
	17.16 Enhance the Global Partnership for Sustainable Development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the Sustainable Development Goals in all countries, in particular developing countries		
	17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships		
	17.18 By 2020, enhance capacity-building support to developing countries, including for least developed countries and small island developing States, to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts	**17.18.1** Proportion of sustainable development indicators produced at the national level with full disaggregation when relevant to the target, in accordance with the Fundamental Principles of Official Statistics	3

Figure 2: Initial GEO/CEOS analysis of EO relevance to the Goals, Targets, and Indicators. CEOS plans to conduct a thorough and exhaustive analysis of the EO contribution to the SDG Targets and Indicators with a detailed review of the methodological guidelines prepared by the Custodian Agencies for the Global Indicator Framework.

- Figure 3 indicates the relevance of satellite EO to each of the 17 SDGs based on the number of corresponding Indicators that are supported. Although this analysis requires further consolidation, it demonstrates the importance of EO to a number of goals, particularly:
- Goal 6 – clean water and sanitation;
- Goal 11 – sustainable cities;
- Goal 14 – life below water;
- Goal 15 – life on land.

Much of the contribution of EO to these goals involves the provision of information in relation to mapping of land cover, land productivity, above ground biomass, soil content, water extent or quality characteristics, as well as air quality and pollution parameters.

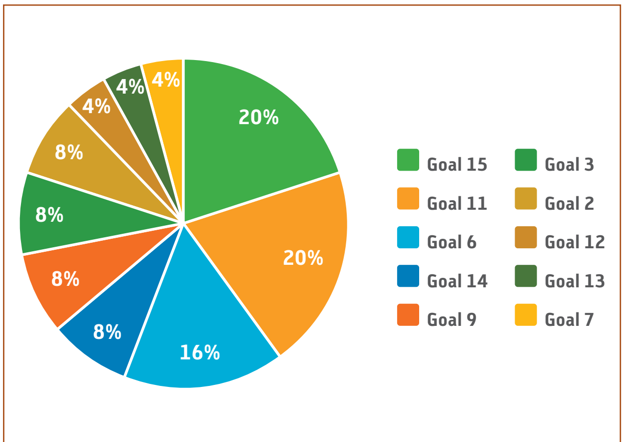

Figure 3: An approximate visual assessment of which Goals are supported by EO

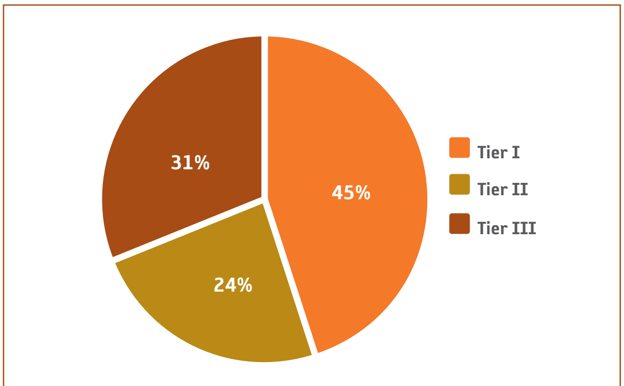

Figure 4: For the Indicators supported by EO, the pie chart shows an approximate correspondence to the Indicator Tier type where:

Tier 1: Indicator is conceptually clear, has an internationally established methodology and standards are available, and data are regularly produced by countries for at least 50 per cent of countries and of the population in every region where the indicator is relevant.

Tier 2: Indicator is conceptually clear, has an internationally established methodology and standards are available, but data are not regularly produced by countries.

Tier 3: No internationally established methodology or standards are yet available for the indicator, but methodology/standards are being (or will be) developed or tested.

The statistics around the custodianship of EO-related indicators reveal that the UN Agencies most relevant to realising the potential of satellite data in the methodologies for the SDG indicators are:

- FAO;
- UN Environment;
- UN-Habitat; and
- World Health Organization (WHO).

Partnerships among these agencies, the space data providers and NSOs will be particularly important. Some examples of existing use of EO data by these organisations are provided in Parts II and III.

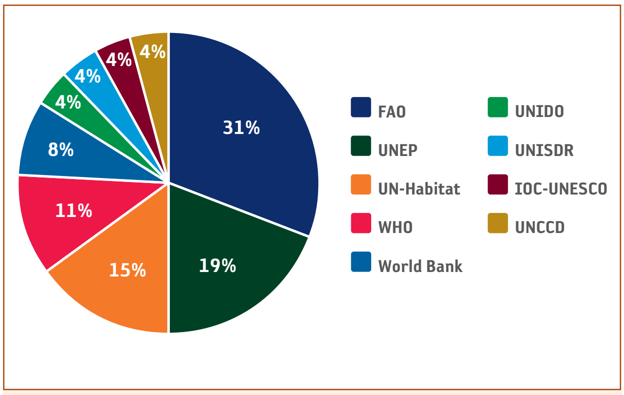

Figure 5: An approximate distribution of the Custodian Agencies for the Indicators supported by EO

Further information

Cape Town Global Action Plan for Sustainable Development Data:
unstats.un.org/sdgs/hlg/Cape-Town-Global-Action-Plan

UN-GGIM:
ggim.un.org

CEOS Missions, Instruments and Measurements Database:
database.eohandbook.com

Institutional Roles

A large number of UN bodies and international organisations play active roles in the 2030 Agenda as Custodian Agencies, supporting countries with methodologies and data for monitoring Indicators.

GEO and CEOS provide important coordination of the EO community and are joining their efforts in showcasing the value of, and facilitating access to, EO in support of the full realisation of the 2030 Agenda.

The scope and scale of the SDGs and associated Global Indicator Framework is such that a broad range of stakeholders are involved and effective partnerships among them are fundamental to success in implementing and monitoring progress towards the Goals and Targets. These stakeholders include UN bodies, NSOs and the line Ministries responsible for the different Indicators, suppliers of spatial data infrastructures, as well as data providers and the international bodies that coordinate them.

4.1 UN institutions

Multiple UN institutions are involved in the implementation and monitoring of the SDGs.

The UN Statistical Commission (UNSC) is a functional commission of the UN Economic and Social Council (ECOSOC) and is supported by the UN Statistics Division, which is the central mechanism within the UN to supply global statistics. UNSC brings together chief statisticians from member states from around the world. UNSC has the mandate to oversee the development of the Global Indicator Framework for the SDGs.

Figure 1 highlights the important role of the various Expert and Working Groups that have been established within the UN system to define the Global Indicator Framework and to address fundamental issues such as the role of geospatial information and its integration with national statistics.

The Inter-Agency Expert Group on SDG Indicators (IAEG-SDGs, established in March 2015) is comprised of representatives of national statistics offices and is in charge of developing and implementing the Global Indicator Framework.

The UN Committee of Experts on Global Geospatial Information Management (UN-GGIM, established in July 2011) is another important player within the UN governance system on SDGs, and leads in the role of developing understanding and application of geospatial information for the monitoring of the Goals and Targets of the 2030 Agenda. UN-GGIM coordinates the specialist **Working Group on Geospatial Information (WGGI, established in March 2016)**, which looks at the Indicator

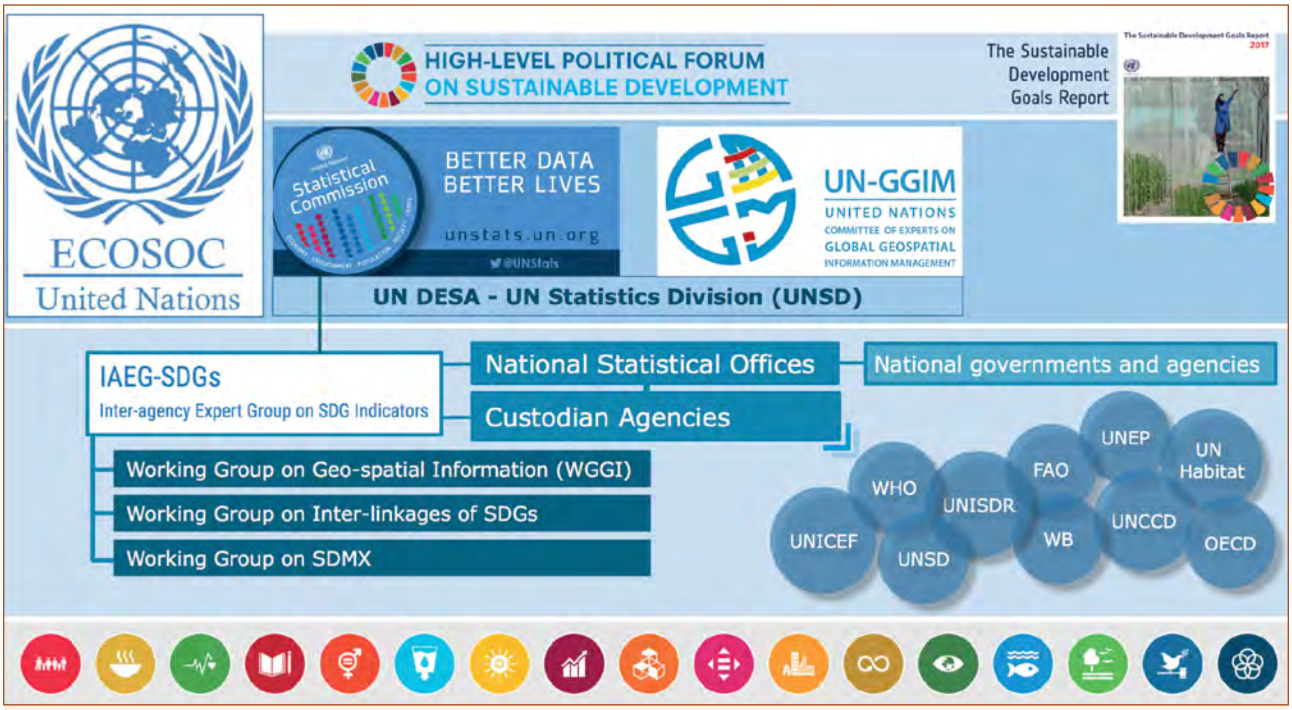

Figure 1: UN governance system for the development and implementation of the Global Indicator Framework on SDGs.

Framework through a "geographic location" lens to identify existing geospatial data gaps and methodological issues and to consider how geospatial information and EO can contribute to its viability. The establishment of the WGGI acknowledges the demand from the 2030 Agenda on Sustainable Development for new data acquisition and integration approaches that can improve the availability, quality, timeliness and disaggregation of data, and consequently support the implementation of the SDGs at all levels.

As explained in Section 2, the UN has appointed specialised agencies (UN agencies and international organisations) to play a coordinating role as **Custodians of SDG Indicators** relevant to their area of expertise or mandate. These Custodian Agencies have the mission to compile monitoring guidelines for measuring and reporting on the indicators, to support countries on their implementation and strengthen national statistical capacities, and to collect national data for the global reporting mechanism.

Finally, progress towards the Goals are reported and reviewed annually through to 2030 within the **UN's High-Level Political Forum (HLPF) on Sustainable Development.**

4.2 National statistical and geospatial institutions

The Indicators are the benchmarks for the monitoring and reporting by national governments of their progress towards the SDGs. NSOs, in collaboration with the relevant UN Custodian Agencies as appropriate, will report against these indicators to the UN Statistics Division for compilation into the Sustainable Development Goals Reports.

Given the fundamental role of geospatial information and EO to the viability of many of the Indicators, there is a substantial role within countries for those agencies responsible for geospatial information, national information systems and national spatial data infrastructures.

It is recognised that for many developing countries, there remains a significant capacity challenge around the access, processing, analysis and production of the necessary data. The translation of geospatial data into information for decisions and reporting on their international engagements, such as on their progress towards the SDGs, will also require significant investment. Bodies such as UN-GGIM with the support of their Regional Committees aim to assist national geospatial information agencies with the relevant geospatial standards, with data and information interoperability and with the integration of statistical and geospatial information.

The hope is that the 2030 Agenda will serve as a catalyst for accelerated development of national spatial data infrastructures and provide a unique opportunity to the geospatial communities to integrate geospatial information into the Agenda and national statistics more broadly.

4.3 EO data and information providers and their coordinating bodies

The success of the 2030 Agenda will depend on the availability of high quality, timely and universally accessible data. The effective use of EO data in support of national monitoring and reporting against the Global Indicator Framework, as well as informed decision making on development policies, will require closer collaboration among national statistical offices and the EO data providers and communities.

GEO

GEO and UN-GGIM have started to work closely with the statistical community, at both national and global levels, to provide inputs into the processes to implement the Global Indicator Framework.

In its role coordinating international efforts to build a Global Earth Observation System of Systems (GEOSS) that better integrates observing systems and shares data, GEO plays an instrumental role in promoting and showcasing the value of EO in support of the SDGs. More than 100 governments and 100 participating organisations collaborate on the GEOSS to better integrate observing systems and share data by connecting existing infrastructures using common standards.

GEO is a unique global network connecting government institutions, academic and research institutions, data providers, businesses, engineers, scientists and experts to create innovative solutions to global challenges at a time of exponential data growth, human development and climate change that transcend national and disciplinary boundaries. The unprecedented global collaboration of experts helps identify gaps and reduce duplication in the areas of sustainable development and sound environmental management.

GEO and the GEOSS incorporate EO from diverse sources, including satellite, airborne, in-situ platforms and citizen observatories. There are more than 400 million open data resources in GEOSS from more than 150 international providers such as national and regional space agencies, international organisations such as the World Meteorological Organization (WMO) and commercial satellite data providers.

In 2015, GEO launched a new initiative called, *'EO for Sustainable Development in Service of the 2030 Agenda (EO4SDG)'*. EO4SDG seeks to realise and expand the potential of EO to advance the 2030 Agenda and enable societal benefits through achievement of the SDGs. One of the contributed articles in Part II of this Handbook focuses on EO4SDG and provides further detail on the activities of this GEO initiative.

In brief, EO4SDG has four implementation mechanisms, some in partnership with custodian agencies, some in partnership with NSOs:

- national pilot projects integrating EO with national statistical data;
- capacity building around development and implementation of methodologies to apply EO data;
- identification and development of data and information products to advance understanding and access to suitable EO resources;
- outreach and engagement activities.

GEO's efforts on the SDGs prioritise Goals and Targets where GEO has strong and active communities with adequate resources and potential to deliver tangible outcomes within the 2017–2019 timeframe, namely:

- SDG 2: zero hunger;
- SDG 6: clean water & sanitation;
- SDG 11: sustainable cities and communities;
- SDG 13: climate action;
- SDG 14: life below water; and
- SDG 15: life on land.

Figure 2: The GEOSS serves a broad range of societal benefit areas of relevance to the SDGs

As well as coordination with many UN agencies and international organisations involved in the development of the SDG Global Indicator Framework, GEO efforts connect to other key SDG stakeholders such as the Sustainable Development Solutions Network (SDSN), the Global Partnership for Sustainable Development Data (GPSDD) and the International Institute for Sustainable Development (IISD).

CEOS

CEOS is the Committee on Earth Observation Satellites, created in 1984 under the aegis of the G7 Economic Summit of Industrialised Nations Working Group on Growth, Technology and Employment.

CEOS was established to provide coordination of the Earth observations provided by satellite missions, recognising that no single programme, agency or nation can hope to satisfy all of the observational requirements that are necessary for improved understanding of the Earth system. Since its establishment, CEOS has provided a broad framework for international coordination on space-borne EO missions.

CEOS has three primary objectives:

- to optimise the benefits of space-based EO through cooperation of CEOS Agencies in mission planning and in the development of compatible data products, formats, services, applications and policies;
- to aid both CEOS Agencies and the international user community by, among other things, serving as the focal point for international coordination of space-based EO activities, including GEO and entities related to global change;
- to exchange policy and technical information to encourage complementarity and compatibility among space-based EO systems currently in service or development, and the data received from them, as well as address issues of common interest across the spectrum of EO satellite missions.

CEOS membership has reached 32 space agency Members in 2018, comprising almost all of the world's civil agencies responsible for EO satellite programmes.

CEOS is formally recognised as the 'space arm' of GEO and has strong links to the GEO community at many levels. CEOS engages directly with specific GEO initiatives to understand how existing and future assets can be optimised to meet specific user needs. CEOS also develops and operates 'virtual constellations' (see Figure 3) that promote continuity of observations for a particular variable (e.g., sea surface temperature), coordinating mission development and operations across space agencies from around the world.

Recognising the fundamental role for satellite EO in the realisation of the Global Indicator Framework, CEOS has identified the SDGs as a top priority and established in October 2016 the CEOS Ad-Hoc Team on SDGs (AHT SDG) dedicated to better coordination of the world's space

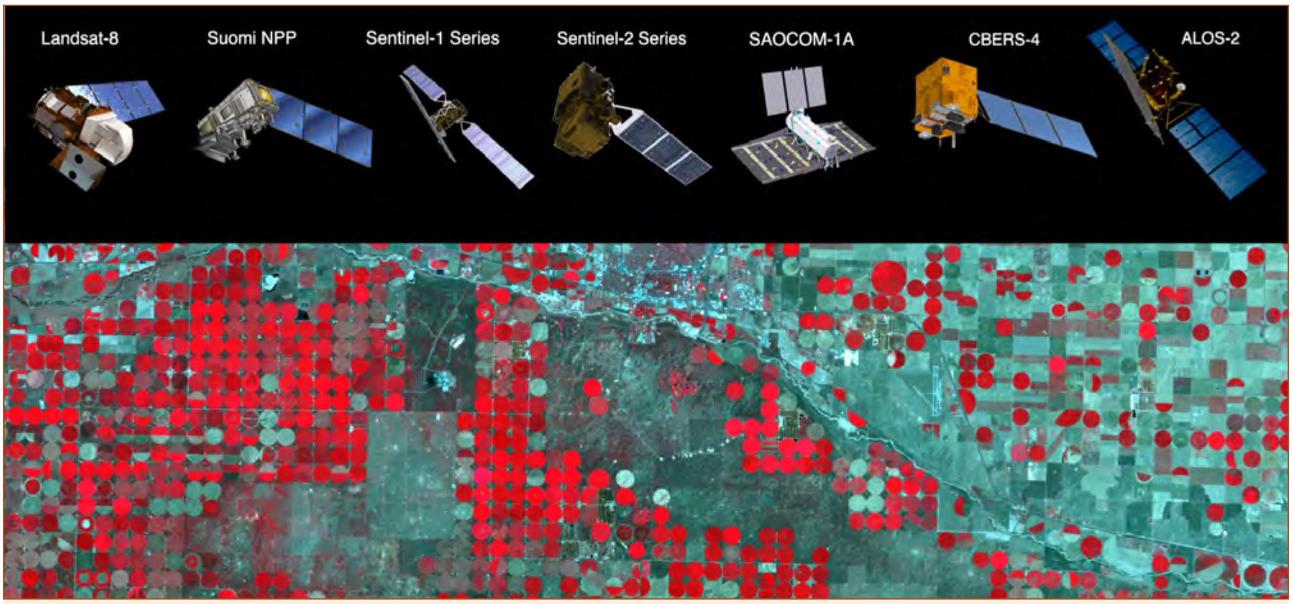

Figure 3: CEOS Virtual Constellations coordinate the investments of space agencies around the world to address specific challenges. This example shows the missions supporting food security and forest management

agencies in support of the provision of satellite data for the 2030 Agenda, in full alignment with the activities of the GEO EO4SDG initiative. An early outcome in cooperation with GEO has been the production of the booklet *'Earth Observations in support of the 2030 Agenda for Sustainable Development'*. This report highlights the potential role of satellite observations to support the Global Indicator Framework; a link to the report is provided below.

Through its AHT SDG, CEOS works on behalf of, and in coordination with, the world's civil space agencies to advocate for and promote measures to progress acceptance and uptake of satellite observations in the 2030 Sustainable Development Agenda. CEOS plans, developed in coordination with GEO/EO4SDG, include:

- showcasing and promoting the contribution of satellite EO to the SDG Targets and Indicators;
- development of a forum for sharing and communicating EO best practices in support of the SDGs;
- engagement with relevant SDG stakeholders inside the UN system (e.g. UNSD, UN-GGIM, IAEG-SDGs, WGGI, Custodian Agencies) and outside the UN system (e.g. GPSDD, IISD, World Bank);
- use of CEOS agency assets to build EO capacity at all levels of the SDG implementation.

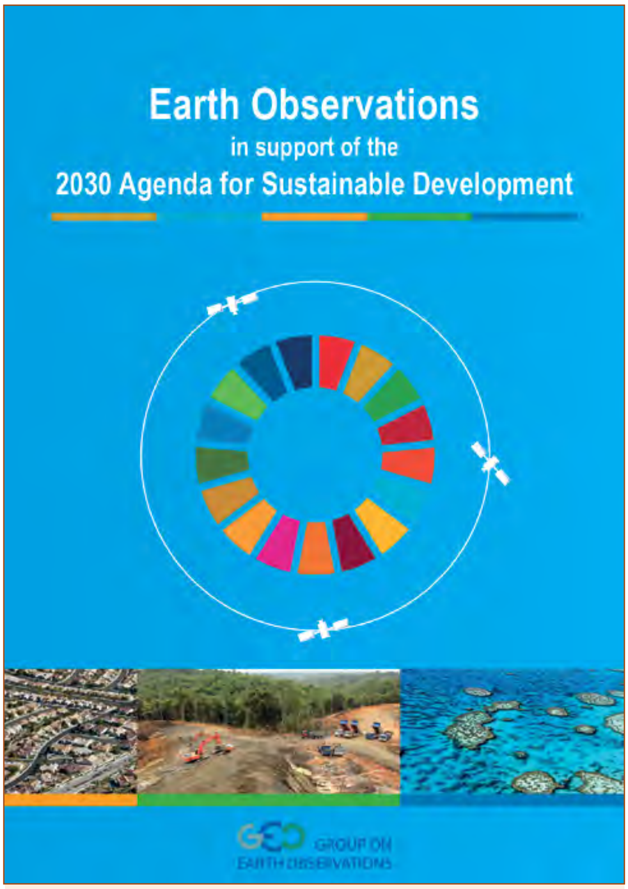

Figure 4: GEO Booklet "Earth Observations in Support of the 2030 Agenda for Sustainable Development"

Further information

GEO:
earthobservations.org

GEOSS Portal:
www.geoportal.org

EO4SDG:
eo4sdg.org

CEOS:
www.ceos.org

CEOS SDG Team:
ceos.org/ourwork/ad-hoc-teams/sustainable-development-goals

GEO Booklet on EO for SDGs:
www.earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf

UN-GGIM WGGI:
ggim.un.org/UNGGIM-wg6

5

Future Challenges

Steps are being taken to reduce EO satellite data size and complexity to allow widespread use and application.

Data continuity is crucial for confidence in national investment in human resources and information systems to handle EO data.

As the 2030 Agenda gains momentum and countries consider the practicalities of measuring, monitoring and reporting against hundreds of Indicators, the recognition is growing of the need for new data acquisition and integration approaches and for *'high quality, timely, reliable and disaggregated data, including Earth observations and geospatial information'*.

The 2030 Agenda represents a unique opportunity for convergence of the interests of the sustainable development community and of the EO community, with both sides recognising this opportunity and the mutual dependence on the other for success:

- without EO a large number of the proposed Indicators will simply not be technically or financially viable;
- uptake of EO data within government information systems and statistics has hitherto been slower than the information value of the data might have suggested – at times to the frustration of EO data providers like space agencies; the Global Indicator Framework represents a truly unique opportunity for the EO community to demonstrate the value of their datasets for evidence-based decision making on all scales.

Big Data is a buzzword heard increasingly in relation to the rapid expansion in the datasets and information now available to governments, industry and even citizens. It also addresses the ability to access, process, analyse, integrate, visualise and manipulate these data for applications and insights across many areas of society. Spanning 232 different Indicators over 15 years, and relating to every country on the planet – rich and poor – we might consider the SDGs and associated Global Indicator Framework as the EO Big Data challenge of our time.

The underlying technical advances behind Big Data include network connectivity, availability of cloud computing solutions for data storage and processing, easy access to data analysis techniques, and increasing free and open access to geospatial, statistical, and EO datasets. All of these technologies and the associated data must be accessible and useable by all countries, irrespective of their capacity, if the 2030 Agenda is to succeed. A number of challenges must be addressed along that path.

5.1 Effective partnerships

The multi-disciplinary nature of the data challenges associated with implementing the 2030 Agenda and the Global Indicator Framework will dictate new levels of cooperation among a broad range of stakeholder communities. Custodian Agencies have the task of supporting countries with their reporting against Indicators. National statistical and mapping agencies will require guidance regarding suitable methodologies, as well as access to and application of geospatial and EO data, and their integration with their traditional statistical datasets. CEOS, GEO and EO data providers of all sizes must work alongside these national agencies and the appropriate Custodian Agencies if such progress is to be realised. Practical methods and structures should also be implemented for countries at all levels of capacity to be able to report in a consistent and comparable way and with guaranteed supply of suitable data over the span of the 15 year Agenda.

The UN Global Working Group (GWG) on Big Data for Official Statistics is exploring the potential of satellite imagery and geospatial data, including how to make use of existing methods for estimating official statistics at high temporal and spatial resolutions. Both CEOS and GEO have established processes aimed at ensuring readiness and support for the SDG framework and can provide practical guidance as required to national and UN agencies. GEO's EO4SDG works closely with the GPSDD to help countries align their national priorities to the SDGs and implement data roadmaps for sustainable development.

Without functional partnerships of this kind among stakeholders, the necessary data will not flow to where it is required and countries will not have the guidance necessary to integrate the data with their traditional statistical sources and techniques to support the reporting that the 2030 Agenda requires.

One current example of the need for such partnerships lies in the efforts of space data providers, through their coordination body CEOS, to ensure that the on-going update of the guidance from the Intergovernmental Panel on Climate Change (IPCC) to countries seeking to report on their national greenhouse gas (GHG) emissions reflects the latest available EO techniques and all available geospatial datasets.

A number of governments have already made and plan significant investments in GHG-observing satellite missions and would like to ensure that national reporting by countries participating in the Paris Agreement take full advantage of these modern capabilities.

The IPCC Guidelines were first developed in 2006 and will be updated by 2019. CEOS will work with a range of stakeholders – including GEO, WMO, the Global Climate Observing System (GCOS), the UN Framework Convention on Climate Change (UNFCCC) and IPCC – to ensure a full and thorough understanding of the potential role of satellite data in these Guidelines and its role in effective implementation of the Paris Agreement. Close cooperation is also required with NSOs for the development of methodologies for effective application of that data by countries in their reporting.

5.2 Data democracy

Underlining the fundamental role of data in support of the 2030 Agenda, the First UN World Data Forum was held in early 2017. This resulted in *The Cape Town Global Action Plan for Sustainable Development Data* that calls for a commitment by governments, policy leaders and the international community to modernise national statistical systems, disseminate data on sustainable development, build partnerships and mobilise resources.

With the recognition that data is at the heart of the SDGs comes the reality that the least-developed countries will have the most difficulty with the related institutional and technical challenges. Significant impediments remain in the provision of sustainable information infrastructures, both for accessing geospatial and EO data and translating it into information for decisions.

Yet the trends behind Big Data continue to lower some of the hurdles facing national mapping agencies and NSOs and their access to, and handling of, large and complex geospatial datasets:

- cloud storage and increased computing capabilities may bypass the need to develop and maintain large, centralised geospatial systems in countries where this may be difficult, akin to the way in which mobile phone penetration has leapfrogged the lack of fixed telephone line infrastructure in some developing countries;
- an increasing number of satellite EO datasets are free and open and all countries may benefit from the significant investment in the space-based infrastructure;
- more than 4 billion people, mostly in developing countries, still have no access to the internet and the benefits of connectivity; universal internet access is recognised as an important part of the SDGs and some of the world's

largest technology companies have committed to its realisation in the coming years.

5.3 EO data complexity and access

Satellite EO data presents unique opportunities for countries to engage in the SDGs. But there are some significant technical challenges, such as the sheer volume of data and our capacity to integrate different data streams, including the combination of geospatial data with traditional national statistical data. Space data providers of all kinds, including public-good agencies and commercial data and value-added information providers, are exploring new strategies for managing the enormous data volumes and for the extraction of the underlying information so that users of all types and size (and not just highly specialised and large institutions) can access and analyse satellite data.

On-line virtual laboratories – such as Google Earth Engine, the Copernicus Data and Information Access Service (DIAS), ESA's Thematic Exploitation Platforms (TEPs), NASA's Earth Exchange, and Descartes Labs – are changing user expectations and stimulating moves towards *'bringing users to the data'* and providing simpler formats and means of analysis.

Many users do not have the financial or technical capacity required to undertake the data handling, calibration and processing involved in extracting the information they need from EO satellite data. Space agencies specialise in these skills and it makes sense for them to bring their data to the maturity level needed to make it 'analysis ready' (for

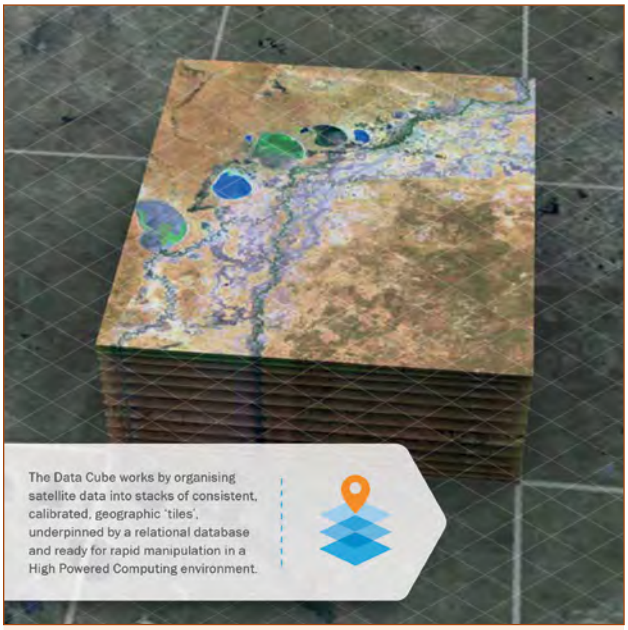

Figure 1: The Open Data Cube

extraction of information by most users and for most uses). By providing value-added services and applications, private companies also play a key role in bringing the potential of EO data to the end users.

All of the major space agencies with EO satellite programmes are actively engaged in initiatives to reduce data complexity and broaden access to its benefits. At an international level these efforts are being coordinated and enhanced by the CEOS strategy on Future Data Architectures that includes:

- CEOS Analysis Ready Data standards and demonstrations of user value;
- exploration of open source platforms – such as the Open Data Cube – for removal of data handling and analysis complexity; the Open Data Cube provides a collaborative infrastructure for many possible users and uses; basic handling, calibration and processing of the EO satellite data are undertaken in a standardised way – once – and made openly available for the benefit of all prospective users and all prospective data providers;
- closer attention to understanding of user needs and obstacles.

Such strategies must include reflection on the needs of the SDG stakeholders, including the NSOs, if the requirements of countries reporting against the Global Indicator Framework are to be properly addressed.

5.4 Data continuity

National mapping and statistical agencies recognise the potential for new types of datasets to revolutionise their ability to assess and track a broad range of indicators for their countries. But they must take a suitably conservative view when planning the evolution of their systems and processes to ingest and integrate such new data. These agencies need confidence that there will be continuity over years and decades for any new data streams before making investments in new systems. This requires satellite EO data providers to provide clarity as to the outlook for continuity in their planning for replacement of satellite missions.

Analysis shows that the average lifetime for governmental EO satellite missions is increasing – now around 7 years – thanks to advances in technology and experience in operations. At the same time, space agencies have recognised the need for confidence in data supply to stimulate investment by users in exploitation of the data stream. Much like the planning for safety-critical weather

Figure 2: The Sentinel satellite series of the Copernicus Programme is funded to offer continuity out to 2030

satellites to ensure uninterrupted data supply, we are seeing more EO satellite programmes designed to ensure redundancy through parallel/overlapping operation of identical satellites and funding of mission series far into the future. The US Landsat programme has provided 45 years of continuous land surface imaging since 1972. In Europe, the Sentinel series of optical, radar, ocean and atmosphere sensors foresee continuous data supply for a range of measurements through to 2030 and beyond through the Copernicus Programme.

The long-term continuity provided by these programmes enable countries to plan with confidence the integration of their data into national statistical systems for the SDGs and a multitude of other national purposes.

5.5 Leave no one behind

A core commitment of the 2030 Agenda is to support the poorest and most under-represented, ensuring that no one is left behind. Ensuring that this principle is met and translated into effective action requires an accurate understanding of target populations and their vulnerabilities by governments and the international community. This also has profound implications for the global data community, comprised of NSOs, data specialists across Ministries and the Custodian Agencies, as well as the EO and geospatial data community, civil society and the private sector.

Space agencies have agreed to work in cooperation, through CEOS, to continue their resolve to enable more countries to be able to use more satellite data for more of their national challenges. This includes further efforts to provide free and open data and to reduce data access and complexity challenges.

Further information

UN Global Working Group on Big Data:
unstats.un.org/bigdata

And its task team on Satellite Imagery and Geo-spatial Imagery data:
unstats.un.org/bigdata/taskteams/satellite

UN World Data Forum:
undataforum.org

Open Data Cube:
opendatacube.org

Landsat:
landsat.usgs.gov

European Union's Copernicus Initiative:
copernicus.eu

Copernicus Sentinel Satellites:
sentinel.esa.int

ESA Thematic Exploitation Platforms (TEPs):
tep.eo.esa.int

NASA Earth Exchange (NEX):
nex.nasa.gov

Google Earth Engine:
earthengine.google.com

Descartes Lab:
descarteslabs.com

6

Where to Find EO Data and Help

Part II of this Handbook provides a broad range of examples and articles from different institutions on the challenges and opportunities regarding the role of EO data in support of realisation of the SDGs and their Global Indicator Framework. Hopefully, NSOs with ambitions to monitor progress towards their Targets and report on Indicators, and Custodian Agencies – responsible for the development of methodologies for the Indicators and for supporting countries in their implementation – can find inspiration for further exploration around application of EO data to their task.

Before proceeding to Part II, interested readers may welcome some guidance as to identifying the necessary EO data and expert advice on its application for their required purpose. Part II provides more detail on some specific EO applications and individual contacts and links for further information can be found within the articles. Below are some more general contacts and resources for institutions and individuals with an interest in the use of EO data for the SDGs.

CEOS Team for the SDGs

CEOS has established an international team dedicated to progressing the role of EO in the SDG framework and dedicated to coordinating CEOS agency activities related to the SDG framework. This team is the natural interface and point of entry for users seeking to establish a better understanding of which satellite data they might acquire in support of their objectives, where such data is available, and how it is best processed and applied. The CEOS Team for the SDGs can also help stakeholders with access to on-line platforms, tools, and datasets.

CEOS represents all of the major, civil, EO satellite programmes worldwide and is the gateway to more than 30 national space agencies operating hundreds of different observing satellite missions. The CEOS Team for the SDGs can provide neutral and comprehensive advice as to the most suitable data and methodologies in support of different Goals and Indicators. The CEOS Team may be contacted at:

sdg-leads@lists.ceos.org

ceos.org/sdg

Free and open datasets

EO satellite data from CEOS Agencies is available on a wide range of terms depending on the data policies of the respective government. An increasing number of satellite missions have a free and open data policy (consistent with the Data Sharing Principles pioneered by GEO), sometimes requiring no more than a simple user registration for access to the relevant information system or portal. Of these, the largest data archives and global coverage missions can be found online at:

Landsat:
earthexplorer.usgs.gov

Copernicus Sentinels Open Access Hub:
scihub.copernicus.eu

Copernicus services:
copernicus.eu/main/services

NASA missions:
earthdata.nasa.gov/earth-observation-data

NOAA Satellite and Information Service:
www.nesdis.noaa.gov/content/imagery-and-data

EUMETSAT mission data:
www.eumetsat.int/website/home/Data/DataDelivery/OnlineDataAccess/index.html

JAXA mission data:
www.eorc.jaxa.jp/en

The CEOS Database of Missions, Instruments and Measurements has details of all CEOS agency satellites and links for further information and data download:

database.eohandbook.com

Specifics on data accessibility and policies can be found here: **www.ceos-datapolicy.org**

GEO EO4SDG

CEOS works within the GEO framework – which includes data providers such as space agencies, governments, UN agencies including several SDG Custodian Agencies, and International Finance Institutions (such as World Bank) – to promote the necessary coordination and collaboration related to EO aspects of the SDGs. GEO has established a dedicated initiative and team for this purpose: EO4SDG. This team may be contacted at:

email: **secretariat@eo4sdg.org**

eo4sdg.org

GEO also provides a portal for the discovery and access of a huge range of geospatial datasets. The GEOSS Portal is available at:

www.geoportal.org

Part II

Perspectives on EO for the SDGs

Perspectives on EO for the SDGs

Part II of this Handbook comprises a range of articles by a variety of different organisation types related to the SDGs and to the role of EO data in particular. Each of these articles is intended to be a stand-alone narrative and they may be read in any order. It is hoped that readers might identify with one or more of the author viewpoints in support of their own circumstances and plans. These include:

- the UN System and its role in ensuring optimal application of EO data for different aspects of the SDGs;
- National Statistical Organisations (NSOs) and their inspiring efforts to apply EO for their national statistics generation;
- Custodian Agencies promoting the use of EO applications in the methodology guidelines of the SDG Indicators for which they are responsible;
- EO data and information providers and their coordination bodies;
- non-governmental organisations that have recognised the importance of EO data and its potential for the SDGs and are working to ensure the necessary connections; and,
- international financing organisations seeking to ensure that development aid projects get the full benefit of EO data capabilities.

The articles are arranged in the following way to help readers identify those of most relevance to their particular circumstances.

The UN System

1. The Role of Geospatial Information and Earth Observations in the SDGs: A Policy Perspective
2. Earth Observation for Ecosystem Accounting

NSOs and their use of EO

3. Forging Close Collaboration Between EO Scientists and Official Statisticians – An Australian Case Study
4. Monitoring the 2030 Agenda in Mexico: Institutional Coordination and the Integration of Information

Custodian Agencies and their use of EO

5. Perspectives from a Custodian Agency for Agriculture, Forestry and Fisheries
6. The 'Urban' SDG and the Role for Satellite Earth Observations

EO Data Providers and Coordination Bodies

7. EO4SDG: Earth Observations in Service of the 2030 Agenda for Sustainable Development
8. Pan-European Space Data Providers and Industry Working in Support of the SDGs

Non-Governmental Organisations

9. The Rise of Data Philanthropy and Open Data in Support of the 2030 Agenda
10. Building a Demand-Driven Approach to the Data Revolution for Sustainable Development

International Financing Institutions

11. Environmental Information from Satellites in Support of Development Aid

The Role of Geospatial Information and Earth Observations in the SDGs: A Policy Perspective

Data, as the basis for evidence-based decision-making, will be critical to the success of the 2030 Agenda. The broad and transformative nature of the 2030 Agenda has ushered in a new era in thinking about sustainable development, with renewed emphasis on countries being able to measure and monitor progress with good policy, science, technology and especially data. The unprecedented data demands and expectations relating to the SDGs necessitate new and innovative data sources, acquisition and integration approaches, and the need for *"high quality, timely, reliable and disaggregated data, including Earth observations and geospatial information"* to address development challenges and to *"leave no one behind"*.

Goal 17, in the area of data, monitoring and accountability, requires us by 2020 to *"support developing countries to increase significantly the availability of high-quality, timely and reliable data disaggregated by income, gender, age, race, ethnicity, migratory status, disability, geographic location and other characteristics relevant in national contexts"*. But do we really even understand the scale and dimensions of the world's development problems, where they are, whom they impact, what the causes and consequences are, and how they can be remedied, let alone how to bring the data to bear to measure and monitor these complex and geographically interconnected problems?

1.1 Global Indicator Framework: measuring, monitoring and reporting on the SDGs

The 17 SDGs and 169 Targets provide the overall policy and results framework for the 2030 Agenda, but in terms of a robust and annual follow-up and review mechanism for its implementation, it is the Global Indicator Framework where the data acquisition, integration and disaggregation will be most needed. The task of determining the Global Indicator Framework was given to the UN Statistical Commission (UNSC). In 2015, the UNSC established the Inter-agency Expert Group on Sustainable Development Goal Indicators (IAEG-SDGs) to develop the Global Indicator Framework as the quantitative means by which national governments can consistently monitor achievement on, and report progress towards, each of the 169 Targets. In July 2017, the Global Indicator Framework was adopted by the General Assembly and comprises an initial 232 Indicators, which will be reviewed from time to time.

The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) and the Group on Earth Observations (GEO) worked closely with the statistical community, at a national and global level, to provide inputs into the processes to develop the Global Indicator Framework with the IAEG-SDGs. As depicted in Figure 1, key messages were that, while global in nature, implementation of the 2030 Agenda will still need to be *'country owned and country led'* and through national development policies, strategies and frameworks. Through this process, statisticians now better understand that measuring and monitoring will require not only statistics, but also geospatial information, EO and other Big Data to provide new and consistent data sources and methodologies to integrate multiple 'location-based' variables to support and inform official statistics and the Indicators for the SDGs.

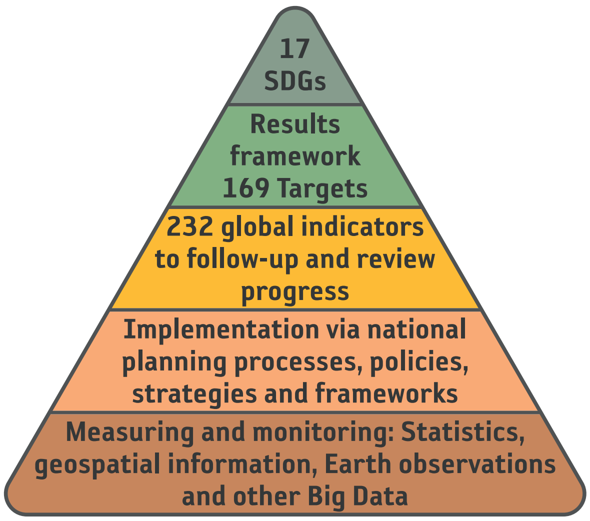

Figure 1: Measuring, monitoring and reporting on the SDGs will require new sources of data that are integrated, interoperable and coordinated.

By bringing together information from various sources, particularly those related to the environment, these data and analytical methods can fill data gaps and/or improve the temporal and spatial resolutions of existing data. This information integration is important, as the Indicator Framework will be the primary conduit to guide and inform Member States, based on individual national circumstances, on how they measure, monitor and report on the SDGs and related targets in the years to come. However, determining the Indicators is just the beginning, as they need to then be appropriately interpreted and implemented via national planning processes and frameworks, and guided by robust metadata and multidimensional data needs. Such data have the real potential of forming a new and emerging 'data ecosystem' for development, in which integrated information systems that are comprehensive and coordinated are able to monitor the state of the Earth, people and planet, and to deliver timely information necessary to citizens, organisations and governments to build accountability and make good, evidenced-based decisions from local to global levels.

To address these issues and specific areas relevant to SDG Indicator implementation, the IAEG-SDGs established a Working Group on Geospatial Information (WGGI) at its third meeting in April 2016. The WGGI – comprising statistical, EO and geospatial experts from national governments, academia and international organisations, including GEO – provides expertise and advice to the IAEG-SDGs and the broader statistical community as to how geospatial information, EO and other new data sources can reliably and consistently contribute to the indicators. The Working Group has now met four times and reports and provides updates to the IAEG-SDGs, the UNSC and UN-GGIM. There is also a close working relationship between the WGGI and the GEO Earth Observations in Service of the 2030 Agenda for Sustainable Development (EO4SDG) initiative.

1.2 Geographic location: the relationship between people, their place and their environment

While the initial development of the Global Indicator Framework largely constituted a statistical data approach, the need for 'disaggregation by geographic location' in a new era of data needs is now well recognised by the IAEG-SDGs to ensure that no one is left behind (Figure 2). This is part of the mind-set change reflected in the 2030 Agenda; development is no longer only knowing about 'people' as national aggregations, but also their 'place' and their environment, their geographic location at a sub-national level. This then cascades into more detail. While having data that informs on the 'how' and the 'what' is valuable, such as how many primary schools are needed or what vaccines are being provided and in what volumes, it is profoundly better if we are able to also know the 'where' in order to provide geographic context and a richer understanding.

The effective use and integration of EO and geospatial technologies, combined with statistical and demographic data, enable countries to analyse and model where conditions are changing; create maps and other visualizations; evaluate impacts across sectors and regions; monitor change over time in a consistent and standardized manner; and improve decisions, policy and accountability. These outcomes can have a transformational impact on many of humanity's most significant challenges in the developing world, such as helping global scientists, resource and planning managers and politicians better monitor and protect fragile ecosystems; ensure resilient infrastructure; manage climate risks; enhance food security; build more resilient cities; reduce poverty; and improve governance. Data is essential for informed policy-making, decisions and actions. Data allows us to know the how, what, when and where for the successful implementation and monitoring of the SDGs.

However, we still need to democratize these technologies and liberate the associated new and alternative data sources and methodologies in such a way that they are easily reachable and useable by developing countries. To succeed in our global development aspirations, we need to go beyond the developing countries to reach the poorest of the poor in the least developed countries. Historically, relatively little attention has been paid to the challenges these countries face in effectively collecting and producing data and in building and strengthening their capacities within the national mapping agencies and statistical offices. With the enabling global mechanism of the 2030 Agenda, the challenge is how to most effectively transfer the available technology, data richness and connectivity to the technology and data poor.

Figure 2: Sustainable data for sustainable development – the new data needs demand disaggregation by geographic location in order to ensure that no one is left behind.

1.3 The problem: where is the data?

In the second annual report on global sustainable development progress: *Sustainable Development Goals Report 2017*, released in July 2017, the United Nations Secretary-General stressed that high-level political leadership and new partnerships will be essential for sustaining momentum, underscoring the need for reliable, timely, accessible and disaggregated data to measure progress, inform decision-making and ensure that everyone is counted. Two years into reporting progress on the SDGs, the Global Indicator Framework has been determined and the production of Indicators for the review and follow-up on the implementation has begun in earnest. Against this backdrop, how are we progressing, what is the role of geospatial information and EO, and where is the sustainable data for sustainable development?

Firstly, let us consider the availability of EO and geospatial 'data' needed to measure progress, inform decision-making and ensure that everyone is counted. More observations and geospatial data are being acquired and made available than ever before, with petabytes being generated every day and growing exponentially. But are we yet bringing the science and data into the development processes in a timely and reliable manner – are we 'industrializing' our capabilities? Perhaps not yet. Unfortunately, phenomenal data volumes, computing gains and processing speeds does not necessarily, or easily, translate into useable information, knowledge and decisions at the fingertips of decision-makers. Further, while the most developed countries are grappling with an abundance of data, a data deluge, in many parts of the world data scarcity is still the norm. Additionally, the data deluge is not being matched by our ability to apply the appropriate analytics and modelling in a commensurate manner in order to make informed and timely decisions. This particularly applies to the Earth sciences and environmental modelling, which are incredibly complex systems in themselves. In order to be robust and rigorous, there is either a long time lag in analytical outcomes or a compromise in quality. Then when the data is available, there are still data access and discovery challenges – it may be incomplete; distributed across multiple agencies; not accessible, interoperable or standards based; and then there is the reality that, with such big datasets, internet bandwidth remains a major impediment for developing countries.

This brings us to the continuing policy dilemma. The EO and geospatial information environment is one that is dynamic, innovative and growing at a rapid rate in data quantity, quality and applicability. Advancements in acquisition techniques and technologies have led to the proliferation of sensors that collect information on smaller platforms, at higher resolutions and repeat rates, faster and in larger volumes. Billions of dollars in space infrastructure, with public and private sector investments, are being realized, giving the world the capability to provide sophisticated, continuous and sustained observations of the entire planet. Practitioners and scientists are familiar with the application of these observations to the task of forecasting, tracking, and alerting society, but this is still not well understood within governments at the policy level when it comes to providing practical development solutions and outcomes.

An impediment continues to be demonstrating how we translate and communicate our data inputs and real-time monitoring into intelligent information outputs that are both understandable and actionable at all levels – from local to global – and which provide a means to make consistent evidence- and science-based decisions. There is no denying that EO and geospatial information are essential operational tools, but still seen as a novelty when it comes to policy and decision-making. Therefore, how do we make these capabilities necessary and invaluable – to the point that countries cannot make decisions without their inputs – forming a new and emerging data ecosystem for development?

1.4 The solution: connecting policy with 'data' through the SDGs

Many countries still need considerable guidance and support as to how they can actively contribute to the implementation of, and track progress on, the SDGs. While there is an increasing realization of the relevance and application of EO and geospatial information for the production of specific Indicators, and more so when we consider data disaggregation and sub-national data, we need to be more aspirational and proactive to strengthen countries' capabilities in integrative national information systems that facilitate and enable a growing data ecosystem that leverages an accessible, integrative and interoperable local-to-global system-of-systems.

While the global Indicators presently provide the national to global reporting outcomes, the future success of the global development agenda will be dependent on data – not whether it is statistical, EO, geospatial, environmental, economic, health, demographic, education or other data – just data! As we are seeing with consumers and users in civil society, it may no longer be a necessity for governments to know exactly where the data they are using and consuming has come from or who has generated it. They will just want assurances that it is authoritative, reliable, repeatable, the best available and fit-for-purpose to make the right decisions and policy. Such outcomes will require data to be more open, platforms to be more usable, analytics to be more accessible and systems to be more integrated. If this is achieved, we will see fundamental EO, geospatial information, positioning infrastructure, policy frameworks, institutional capacity and economic development moving up the value chain in all countries, including at the policy level.

The future reporting needs of the Global Indicator Framework will have to consider disaggregated data, from the sub-national to national level, while also allowing for aggregated global reporting that builds directly on the national data developed by countries, as well as that from custodian agencies. Additionally, national level indicators will be developed by countries, and likely not be produced by each country in the same way. The good news is that the statistical community is familiar with data aggregations and national data, while the EO and geospatial communities are familiar with data disaggregation and sub-national data. With a unique understanding of context and circumstances, and allowing for incremental improvement, our combined professional expertise is well positioned to contribute to measuring and monitoring the SDGs and tracking annual progress with EO and geospatial information.

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Further information

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http://ggim.un.org

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2

Earth Observation for Ecosystem Accounting

Ecosystem accounting is a new and emerging area of statistics that can inform the 2030 Agenda for Sustainable Development. The System of Environmental-Economic Accounting (SEEA) Central Framework, adopted as a statistical standard in 2012, measures how the economy uses the environment as input in the production process through the extraction of natural resources, how it impacts the environment through the release of emissions to water and air as well as solid waste. The SEEA Central Framework is complemented by the SEEA Experimental Ecosystem Accounting (SEEA EEA), which measures the functioning of ecosystems in relation to human activities.

This article provides examples of how the integration of EO data with statistical data in an internationally agreed statistical framework underpinned by an agreed system of classifications for land cover, land use and ecosystem types ensures coherent, consistent and comparable measures. This in turn has an impact on the derived indicators, including the SDG Indicators, which are accurate and comparable over time and across countries. In particular, it provides examples on compiling ecosystem extent, carbon and water accounts.

2.1 Introduction

The SEEA EEA, ecosystem accounting in short, presents the basic accounting framework to measure the extent and condition of ecosystems and the flows of ecosystem services to the economy and, broadly, to humanity. Together, the SEEA Central Framework and the SEEA EEA provide a coherent and integrated approach to the assessment of the economy-environment nexus, thus providing an important framework in support of sustainable development analysis and policies.

Ecosystem accounting is unique in the spatial or geospatial reference it provides to the accounts. It has been made possible by the ease of access and use and increased accuracy of a range of spatially explicit data sources, such as EO data, in the form of satellite and aerial images, among others. The EO data combined with the accounting structure facilitates the integration of environmental information with economic statistics to depict the contributions of the ecosystems and the impacts of economic activities on the ecosystems. They give an indication of the extent and condition of – and services provided by – ecosystems, contributing to the decision-making on ecosystem management, including the allocation of resources to preserve or improve their status. Ecosystem accounting can be undertaken at any scale – country, region, province, river basin, protected area and so on. However, the link with the economic accounts can only be done at scales where economic information is available.

2.2 Ecosystem Extent Accounts

Ecosystem extent accounts organise information on the extent or area of the different types of ecosystems that exist within a country or region. Land cover data, classified according to the SEEA Central Framework standard classification and complemented by additional

System of Environmental-Economic Accounting Experimental Ecosystem Accounting (SEEA EEA).

The main goal of SEEA is to establish the link between the environment and the economy in a consistent, comparable and coherent manner. The SEEA EEA starts from the perspective of ecosystems and links ecosystems to economic and other human activity. In particular, it brings the spatial dimension into environmental accounting and the need to link statistical accounts to geospatial information and Earth observation.

The SEEA EEA is underpinned by a set of accounts and tools, as shown below. The main accounts of extent, condition, and ecosystem services are complemented by thematic accounts of land, water, carbon and biodiversity, altogether supported by tools, such as classifications, spatial units, scaling and biophysical modelling.

SEEA EEA Accounts, Tools and Linkages

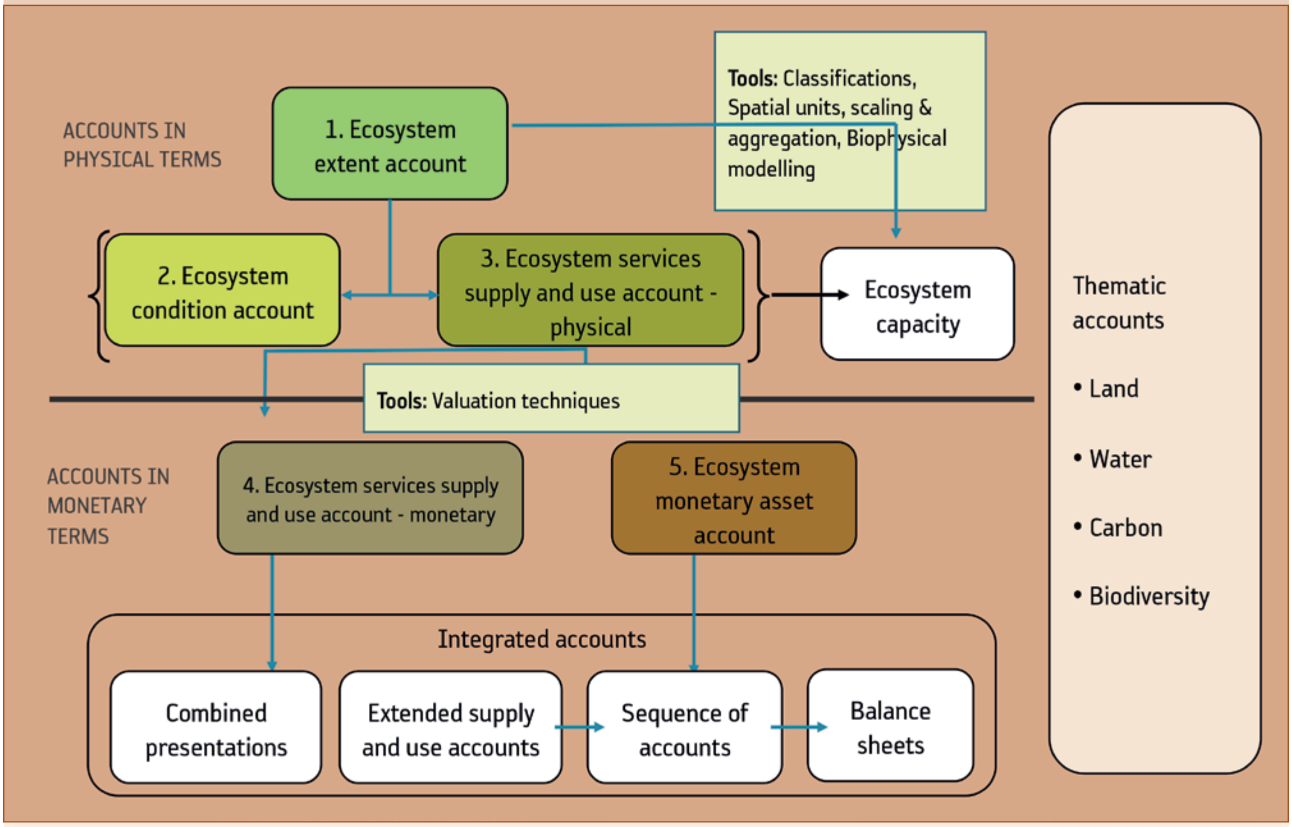

Figure 1 from: 'Technical Recommendations in support of the System of Environmental-Economic Accounting 2012 – Experimental Ecosystem Accounting'. The white cover publication was published in December 2017. (https://seea.un.org/sites/seea.un.org/files/technical_recommendations_in_support_of_the_seea_eea_final_white_cover.pdf)

characteristics such as land use, elevation and ecosystem services provided, helps to further classify the land according to ecosystem types. Land cover accounts are directly linked to several SDG Indicators, including **Indicator 15.3.1 on land degradation, Indicator 6.6.1. on freshwater ecosystems, or Indicators 11.3 and 11.7 on land use**. Ecosystem extent accounts supporting these Indicators are usually compiled by using EO data combined with statistical observations and ground truthing. Examples in Brazil and Nepal of land cover and use accounts are provided below. Additional examples are provided by Mexico in their article in this Handbook. The ecosystem extent account in Mexico is used in support of providing information for the monitoring of SDG **Indicators 15.1.1 and 15.3.1**.

Example 1: Land-cover and land-use changes in Brazil

The Brazilian Institute of Geography and Statistics (IBGE) has carried out a project using EO techniques to detect changes in land-cover and land-use. These changes are represented through the change in proportion of cover and use classes measured in time and space. Tracking these changes over time provides an analysis of the changes in the extent of ecosystem assets, changes in landscapes and the impact of such changes on the provision of ecosystem services.

The work involved the acquisition, conversion, enhancement, segmentation and classification of MODIS (Moderate Resolution Imaging Spectrodiameter) images with 250m resolution, from the TERRA and AQUA satellites. Subsequently, matrix editing to correct possible imperfections required the use of other sources of information, such as thematic maps and statistical data, as well as input of data on deforested areas and data from the agricultural census.

This work produced three land-cover and land-use maps for the three periods analysed (2000–2010, 2010–2012 and 2012–2014) and class changes by overlying these maps. The class changes allow tracking and analysing changes of overall classes or transition between specific classes. Figure 2 shows the land-cover/land-use map of the State of Rondonia in Brazil for 2010 and 2014.

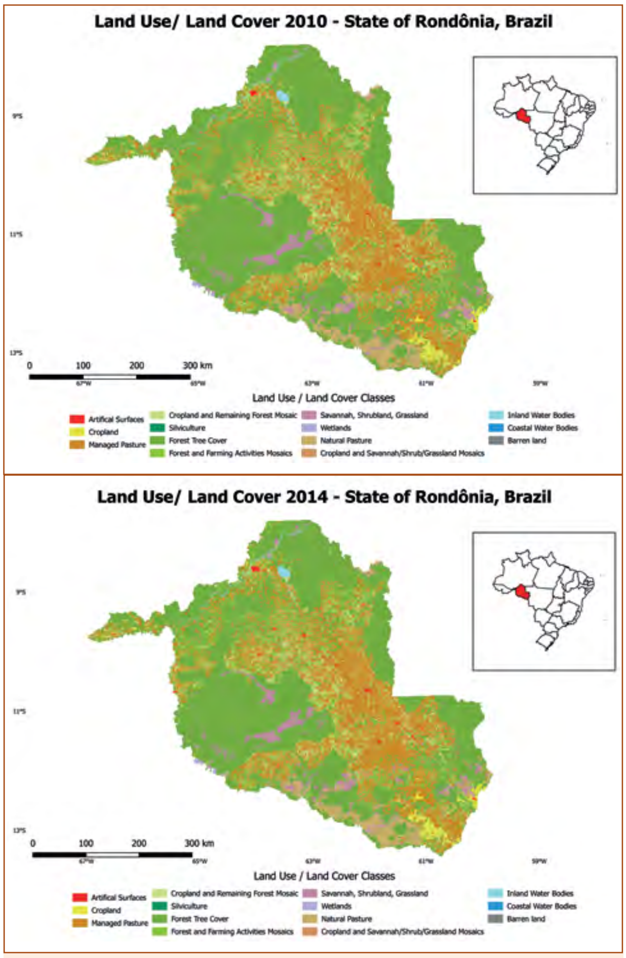

Figure 2: Land-cover/land-use in the State of Rondonia, Brazil.
Source: Brazilian Institute of Geography and Statistics (IBGE), 2017

Example 2: Land cover in Nepal

Nepal is landlocked and challenged by many environmental concerns that are directly related to its topography, including deforestation, natural disasters, climate change and urbanisation. With the technical assistance of the Economic and Social Commission for Asia and the Pacific (UNESCAP), the Central Bureau of Statistics (CBS) has developed land and forest accounts based on the SEEA for 1990, 2000 and 2010 in order to understand and manage the environmental impacts. The existing land-cover maps were produced by the International Centre for Integrated Mountain Development (ICIMOD) by locally correcting Landsat satellite imagery from 1990, 2000 and 2010. Efforts are currently under way to address some discrepancies that were identified between the maps and the official total land area of the country. These discrepancies could be caused by the EO maps being collected during different times of the year, thus making the representation of the regression of glaciers unreliable, and the use of different concepts and classifications when the various maps were produced. An interdepartmental working group was established with the objective of adopting common concepts and classifications on land-cover/land-use and developing an agreed single map at the country level.

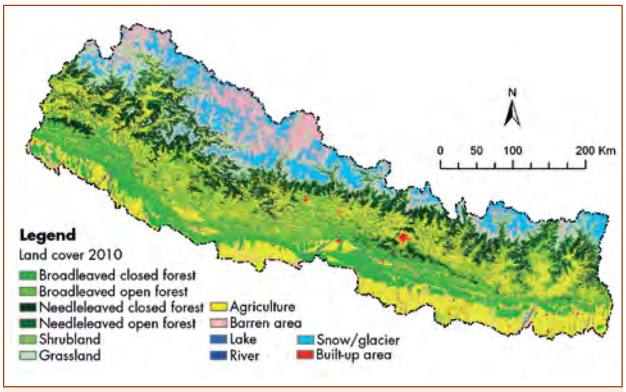

Figure 3: Land-cover map of Nepal.
Source: Uddin et al. 2014

2.3 Water accounts

The SEEA EEA includes thematic accounts for water, carbon and biodiversity. Thematic accounts are compiled across different ecosystem types to support assessments for specific management purposes including land management and planning, and water resource management.

Ecosystem services related directly to water include the provisioning of water, in terms of volume of water used for different purposes (e.g., drinking, irrigation, cooling, hydropower generation, etc.); water regulation (e.g., filtering pollutants or regulating water flow); and cultural services such as for recreation (e.g., swimming, boating). This information is of crucial importance for the monitoring of SDG 6 on water availability and sustainable management of water. The example in the Netherlands shows how water accounts can support the monitoring of **Target 6.4**.

Example 3: Monitoring of Target 6.4 in the Netherlands

Indicators in relation to SDG Target 6.4 focus on **water use efficiency (6.4.1)** and **water scarcity (6.4.2)**. Data for these two Indicators can be obtained from different sources, among them statistical sources, model-based data and EO data. In particular, the estimation of actual evapotranspiration (AET) is quite important for the measurement of water-related SDG Indicators, including measuring water use in agriculture and the availability of water. AET is defined as the sum of evaporation and plant transpiration from Earth's surface to the atmosphere and it can be calculated using algorithms that use EO data as a source.

In order to assess AET, a range of remote-sensing data is freely available (e.g., MODIS, Landsat, Proba-V and Sentinel-2), and several AET databases have been developed, such as MOD16 (NASA) and the Land Surface Analysis Satellite Applications Facility (LSA SAF). Statistics Netherlands has partnered with eLEAF, an EO analysis company, to produce an AET map for the Netherlands in order to obtain spatial and temporal resolution that is superior to data sources in the public domain. The resulting map is shown in Figure 4.

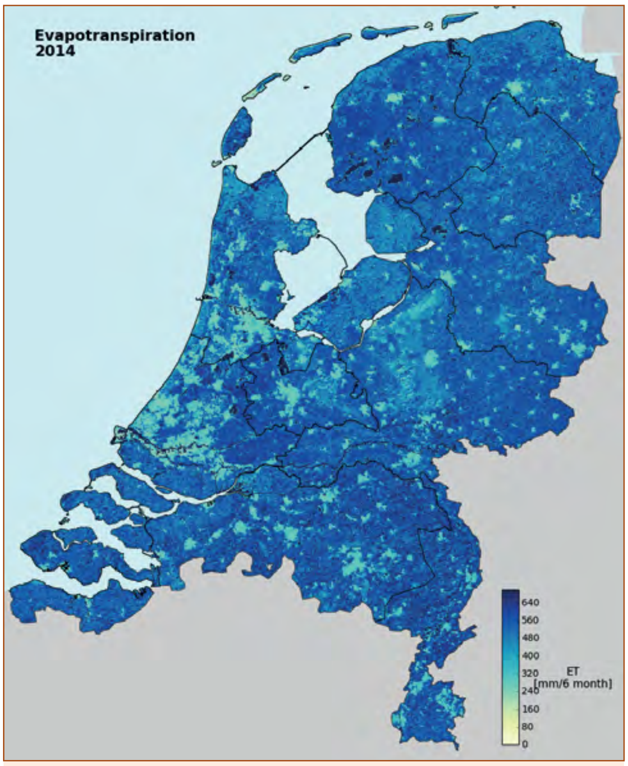

Figure 4: Actual evapotranspiration (in mm) for the Netherlands at a 250m resolution.

Source: Graveland et al., 2016

2.4 Carbon accounts

In the SEEA EEA, the scope of carbon accounting encompasses measurement of carbon stocks and flows for all parts of the carbon cycle and carbon pools. The measurement of stocks and flows of carbon can support discussion of many policy-relevant issues, including the analysis of greenhouse gas emissions, use of energy and extent of deforestation. As such, carbon accounting supports the measurement of several of the SDG Indicators, **including Indicator 15.3.1 that specifies carbon stocks** as one of the aspects of degradation of land. Carbon accounts can be compiled using existing land-cover maps, but also directly using EO data by using the Normalized Difference Vegetation Index (NDVI) or other techniques.

Recent methodological developments in remote-sensing techniques allow measurement of carbon stocks as well as changes in carbon stocks directly with adequate accuracy (see Figure 5). Such approaches may be important when alternative data sources and ground truthing is sparse.

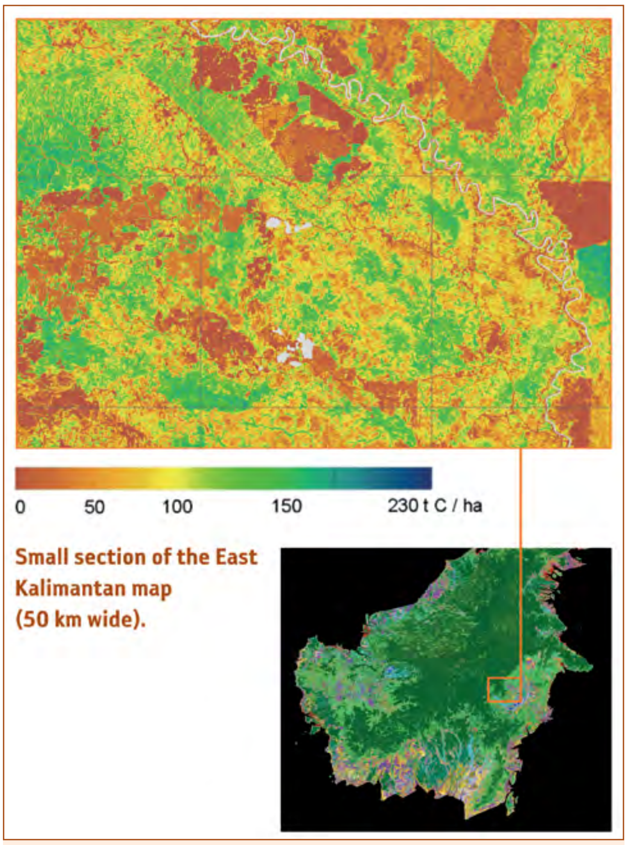

Figure 5: Biomass and carbon monitoring using EO data.

Source: SarVision, 2012

2.5 Conclusion

The examples above demonstrate that EO data are an important source in the construction of ecosystem accounting. The availability of EO data and its alignment with the requirements of environmental-economic accounting would further improve the access and use of EO data and would also improve the quality of ecosystem accounts. The growing partnership among the various communities of statisticians, Earth observation and geospatial specialists, scientists and economists will further improve the development of standards and in turn the usability, quality and policy relevance of data.

There is also scope for joint development of tools and standards, such as classifications and open source software tools to assist countries with the capture, processing and integration of data. The use of EO data for land-cover accounts would benefit from common land classifications agreed by various communities. In this context, the statistical community has on its research agenda the finalisation of the proposed preliminary classification of land-cover as well as the development of a system of classifications including land-cover, ecosystem types and ecosystem services, taking into consideration existing approaches and availability of source data, especially that from EO. This work is being undertaken as part of the international revision process of the SEEA EEA that has been recently launched with the objective of adopting international agreed concepts, classifications and methodologies for ecosystem accounting. The involvement of the EO community in this work is not only welcome but needed.

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The paper reflects the views of the authors and not those of the United Nations.

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Forging Close Collaboration Between EO Scientists and Official Statisticians – An Australian Case Study

EO data are increasingly being recognised by official statisticians as an important data source for the production of official statistics. Since the establishment of the UN Global Working Group on Big Data in 2015, the relationship between official statisticians and EO scientists has grown beyond Australian Bureau of Statistics (ABS) and Geoscience Australia (GA) in the use of EO data for environmental accounts, to include the Commonwealth Scientific and Industrial Research Organisation (CSIRO, a member of CEOS), other Australian Federal and State agencies and academics in the development of an EO Handbook for official statistics, and content for capacity-building workshops in Asia and Latin America. The positive experience in this collaboration not only increased the understanding of official statistics production and EO data sources, as well as its strengths and weakness, but also provides a pathway for more creative and productive use of EO data between official statisticians and EO scientists in the years to come.

3.1 Uses of EO data in Australia's official statistics

Australia's decision-makers need reliable information about changes in the use, condition and value of land and how this relates to broader economic activity and the state of our environment. This information is used in policy making and spending decisions in land management and economic development. Official statistics are well placed to provide this vital information by integrating geospatial and environmental data with a range of economic indicators.

The ABS uses the *UN System of Environmental-Economic Accounting Central Framework (SEEA)* to guide the production of data concerning the environment and economy. Land Accounts form the foundation of all environment-economic accounts, and the ABS has produced a series of Experimental Land Accounts across several jurisdictions in Australia. Rather than collecting the required data itself, the ABS sources and integrates data from a number of government organisations to produce these Land Accounts.

An important input to Land Accounts is data about land cover, both the biophysical cover and the built environment. Through the application of geoscientific expertise and capabilities, the raw satellite observations can be used to detect and map land cover.

The ABS currently works in partnership with GA, which is also providing EO services, expert advice and capabilities, and information for decision-makers, to realise the value of geospatial data and EO data to enhance the production of official statistics in Australia. A combination of high level engagement and technical collaboration has strengthened a productive and mutually beneficial inter-agency relationship. This national partnership has been critical in ensuring that GA's Dynamic Land Cover Data (DLCD), a consistent national dataset of land cover, has been available for the production of Experimental Land Accounts. The use of the DLCD time-series in Land Accounts provides a 'line of sight' between EO data and the information available to policy makers via statistical products.

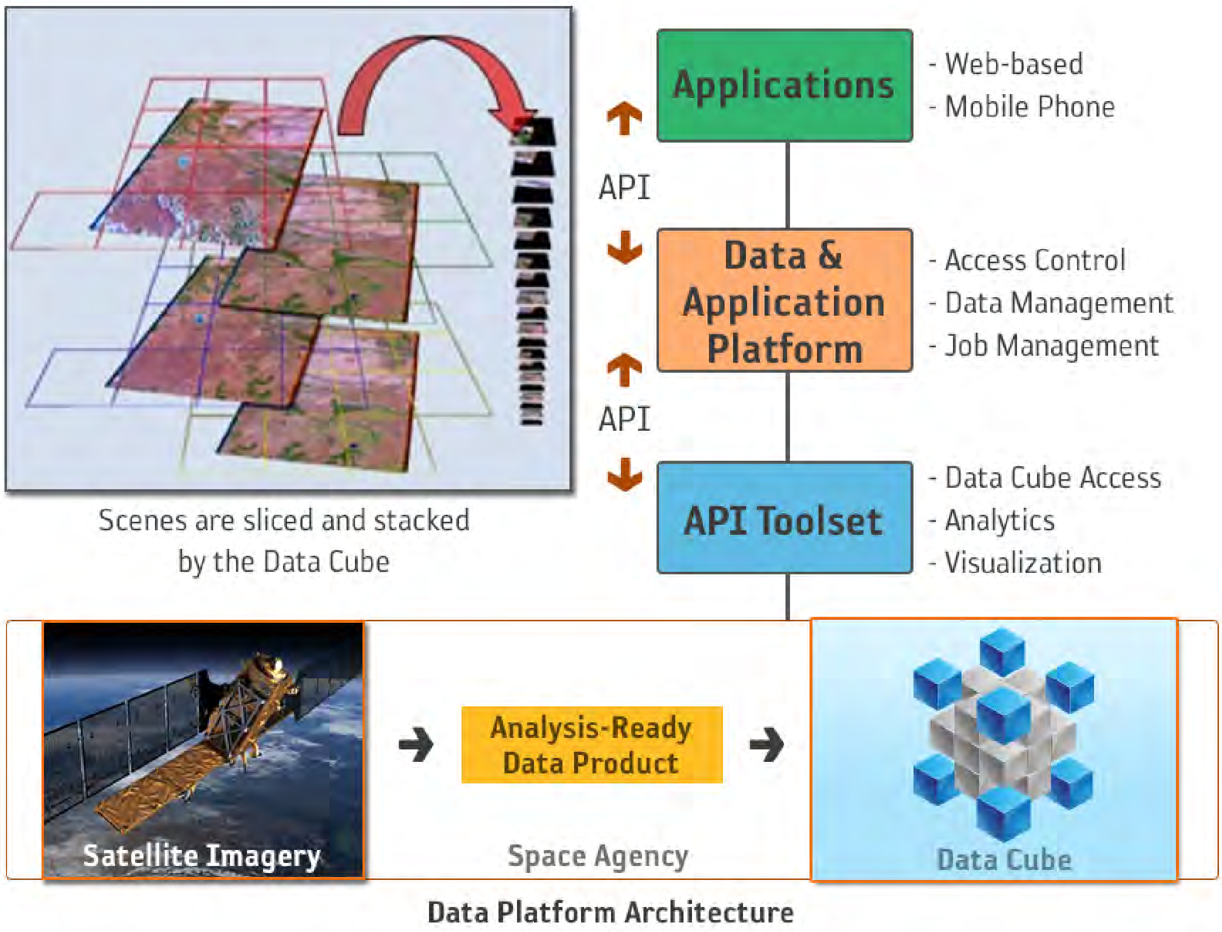

Figure 1: The Data Cube concept

This has also motivated GA to continue the production of DLCD. GA has worked closely with the ABS on the release of a new version of DLCD for Australia. This new data became available in time for the preparation of the *Land Account: Queensland, Experimental Estimates, 2011 – 2016* publication by the ABS, which was released in June 2017.

3.2 A global platform for collaboration

The UN Global Working Group (GWG) on Big Data for Official Statistics was created in 2014, as an outcome of the 45th meeting of the UN Statistical Commission (UNSC). In accordance with its terms of reference, the UN GWG provides strategic vision, direction and coordination of a global programme on Big Data for official statistics, including for indicators of the 2030 Agenda for Sustainable Development. It also promotes practical use of Big Data sources, while supporting capability building, training and sharing of experiences. Finally, the UN GWG fosters communication and advocacy of use of Big Data for policy applications and offers advice in building public trust in the use of Big Data from the private sector.

Between 2014 and 2017, ABS chaired the UN GWG and one of its Task Teams (TT), Satellite Imagery (EO data) and Geo-Spatial Statistics. Consistent with the strategic vision and direction of the GWG, the ABS TT decided at its early meetings to establish a work programme to share best practice in using EO data in the production of official statistics on agriculture and environmental accounts, and to host workshops in Asia and Latin America to help build the capability of Asian and Latin American National Statistical Offices in using EO data for official statistics.

In developing the TT Handbook on EO data, and in developing the content of the methodology workshops (a trial run of which was held in Canberra, Australia, in early 2017), official statisticians from ABS worked closely and collaboratively with EO scientists from CSIRO; GA; Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES); and Queensland Department of Science, IT and Innovation (DSITI); and academics from

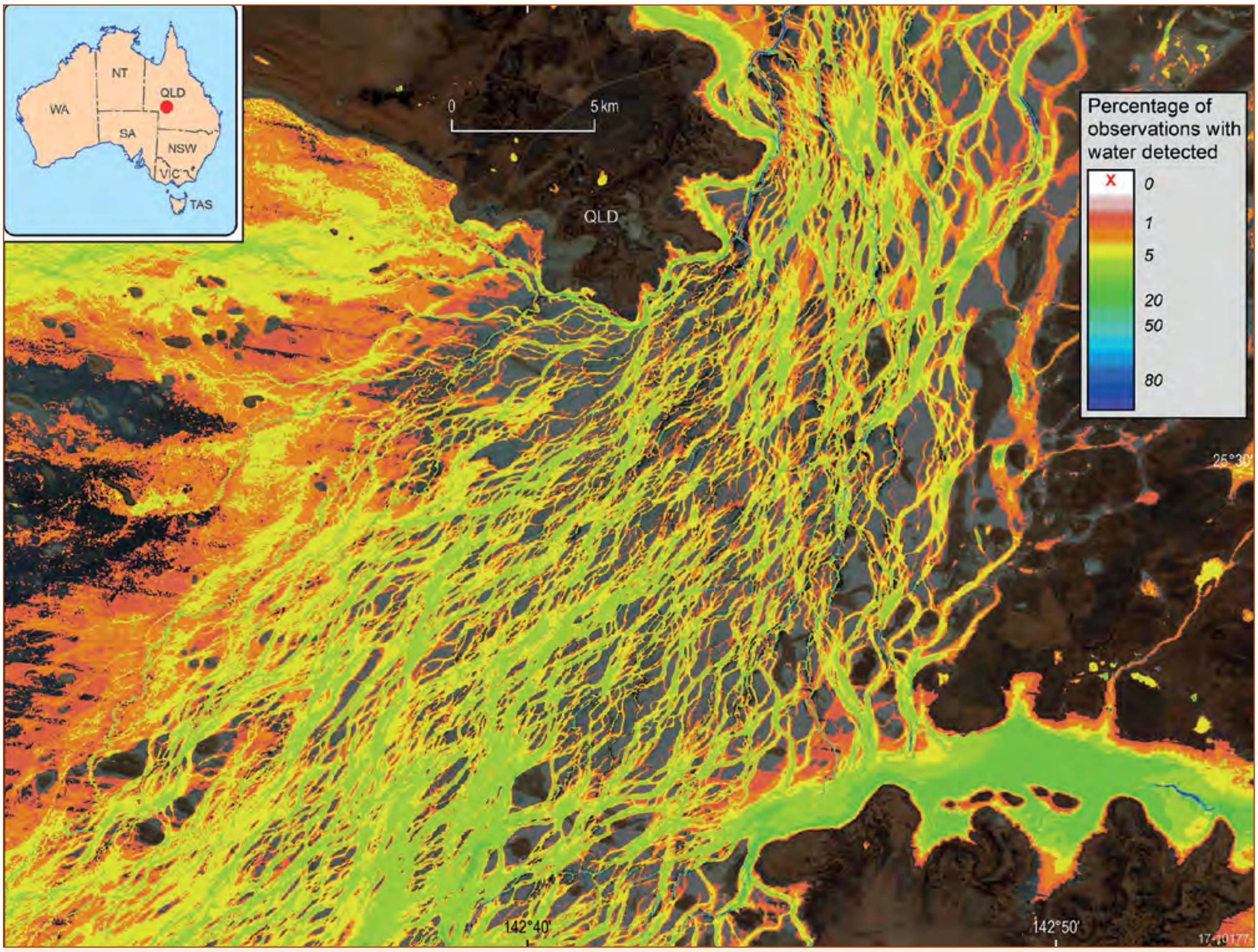

Figure 2: Water Observations from Space (WOfS) results for the braided river network of Coopers Creek in south-western Queensland, Australia

the Queensland University of Technology (QUT) chapter of Australian Research Council Centre of Excellence in Mathematics and Statistical Frontiers (ACEMS).

Throughout the Handbook, many case studies and examples are showcased. In particular, the SDG indicators were often referred to as examples, since they appear as a unique opportunity for EO and NSOs to work in close collaboration. As such, forest monitoring – and especially deforestation tracking to help achieve Goal 15 (Life on Land) – is an example where EO brings a unique contribution. The Global Forest Observations Initiative (GFOI) of GEO, which relies on a few core sub 30-m resolution satellite data sources, enables a continuous, annual and global coverage to monitor such indicators worldwide over the years. It will thus directly help monitoring indicator 15.2.1 (Progress towards sustainable forest management).

3.3 Task Team Handbook

The TT led by ABS produced a Handbook to provide guidance to NSOs about the use of EO data, which include both satellite and in-situ data, for official statistics. This was reviewed by experts including the UN Food and Agriculture Organization (FAO) and the Joint Research Centre of Eurostat before being finalised in June 2017.

CSIRO played a significant role in producing the Handbook as the primary authors of Chapter 2, with some inputs from GA. The content of the report has been driven by the direction given by the UN Statistics Division (UNSD) for TTs to produce a set of guidelines that include:

- Introduction that provides the motivation and makes the business case, including modernisation of official statistics and monitoring the 2030 Sustainable Development Agenda through the SDGs;
- Data sources – description and explanation, as well as scope of the guidelines;
- Statistical methodology and applications;
- Concluding section with further work to be done.

The report also outlines the TT pilot projects and guidelines for practitioners exploring the use of EO data for the first time.

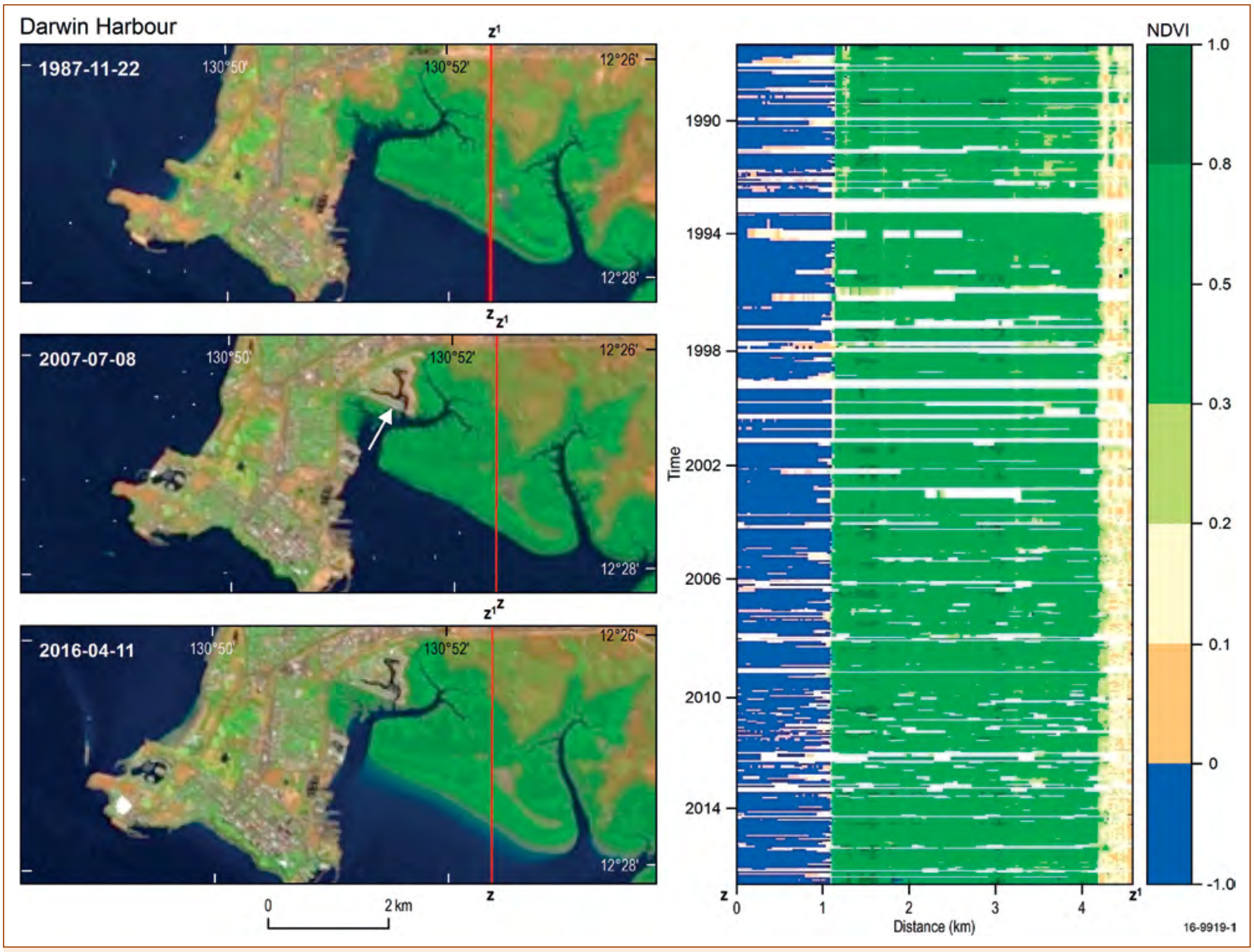

Figure 3: Darwin Harbour: representative Landsat images and the time series along a transect through the mangrove forest at Frances Bay. White arrow: area of urban expansion.

The TT pilot projects described in the report are:

- Pilot Study Proposal for the application of satellite imagery data in the production of agricultural statistics (ABS);
- UNSD – Skybox Commodity Inventory Assessment (Google);
- Preliminary Analysis of Climate Scenarios to Improve the Environmental Characterization of Various Climatic Regions in Mexico (INEGI, Mexico);
- Use of satellite images to calculate statistics on land cover and land use (DANE, Colombia).

The crop yield work by Statistics Canada is also included as an example of how satellite imagery can be used in the production of official statistics in practice. Statistics Canada is an NSO that has used remote-sensing data since the early 1980s for applications such as census and survey validation, crop mapping and area estimation and support program development. In 2016, Statistics Canada became the first NSO to replace a statistical survey with a remote-sensing model-based approach. The goal of the model was to produce a preliminary estimate of the expected harvest yield of the crops in late summer using information from existing data sources.

ABS is also considering EO data for statistical outputs as part of the larger administrative data initiative and has received presentations from Statistics Canada about their methods and experiences. This has been very useful to the ABS agricultural statistics area, the Satellite Imagery TT report and EO workshop development.

3.4 ABS, CSIRO and GA collaboration

Since the inception of the ABS TT, CSIRO has been providing substantial inputs on a number of dimensions of the Handbook, including EO data sources available (besides the most common MODIS and Landsat images), how to get access to it, how to process and analyse it (using new statistical methods and algorithms), and how ABS and CSIRO can share and build on their expertise to collect and use more satellite data to enhance the official statistics for public good.

Through this collaboration, EO concepts like 'validity', 'accuracy', 'timeliness', or 'coherence' and 'analysis-ready data' (ARD), as well as the different EO sources, their advantages and disadvantages, are adequately explained in the Handbook to help official statisticians make informed decisions on choices of EO data for official statistics.

As mentioned earlier, collaboration between ABS and GA, which started in early 2000s, motivated GA to develop the DCLD and resulted in the incorporation of EO data in the ABS June 2017 release of a Land Account publication.

This national and growing collaboration (future projects includes Data Cube technology for agricultural statistics in Australia) has provided a tremendous opportunity to make EO data more accessible, known and used by official statisticians and hopefully showcases an example for similar partnerships to be forged in other countries.

Following this initial positive collaboration in the context of the TT, Australian agencies including ABS, CSIRO and GA will continue to pursue their efforts in working together and bringing more EO data into the official statistical framework and will continue to share their experience and expertise in official statistics and EO data to provide better information for decision-making in Australia.

3.5 Concluding remarks

As ABS becomes more experienced with EO, the organisation is committed to sharing this knowledge with the international statistical community and helping build the capability of other NSOs in the use of EO data for official statistics.

In this exercise, ABS has found that partnerships between EO scientists and academia are important to progress the use of EO data for official statistics. Through such partnerships, developing and maintaining strong ties with international organisations such as CEOS is essential to successfully harness EO data for official statistics.

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Part II

4

Monitoring the 2030 Agenda in Mexico: Institutional Coordination and the Integration of Information

Mexico is one of only two countries in the world, together with Brazil, where the National Statistical Office and the National Mapping Agency have been integrated into a single organisation. Established in 1983 and granted constitutional autonomy in 2008, the National Institute of Statistics and Geography (INEGI, by its Spanish acronym) is the organisation in charge of the production and coordination of statistical and geographical information in Mexico, thus allowing the development of both disciplines in constant interaction.

Valuable feedback and benefits between producers of official statistics and geo-products, and the final users of such integrated data, allow for the development of better public policies, the monitoring of international goals and agreements, such as the SDGs, as well as swifter and more accurate decision-making during disaster management situations.

4.1 Institutional setting

In 2008, INEGI became the single public agency responsible for coordinating and regulating the newly-created *National System of Statistical and Geographical Information (SNIEG)*, whose main function is to collect, process and publish information of national interest, in other words to generate, coordinate and disseminate the nation's official data. The *SNIEG* provides the Mexican State, and society, with high quality, timely and freely available information that can aid in national development and other processes. It produces statistical and geographic information on all areas of sustainable development (economic, socio-demographic, environmental and on government and justice); disseminates it in a timely fashion; promotes the knowledgeable use of such information; and is responsible for storing and preserving this information.

With all the associated tools that this integration has allowed, it is possible to geo-reference many relevant statistics; determine the exact location of economic, social and environmental issues and needs, including the unveiling of otherwise hidden inequalities and other complex interactions; and monitor damage, rescue and recovery efforts deriving from natural disasters and other emergencies that help improve public programmes and maximize resources for the overall benefit of people and territory. The use of satellite imagery, as well as other EO-derived data, has been key in the geo-statistical integration process and several tools have been developed to aid in policy design and monitoring in all dimensions of sustainable development.

Geo-statistical integration has allowed for the development of a free and open online platform, known as the *Digital Map of Mexico (MxSIG)*. This adaptable, user-specific geo-statistical information integration and visualization software features a built-in system of international standards, is free to download and use, and does not require additional commercial software licenses. It allows the visualization and analysis of geographic and geo-referenced statistical information offering 208 vector data layers, with more than 71 million geographic objects and 4 raster layers covering the whole country, including geographical limits, geodesy,

GEO-STATISTICAL INTEGRATION to MONITOR NATIONAL PRIORITIES & SDGs			
Satellite Imagery	**Other sources**	**National Uses**	**SDG I other applications**
High resolution (2.5 m) **SPOT ERMEX** Very high resolution (0.5 m) **GEOEYE EVISMAR**	**Population Census** **National Housing Inventory** **Economic Census** **Technical Standard on addresses** **COA-Web** **In situ validation**	Geo-statistical framework **Updating of:** Topographic charts **Visualization of:** Population, Economic, Housing, Gender, Health, Education & public services Urban & rural development Water and sanitation Infrastructure GHG emissions/hzd waste	**1. No poverty** **2. Zero hunger** **3. Health and well-being** **4. Quality education** **5. Gender equality** **6. Water and sanitation** **7. Affordable & clean energy** **8. Decent work & economic growth** **9. Industry & infrastructure** **10. Reduced Inequalities** **11. Sustainable cities & communities** **12. Life on land**
Medium resolution (5-30m) **RAPIDEYE LANDSAT**	**Natural resources & topographic charts** **Forestry & water data** **In situ validation**	**Land Use & Vegetation map series** Deforestation, land use changes **Monitoring crops**	**2. Zero hunger** **16. Clean water and sanitation** **13. Climate action** **14. Life below water** **15. Life on land**
Low resolution (250 m) **MODIS**	**Topographic maps** **Land use & vegetation**	**Disaster monitoring** Fires, large flooding	**Sendai Framework** **Climate action**
Radar **RADARSAT**		**Disaster monitoring** Flooding, digital models in foggy areas	**Sendai Framework** **Climate action**

Table 1: Mexico's integrated use of geospatial/EO information and statistics to monitor national and global indicators.

water infrastructure, geographical names, hydrography, terrain data, geographical addresses and localities.

In addition to these institutional settings and integrative tools designed to fulfil national priorities, with the integration of statistics and geography at its core, Mexico has undertaken a state-wide effort for the monitoring and fulfilment of the Sustainable Development Goals (SDGs), through a *National Council for the 2030 Agenda for Sustainable Development*, coordinated at the highest level by the Office of the President and involving all relevant state units, including line Ministries, Congress, and state and municipal governments. This cross-sector initiative includes an online platform (www.agenda2030.mx) that includes information on national SDG measurement and monitoring progress. Currently, 25 SDG indicators are ready to be measured at a national level, with further additions and updates expected on a regular basis. According to a recent national crosscutting analysis, there is sufficient – and consistent – data and methodologies to adequately measure up to 94 SDG indicators (i.e., considered as belonging to Tier I according to the IAEG-SDG classification), compared to 81 globally according to the UN system. Also, upwards of 50 indicators have been identified at the national level that could either directly benefit from the contribution of geospatial information and/or Earth observations (GI/EO), or complement and enrich the information provided by statistics and administrative records.

Based on the IAEG-SDG Global Indicator Framework, a comprehensive analysis has also delivered a list whereby both geospatial and EO data can contribute to better measurements (including transitioning from a Tier III to a Tier II, or even a Tier I, classification), either directly or indirectly. A number of such examples are presented herewith.

This national effort follows Mexico's international leadership on the 2030 Agenda follow-up and the use therein of GI/EO. This includes the country's active participation in the multilateral negotiations at the United Nations leading to the 2030 Agenda and SDGs, as well as its current role, through INEGI, as co-chair of the IAEG-SDGs and of the IAEG-SDGs' Working Group on Geospatial/EO information.

In this regard, Mexico's participation in the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), as well as in the Group on Earth Observations (GEO) through its initiative in support of the 2030 Agenda (EO4SDG), has been particularly fruitful.

Furthermore, a collaboration is currently underway between Mexico (through INEGI and the Environment Ministry SEMARNAT), the United Nations Statistics Division (UNSD) and UN Environment on the implementation of the System of Environmental Economic Accounting – Experimental Ecosystem Accounting (SEEA EEA), including the use of EO and geospatial information in support of the SEEA framework. A further article on this topic may be found in Part II of this Handbook.

4.2 Measurement of specific SDG Indicators using EO and GI

Indicator 9.1.1 – Proportion of the rural population who live within 2 km of an all-season road.

This indicator is derived using a combination of statistical (Census Data, ITER 2010) and geographic data (National Topographic Data Set, including transportation layers and validation using satellite imagery).

Indicator 15.1.1 – Forest area as a proportion of total land area

This indicator is derived entirely from geospatial and satellite data. It uses five datasets of land use and vegetation (derived from remote-sensing images). The classification system comprises 57 types of vegetation, including temperate and tropical forests, grasslands, shrubland, mangroves and other categories, such as agricultural and built-up/urban areas.

Indicator 15.3.1 – Proportion of land that is degraded over total land area

According to the UN Convention to Combat Desertification (UNCCD), this indicator is defined as the amount of land area that is degraded. Its measurement unit is the spatial extent expressed as the proportion of land that is degraded over total land area. Indicator 15.3.1 is derived by summing all those areas subject to change, whose conditions are considered negative by national authorities (i.e., land degradation) while using *'good practice guidance'* in the measurement and evaluation of changes to each of the following three sub-indicators:

i. **Land cover and land cover change**, which can be derived from the land cover and vegetation time series, as described for indicator 15.1.1 (see above). In Mexico, these indices are already being calculated for national reports on carbon emissions due to land cover/use change, as well as on reports on deforestation by the FAO's Global Forest Resources Assessments (FRA).

ii. **Land productivity**, which is calculated using the normalized difference vegetation index (NDVI), a simple graphical indicator that can be used to analyse remote-sensing measurements, typically from a space platform, and assess whether the target being observed contains live green vegetation or not. In Mexico, this index is calculated using MODIS, Landsat and Sentinel satellite imagery, which acquire data in visible and near-infrared in plant reflectance to determine spatial distribution.

iii. **Carbon stocks above and below ground**, calculated using digital mapping from organic carbon content in soil samples, together with field data from around 20,000 soil profiles in Mexico's National Forest and Soil Inventory (INFyS) by the National Forestry Commission (CONAFOR).

All indicators related to land cover, land use, land degradation, agricultural area and the like benefit both from the Land Use and Vegetation Chart Series (scale 1:250,000) mentioned earlier and from the National Forest and Soil Inventory (www.cnf.gob.mx:8090/snif/portal/infys).

The INFyS is updated yearly (and completely every five years) using satellite imagery and field data, including GPS and photography, through the measurement of over 170 variables. Data collection in the field is the systematic stratification of over 26,000 conglomerates (from over 81,000 sampling sites), covering all climates and vegetation in the country. This information is combined with data on roads, watersheds, climate, soils, natural protected areas and various forest inventories. Forest monitoring involves the interpretation of MODIS satellite images by means of specialized software, and supported by the field work for the INFyS, to determine the dynamics of changes in vegetation every year.

4.3 EO/GI in the monitoring of other processes for the 2030 Agenda

Disaster risk reduction

When disaster strikes, geospatial information becomes a critical asset for actions that can mitigate its effects. This information should be timely, accessible and of adequate quality to offer the best response possible.

To ensure the availability of this information in Mexico, INEGI has put into operation a collaborative online platform for disaster response, the ***Collaborative Site for Disaster Response***, where the relevant state agencies can exchange information to perform their respective functions in a more timely and efficient manner.

The collaborative site is a restricted access website for users at several government agencies ranging from those related to the production of disaster-related geospatial and statistical information to those directly in charge of the emergency response. These include the Interior, Transportation, Environment, Energy, Agriculture, Army and Navy ministries, among other entities, coordinated by the Disaster Prevention Centers and the Civil Protection System.

Once an authorized user gains access to the main page, the following sections are displayed: **Recent Events, Historic Events, Available Information, News, and Contact Information**.

The section on **Recent Events** contains information related to disaster events where the response is on-going or has occurred within the past year. Each event can be considered as a 'sub-site' within the main site. Access is given to relevant datasets, either through links to downloadable files or the URLs to Web Map Services. Examples are population (census) data at the street block level for towns or cities in the affected area, hydrographic networks, road networks and satellite imagery, both prior to the event and, whenever possible, in the hours or days after the event so that affected areas and features can be located.

Figure 1: Calculation of SDG indicator 9.1.1 (Proportion of the rural population who live within 2 km of an all-season road), using census, topographic, road and satellite data. Green: populated places within 2 km of an all-season road.
Pink: populated places further than 2 km from an all-season road.

A specific message board is created for each event, so that multiple users can exchange comments, questions and experiences. There is also a section for data visualization.

The **Historic Events** section provides access to data sets related to events that happened in previous years or where the emergency phase has ended. The general structure of this section is the same as that for recent events.

As a disaster may occur anytime and anywhere in the country, the **Available Information** section gives permanent access to some basic – or framework – data sets. Access to this information is through downloadable links or URLs to Web Services: Web Map Services, Web Feature Services and Web Coverage Services.

This multi-user data-sharing platform relies on satellite optical and radar data, along with other EO sources. Different types of satellite data are acquired in consideration of the type of disaster and meteorological conditions. Optical data is used for fires, earthquakes, volcanoes, floods and landslides. Before/after images are mainly supplied by the Army and Navy, as well as by drones from the Disaster Prevention Center (CENAPRED), and supplemented by private providers, which are regulated through flying permits.

Radar data are used for floods, landslides and earthquakes, and for all of the above in case there are no conditions for optical imaging. Vertical displacements are identified using interferometry. Also, Global Navigation Satellite System (GNSS) data is used to quantify land displacements after earthquakes. Additionally, volunteered geographic information (VGI), in the form of geo-tagged photographs and other types of geo-referenced citizen data, is incorporated to the site after proper validation and can prove particularly valuable, especially in cases where communications have been affected or an affected site has been isolated after a disaster.

This platform has been instrumental during past emergencies, such as when hurricanes Ingrid and Manuel struck the Atlantic and Pacific coasts of Mexico within a 24-hour period in September 2013. More recently, it proved key during the response to hurricanes Franklin, Katia and José, as well as several powerful earthquakes affecting southern states and Mexico City in September 2017.

4.4 National Gender Atlas

This is an online platform aimed at gathering, integrating and visualizing, in a geographic context, some of the most outstanding socio-demographic and economic indicators

Figure 2: Overview of the national collaborative site for disaster response and preparedness, including coordinated data inputs from relevant agencies for recent and historic events.

with a gender perspective, to make visible not only the gender differences but also the additional differences derived from their geographical location disaggregated at the state level of the national territory. Maps that show the behaviour of demographic, social, work, time use, entrepreneurship, poverty, decision-making and violence against women, related to human rights and with issues of public interest, are easily accessed on the portal (http://gaia.inegi.org.mx/atlas_genero).

The Gender Atlas derives from a collaborative agreement between INEGI, The National Women's Institute (INMUJERES), UN Women and the UN Economic Commission for Latin America and the Caribbean (UN ECLAC). Launched in 2016, it is oriented towards policy analyses that derive in substantive gender and regional equality. It is presented as an online platform for easy access and visualization of the issues addressed. It contains both statistical data and references to the sources of the indicators that are presented on the maps.

Figure 3: Radarsat image acquired after Hurricane Patricia made landfall in the state of Colima, on October 24th 2015. The blue polygon shows a flooded area, mostly cropland, around the Marabasco river.

Currently, the site includes 78 national indicators related to gender statistics, **including SDG 5 indicators on gender equality**. Metadata include methodological aspects and geographic disaggregation. The information of the Gender Atlas will be updated and expanded on a permanent basis, considering new statistics as well as national planning and government programmes and policies and international agreements linked to the empowerment of women and equality between women and men. Efforts are underway to develop similar platforms in other Latin American countries, which would be linked and interoperable for cross-regional analyses. Its multi-dimensional nature will ensure that gender, as envisioned in the SDGs, will be addressed in a cross-cutting and integral way, considering its social, economic, political, administrative, environmental and geographical aspects.

Figure 4: Drone image over Juchitan, Oaxaca, showing collapsed buildings after the 8.1 magnitude earthquake on 7 September 2017.

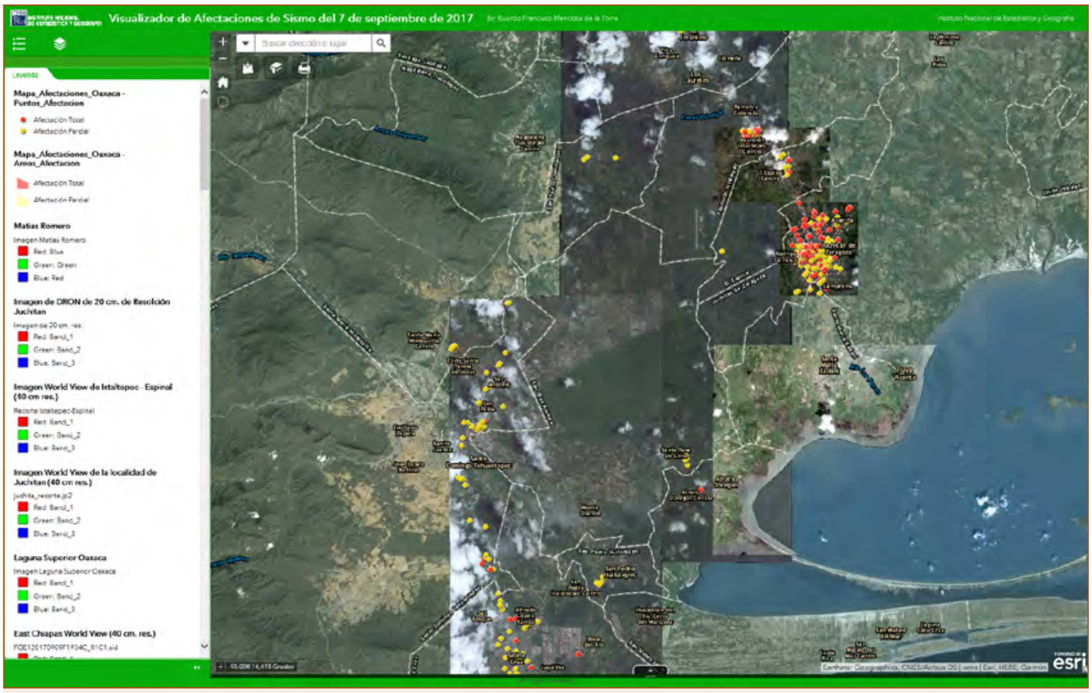

Figure 5: Mapping of affected areas in Oaxaca City, Mexico after the 8.1-magnitude earthquake on September 7 using satellite images from different sources (visualization within the Collaborative Site for Disaster Response).

4.5 Conclusions

– Geospatial Information, Earth Observations, Big Data and Statistics can and should be integrated in support of national policies and the implementation of international agreements. Efforts should be made at the national, regional and global levels to generate collect and curate these sources of information in a high-quality and consistent manner for their systematic use in complementing official statistics/information in a sustainable manner.

– Geospatial information facilitates the monitoring of social, economic and environmental indicators to support, design and monitor public policies.

– Integration facilitates location of needs, assessment of policy/global goals (such as the SDGs), as well as progress over time.

– Institutional capacity and inter-institutional coordination, including with non-state actors such as the private sector, academia and civil society, are key in order to focus skills and resources, avoid duplications and effectively use all pertinent tools to achieve priorities.

– Participation from all sectors of society is key, including academia, civil society and the private sector.

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Further information

Digital Map of Mexico (MxSIG):
http://gaia.inegi.org.mx/mdm6

National System of Statistical and Geographic Information (SNIEG):
www.snieg.mx

National Gender Atlas:
http://gaia.inegi.org.mx/atlas_genero

Collaborative Platform for Disaster Response (SICADE):
http://geoweb2.inegi.org.mx/sicade/login.jsp

National Forest and Soil Inventory:
www.cnf.gob.mx:8090/snif/portal/infys

Land Use and Vegetation Series:
www.inegi.org.mx/geo/contenidos/recnat/usosuelo/default.aspx

System of Environmental-Economic Accounting (SEEA) Experimental Ecosystem Accounting (EEA):
www.teebweb.org/seea-mexico-inception-mission

5

Perspectives from a Custodian Agency for Agriculture, Forestry and Fisheries

Food and agriculture lie at the heart of the 2030 Agenda, with closely related development outcomes that range from ending poverty and hunger to maintaining and protecting the natural resource base, and responding to climate vulnerability and change. As a result, FAO was chosen as the Custodian Agency of 21 SDG indicators, with responsibilities for the methodological development, the provision of technical assistance and the collection and dissemination of data for monitoring progress towards a number of targets under Goal 2 'Zero hunger', Goal 5 'Gender equality', Goal 6 'Clean water and sanitation', Goal 12 'Responsible consumption', Goal 14 'Life below water' and Goal 15 'Life on land.' Data collected from countries and new sources will allow monitoring annual progress at a sub-regional, regional and global level and will provide the evidence base for the planned follow-up and review processes in the context of the SDG High Level Political Forum.

5.1 Tracking progress towards sustainable development

Earth observations (EO) can provide a significant contribution to the measurement of many of the SDG indicators under FAO custodianship. In particular, remote-sensing images and georeferenced data can support the design and development of more efficient and accurate sampling frames in the preparation of integrated agricultural surveys used for monitoring SDG indicators. Secondly, area changes in natural vegetation assessed from satellite imagery directly inform the measures of specific indicators, such as the Green Mountain Index. Thirdly, EO stratified by land cover information are useful auxiliary variables to enhance data coherence and accuracy. For instance, satellite imagery may complement ground observations for computing critical sub-components of more complex indicators, such as the measurement of the area under sustainable and productive agriculture. Finally, EO are key data for spatial disaggregation, including for the distinction of rural and urban areas required for the computation of several SDG indicators.

Accordingly, FAO's support to countries, in the context of the SDG indicators, increasingly includes capacity development activities based on geospatial tools. This article provides examples of the applications mentioned above, as implemented by FAO, including with support of the Global Strategy to Improve Agriculture and Rural Statistics, demonstrating the specific role EO can play in helping countries meet the monitoring challenges ahead.

5.2 Farm-based surveys and the use of geospatial information

Progress towards achieving **Target 2.3** and **Target 2.4** of Goal 2 is measured by three global indicators that are meant to be informed by agricultural surveys whose statistical unit is the farm. Target 2.3, in particular, focuses on the economic performance of small-scale food producers, measured by their income and productivity:

- **indicator 2.3.1**: volume of production per labour unit by classes of farming/pastoral/ forestry enterprise size;
- **indicator 2.3.2**: average income of small-scale food producers, by sex and indigenous status.

Indicator
2.1.1 Prevalence of undernourishment
2.1.2 Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)
2.3.1 Volume of production per labour unit by classes of arming/pastoral/forestry enterprise size
2.3.2 Average income of small-scale food producers, by sex and indigenous status
2.4.1 Proportion of agricultural area under productive and sustainable agriculture
2.5.1 Number of plant and animal genetic resources for food and agriculture secured in medium or long term conservation facilities
2.5.2 Proportion of local breeds, classified as being at risk, not-at-risk or unknown level of risk of extinction
2.a.1 The agriculture orientation index for government expenditures
2.c.1 Indicator of (food) price anomalies

Indicator
5.a.1 (a) Percentage of people with ownership or secure rights over agricultural land (out of total agricultural population), by sex; and (b) share of women among owners or rights-bearers of agricultural land, by type of tenure
5.a.2 Percentage of countries where the legal framework (including customary law) guarantees women's equal rights to land ownership and/or control
6.4.1 Change in water use efficiency over time
6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
12.3.1 Global food loss index
14.4.1 Proportion of fish stocks within biologically sustainable levels
14.6.1 Progress by countries in the degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing
14.7.1 Sustainable fisheries as a percentage of GDP in small island developing States, least developed countries and all countries
14.b.1 Progress by countries in adopting and implementing a legal/regulatory/policy/institutional framework which recognizes and protects access rights for small-scale fisheries
15.1.1 Forest area as a percentage of total land area
15.2.1 Progress towards sustainable forest management
15.4.2 Mountain Green Cover Index

Figure 1: The 21 SDGs indicators under FAO custodianship

Target 2.4 focuses on the sustainable increase of agricultural productivity:

- **indicator 2.4.1**: proportion of agricultural area under productive and sustainable agriculture, which entails maintaining agriculture's ecosystems function, by improving land and soil quality and strengthening its capacity for adaptation to climate change, including improved resilience to extreme events and disasters.

Monitoring this target involves measuring the economic, social and environmental dimensions of agricultural sustainability with appropriate sub-indicators.

The official global indicators selected to measure progress against targets 2.3 and 2.4 require a common data collection framework, able to gather timely and relevant environmental, economic and social information at the farm level, with the possibility of capturing disparities between small- and large-scale food producers.

In order to better meet these requirements and more generally the need to improve the quality, consistency and timeliness of national and sub-national agricultural data, FAO has recently proposed a new approach to agricultural surveys, the Agricultural Integrated Surveys (AGRIS), which aims to gather information on both the core activities and the key characteristics of the farm, in particular those that will be needed for monitoring of SDG indicators 2.3.1, 2.3.2 and 2.4.1.

EO data, in particular satellite imagery and ortho-rectified aerial photographs, together with geo-referenced information are essential tools in designing a consistent, efficient and well-integrated sampling frame for AGRIS in order to enable sampling and reporting with equal efficiency at farm, household and landscape scales, with the ability to link information across multiple thematic domains. Stratification of satellite imagery by relevant land cover strata improves the sampling efficiency of agricultural surveys, with respect to both types of area and list sampling frames, which are typically used jointly for agricultural purposes. The use of satellite imagery also supports and increases the efficiency of ground work, facilitating ex-post data corrections needed to improve quality control of the survey estimates.

AGRIS is a programme of integrated farm-level surveys, bridging the 10-year gap that normally exists between Agricultural Censuses. AGRIS collects data every year for a core module – which includes current agricultural production and its value – while four other modules are administered on a rotational basis (Economy; Labour; Production Methods and Environment; Machinery, Equipment and Assets), to collect structural information on the key technical characteristics of the farm.

Figure 2: FAO's Open Foris is a set of free and open-source software tools that facilitates flexible and efficient data collection, analysis and reporting.

5.3 EO data for direct monitoring of SDG indicators

In response to the SDG monitoring needs, FAO has stepped up its own efforts to exploit cutting-edge technologies designed to access and analyse information on land and natural resources from remote-sensing sources. For instance, FAO has developed the Open Foris suite in partnership with Google. Open Foris is a set of open-source software tools, including Collect Earth in particular, that are instrumental to the data measurement of several indicators especially relevant to Goal 15 'Life on land'.

Within goal 15, **SDG indicator 15.4.2** focuses on a wide range of universally important services provided by mountain ecosystems, as a basis for sustainable mountain development. The indicator's methodology focuses on measuring changes in the area of green vegetation in mountain areas (forest, shrubs and pasture land, and cropland) as a proxy for changes in ecosystem function of mountain environments. FAO supports monitoring of indicator 15.4.2 "Mountain Green Cover Index" through a customized application of Collect Earth. Collect Earth was applied to extract index values disaggregated by country, elevation class and IPCC land use categories and to compile them in a 2017 baseline. Changes in mountain vegetation over time will be assessed against this baseline.

5.4 EO as complementary variables for national assessments

The indicator 15.1.1 "Forest area as a proportion of total land area" measures the status of conservation or restoration of forests in a country, indirectly contributing to measuring to what extent they are sustainably managed. Changes in forest area may reflect changes in demand for other land uses due to economic activity and pressures. To this end, this indicator provides crucial information for policies in support of sustainable forest and landscape planning. To monitor forest cover and changes, EO is increasingly complementing the data that FAO has historically collected through the Forest Resources Assessments (FRA). Offering better access to satellite imagery and to tools for image processing and data interpretation, new FAO applications such as Collect Earth and the System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL) are contributing to improved forest monitoring, complementing more traditional collection of national data through questionnaires.

In the context of **indicator 2.4.1**, high-resolution imagery contributes to assessments and mapping of soil organic carbon (SOC) at farm scale, as part of regression models and as a source of land use stratification. SOC is a critical aspect of soil health, which is in turn one of the components used to assess the environmental dimension of agricultural sustainability.

With regard to **indicator 14.6.1**, monitoring systems housed on fishing vessels and based on satellite data are being proposed for tracking illegal fishing activities in real-time and could significantly contribute to FAO's efforts to combat illegal, unreported and unregulated fishing (IUU).

Coherent frameworks of data collection, monitoring and reporting can stimulate synergies among UN agencies and with national statistical authorities. The use of EO has been instrumental in building these synergies for **indicator 15.3.1** that monitors the status and trends in land degradation. The UN Convention to Combat Desertification (UNCCD) is the Custodian Agency for this indicator, but FAO supports the monitoring of one component of this indicator by contributing its expertise on land-related statistics. FAO has traditionally led the development of international standards for land-use and land-cover classifications, such as those adopted in the 2020 World Programme for the Census of Agriculture (WCA 2020) and the System of Environmental-Economic Accounting (SEEA) Central Framework. In addition, FAO coordinates a long-standing reporting process on land-use information from member countries, which may use remote-sensing land cover mapping for the validation of national data. In order to support this process, FAO has recently developed reference statistics based on global land cover maps, disseminated via FAOSTAT (www.fao.org/faostat/en/#data/LC).

Finally, FAO is now partnering with the European Commission, OECD, the World Bank, the Global Strategy to Improve Agricultural and Rural Statistics, and other UN organisations to develop an agreed international definition of urban and

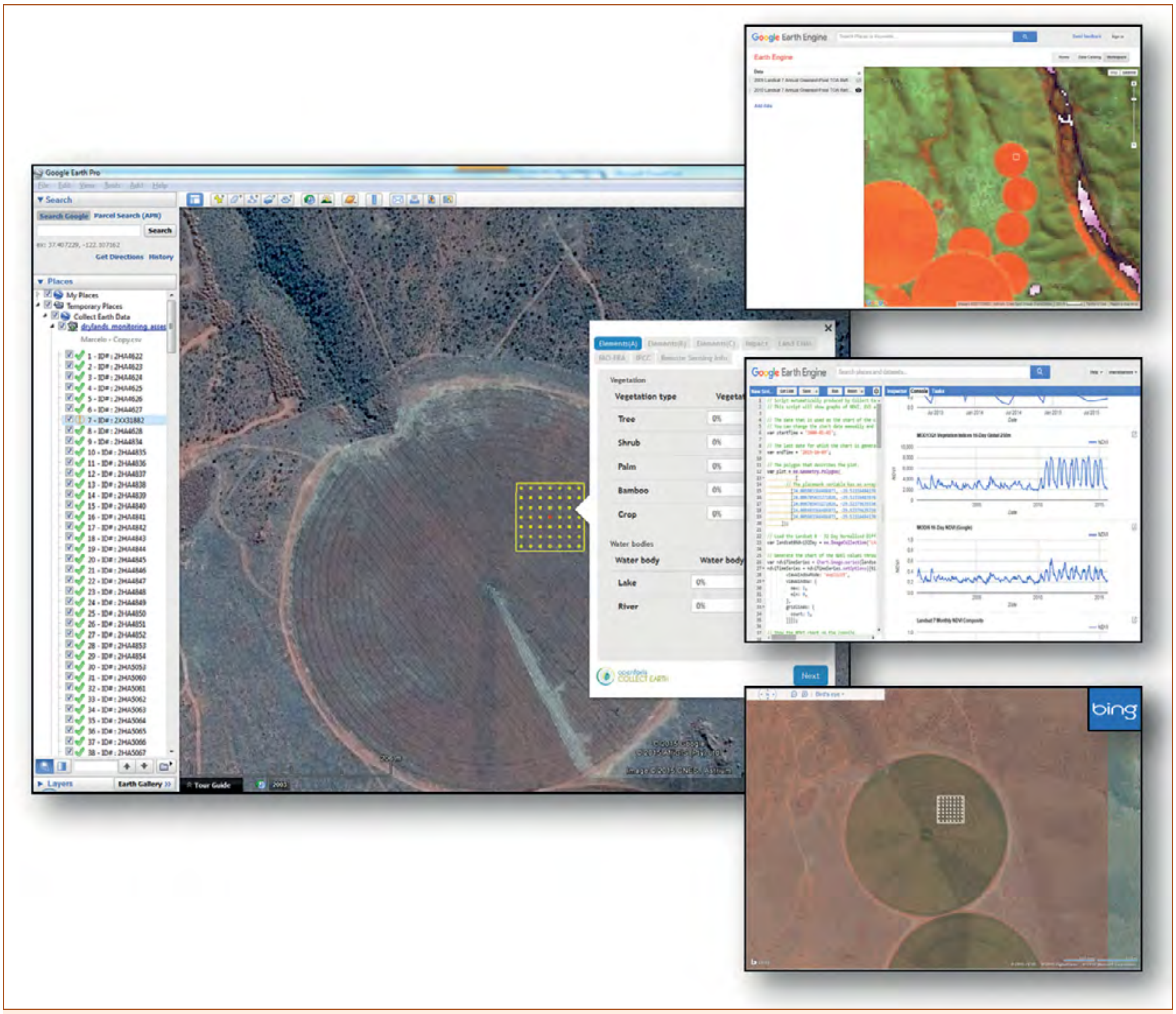

Figure 3: Built on Google desktop and cloud computing technologies, Collect Earth facilitates access to an unparalleled amount of freely available archives of satellite imagery, including very high resolution and frequency imagery. Collect Earth streamlines the use of probability sampling offering a robust and fully customizable framework for data collection. It allows the capture of new information on agriculture and natural resources for monitoring targets across the 2030 Agenda, from crop monitoring to land and forest cover, from pest/locust control to water management, from plant health to losses due to natural disasters.

rural areas for consistent reporting of SDG indicators and beyond. The methodology classifies Local Administrative Units on the basis of a combination of criteria of geographical contiguity, minimum population thresholds and economic activity of the resident population applied to 1 square km population grid cells. Medium to very high-resolution imagery are the source of existing global land cover maps and human population distribution layers that underlay the proposed methodology to distinguish rural and urban areas globally. More on these aspects may be found in the UN-Habitat article here in Part II.

5.5 Country and international data for global reporting: challenges and opportunities

Reaching the goals and targets of the 2030 Agenda for Sustainable Development requires the establishment of global monitoring and reporting processes. These processes should be based as much as possible on national data in order to ensure country ownership. In some instances, however, international agencies may use non-official data to construct international data series in fields that are not covered by existing official sources, or where a single source (e.g., EO satellite imagery) may provide more consistent and lower-cost data to measure a global or trans-national phenomenon than the results of amalgamation of multiple individual country datasets.

The System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL) is a platform for processing and interpreting satellite data using a cloud-based supercomputer; one of its strengths is that it can help surmount barriers posed by poor internet connections and a lack of computing power.

Non-official sources might sometimes also be used by international agencies to estimate country-specific values of SDG indicators when national official data do not exist, are incomplete or do not comply with international standards; or to impute missing values within a national official time series or to extrapolate official time series. In this respect, land, water and agri-environmental statistics derived from satellite imagery support the construction of a consistent data framework across sub-national, national and global scales.

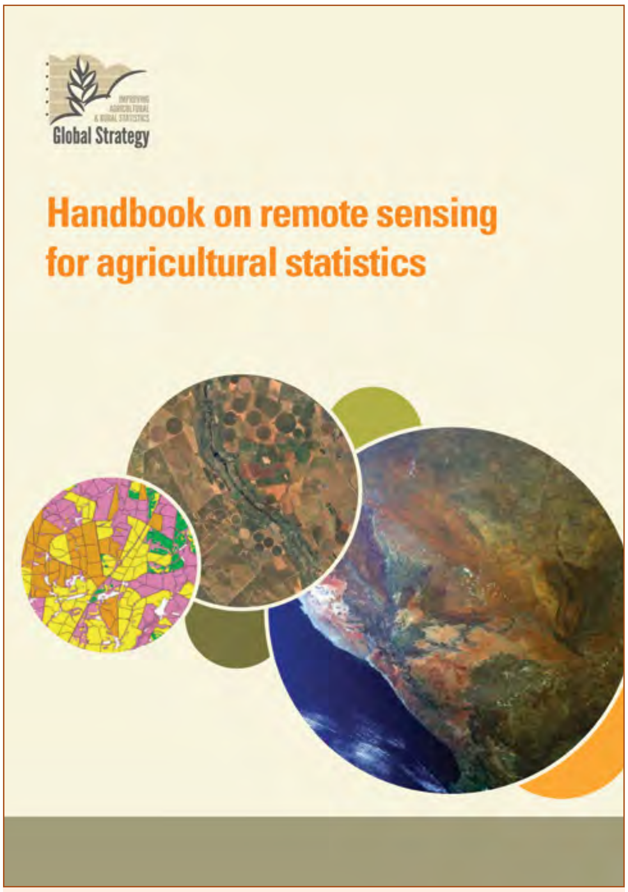

Figure 4: FAO and Global Strategy guidelines on applying remote sensing information to improve crop statistics.

As a result of this work, discrepancies may arise between international and national estimates of similar SDG indicators. This may be a cause of concern for some national authorities given the reputational risk for countries to have their data contradicted by those published by international organizations.

International organizations can address these concerns by strengthening the statistical capacity of countries in areas where data are not available or not compliant with international standards, with the goal of enabling them to produce their own data in the long run. FAO's activities towards improved national statistics of its member countries are an integral part of this effort. EO and Big Data complement local knowledge and expertise and can boost the efficiency, quality, transparency, credibility and above all the timeliness and efficacy of data collection and the validation of existing global products.

Applications based on remote-sensing data play a major role for building statistical capacity in countries and for promoting knowledge sharing at the regional level. FAO is offering training on the use of FAO software tools such as Open Foris and Collect Earth to national experts who will be able to conduct – in a few hours – mapping and classification exercises that used to take weeks or months.

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Further information

FAO, Office of the Chief Statistician:
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Open Foris tools:
www.openforis.org

Handbook on remote sensing for agricultural statistics:
http://gsars.org/wp-content/uploads/2017/09/GS-REMOTE-SENSING-HANDBOOK-FINAL-04.pdf

AGRIS:
agris.fao.org

FAO efforts to combat illegal fisheries:
www.fao.org/fishery/iuu-fishing/en

The 'Urban' SDG and the Role for Satellite Earth Observations

UN-Habitat is leading the coordination of several methodological developments for monitoring of urban-related SDG indicators as a Custodian Agency and is supporting the cross-sectoral coordination of the human settlements indicators to allow for synergies and consistency in the monitoring and reporting amongst institutions on all urban-related indicators. This role also involves developing new ways of data collection and guiding partners on use of new technologies in monitoring locally and globally the urban-related SDGs. This article highlights some of our experience using Earth observation (EO) data and the associated challenges and opportunities for measuring and monitoring the performance of cities through such data.

6.1 Sustainable cities

SDG 11, *"Make cities and human settlements inclusive, safe, resilient, and sustainable"*, stands out as a goal that has placed explicit focus on the measurement of indicators at a sub-national level (cities or human settlements), with several indicators requiring geospatial data for monitoring. This geospatial data dependency offers a unique opportunity to integrate geospatial information into the national and global statistical data infrastructure demands in a more holistic and policy-driven manner. But it is also symptomatic of the need for capacity development at multiple levels across the entire national statistical systems that will support SDG data collection.

The focus on cities and urbanisation underscores their roles as predominant sites of economic, social, environmental and health issues at the centre of global development policy discussions today. Whilst the linkages between cities and urbanisation to development outcomes may be clear conceptually, measuring SDG indicators at the level of cities and human settlements raises a number of challenges, such as:

- definition - of what constitutes *cities* and *settlements*;
- scope – *and which cities or urban areas to include for monitoring*;
- *what capacities exist at national statistical levels to support new ways of data collection*;
- the potential for EO data - to inform SDG monitoring efforts; and
- its integration with existing datasets for spatially explicit definitions of cities in a globally consistent manner.

Significant work has been invested in establishing an understanding of the distribution and size of human settlements that can help with the issues of definition. As with all of the SDGs, it is imperative to have consistent definitions applied across national reporting mechanisms if meaningful and consistent comparisons and global statistics are to be derived. National Statistical Offices (NSOs) employ differing criteria to classify settlements along the urban-rural divide, such as population or population density thresholds, and the threshold values may vary greatly across countries. Since an urban settlement in one country may be rural according to another country's standard, national definitions cannot be used to derive and apply a consistent global assessment of urban versus rural. The recent availability of global built-up area datasets (see the further information links at the end of the article) makes it possible to pursue spatially explicit and globally consistent approaches to defining settlements that provide a more accurate assessment of the number of settlements, their boundaries and their associated areas.

Work on the *Atlas of Urban Expansion* that was led by UN-Habitat and New York University provides an estimate of the total population living in 'large' cities with populations of at least 100,000 (in 2010). This work identified 4,231 self-standing cities and metropolitan areas, representing a total population of approx. 2.5 billion people. The names, locations and populations of these cities were identified after a year and a half of research, comparison and consultation with multiple data sources and organisations, including *www.citypopulation.de*, the UN Population Division, the Chinese Academy of Sciences and the European Commission.

The contribution to global population of these cities of different sizes is illustrated in Figure 1. This shows, for example, that cities with a population of more than 12.8 million people were home to a total of around 328 million people in 2010. It also illustrates that definition and scope of monitoring urban environments will have a significant impact on how much of the global population and their settlements is covered by the SDG indicator framework – with over 300 million *more* people (and *another* 4000+ cities) included should the scope extend to cities as small as 50,000 in population.

6.2 Our use of EO data

Urban extent and boundaries are an obviously important part of getting scope and definitions consistent and EO data can certainly help here. However, translating EO datasets into settlement boundaries requires analytical approaches that group remotely-sensed built-up areas and open space pixels in ways that match our preconceived notions of how cities and metropolitan areas manifest spatially. Not all cities meet the simplistic notion of a compact cluster of built-up area completely surrounded by wide open countryside. Individual clusters may be completely surrounded by open space but they are not necessarily individual settlements; non-contiguous built-up areas and the open spaces surrounding them and captured by them may represent a singular connected area, such as an integrated labour market we associate with a metropolitan area.

One criterion that we know is available globally, and that we have applied in our analysis, exploits the spatial relationships of built-up and open pixels contained within the remotely-sensed datasets. We analyse raster datasets and employ a variation of a gravity model whereby non-contiguous clusters of built-up area are joined together if their sizes and the distance between them meet some threshold, suggesting that the clusters 'interact' across space as part of an integral unit. The spatial clustering rules we employed are visually intuitive and easy to apply with existing data sources.

The above rules were applied globally to 200 study areas to delineate settlement boundaries or urban extent

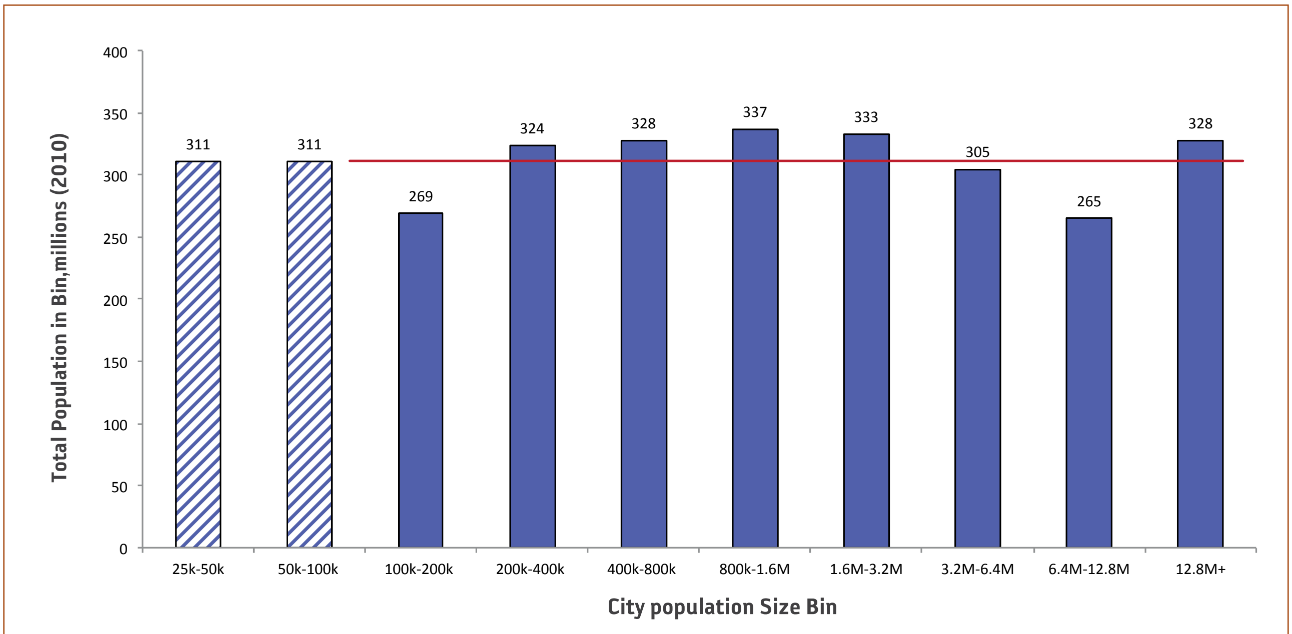

Figure 1: The 4,231 cities in the 2010 universe of cities arranged in population bins

boundaries across three time periods, 1990, 2000 and 2015. The results were positive in that they delineated settlement boundaries both for large metropolitan areas and small cities of 100,000 with high accuracy, to the extent that the boundaries matched expert opinion of what acceptable settlement boundaries would be. Certain settlement types, such as very large conurbated regions or areas separated by large bodies of water required manual editing; additional work is needed to refine the automated procedure for these cases.

Rules incorporating commuting or mobility data, which indicate actual spatial interaction and the level of connectedness between non-contiguous areas, or rules that use population or employment densities measured over small areas, representing the level of human activity across space, can be applied to devise more sophisticated and externally objective grouping rules. These criteria are in fact applied by statistical agencies where this data is available, but today this is typically only in a small number of OECD countries.

At the global level, 'urban'-related SDGs require an operational human settlement or city definition that brings these objects of study into focus. The definition should be intuitive and measurable and it must be applicable globally with existing or easily obtainable data sources. More importantly, the definition should ensure that it is easy to count and account for all the spaces and settlements in the statistics in line with the SDG's principle of "leaving no one behind".

EO data provides researchers an increasingly better understanding of the location, number and size of human settlements on the planet, since they are typically associated with impervious surfaces used for roads or building materials. The technological capability to identify these surfaces from space has existed at least since the early 1970s and with improved spatial resolution and revisit frequency from multiple satellite series today. But EO data used in this way will always need to be supplemented with *in-situ* observations and interpretation since not all built-up areas represent human settlements and not every human settlement may be of interest for monitoring urban indicators associated with SDGs.

Many of the Goal 11 targets address social, economic, environmental and health concerns that require some level of *in-situ* data collection within settlement boundaries. The data collection strategy must be comprehensive in the sense that the outcome should be an accurate measure over the settlement area of its population. A few Goal 11 targets may be observable from space or largely observable from space, such as those related to air quality, transport and urban sprawl, but measuring Goal 11 indicators will almost certainly require on-the-ground data collection efforts, either by the municipal authorities within the settlement boundary or by outside parties. Given the extremely low likelihood that this data can be collected for all settlements (however the universe of settlements is defined), a sampling approach seems more feasible, the results of which can be generalised to understand the distribution of values for the regions and countries of interest. UN-Habitat has developed a guide for member states to apply this model, commonly referred to as the "national sample of cities (NSC)" approach.

6.3 Going forward on SDG 11

Enablers such as the internet, cloud computing, Big Data, mobile devices, unmanned aerial systems, social media and the explosion of location-based services have ensured that people all over the globe are beginning to study and characterise their settlements more thoroughly and frequently.

EO data is no doubt going to play a significant and central role in the global reporting processes for the next 15 years. Its use will not be in isolation and must be guided by issues around definition and scope and supported by complementary *in-situ* information. Concrete guidance on definitions, measurements and unified standards is necessary to make sure that we work with harmonized and mutually agreed concepts.

For Goal 11, the following indicators will have a heavy dependence on EO data for their feasibility:

11.1.1 *Proportion of urban population living in slums, informal settlements or inadequate housing.*

11.2.1 *Proportion of population that has convenient access to public transport, by sex, age and persons with disabilities.*

11.3.1 *Ratio of land consumption rate to population growth rate.*

11.6.2 *Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities.*

11.7.1 *Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities.*

6.4 Examining progress on SDG 11.3.1

Efforts on monitoring SDG indicator 11.3.1 on 'land consumption rates' (from our global sample of cities work) have demonstrated that the opportunities and challenges for global monitoring come in equal measure. At the global level, more EO data is now available today with higher revisit frequency and at higher resolution to facilitate the monitoring of several urban SDG indicators including 11.3.1. But data itself is not sufficient and capacity building of national data systems, as well as removal of data complexity, must be addressed.

So too must the need for standard methodologies and definitions to allow consistent and comparable national reporting. UN-Habitat proposes the use of *'urban extent'* for the delimitation and measurement of cities and urban agglomerations in monitoring and reporting on indicator 11.3.1. The adoption of this concept will enable national governments and development partners to standardise the definition and the unit of measurement for global urban reporting. This standard definition will not necessarily usurp local definitions but it will prevent inconsistencies arising from the use of different urban definitions when collecting and analysing information at city and sub-city levels.

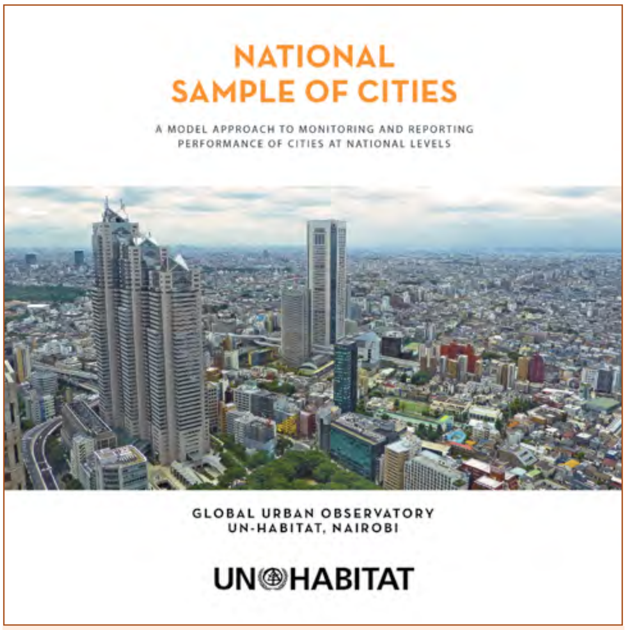

Figure 2: UN-Habitat - a guide for member states on the application of the concept of National Sample of Cities is now available: http://unhabitat.org/national-sample-of-cities

The application of EO data at local or sub-national levels will no doubt create steep learning curves for even the most data advanced countries. At the national level, we anticipate several challenges given the variations in levels of understanding and ability to apply or deploy the use of EO data in many national statistical organisations. At the local level, skill shortages will be an issue. North-South and South-South cooperation around capacity development will be needed and should be coordinated through existing regional bodies and networks as an initial starting point.

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Further information

The Global Urban Observatory:
unhabitat.org/urban-knowledge/guo

City Prosperity Initiative:
cpi.unhabitat.org

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7

EO4SDG: Earth Observations in Service of the 2030 Agenda for Sustainable Development

The Earth Observations for the Sustainable Development Goals (EO4SDG) Initiative organises and realises the potential of EO and geospatial information to advance the 2030 Agenda and enable societal benefits through achievement of the SDGs. In particular, the Initiative aims to advance a portfolio of national pilot projects in one or more GEO Member countries focused on integrating EO with national statistics to better measure, monitor and achieve the SDGs. Supplemental implementation mechanisms include: capacity building activities to help provide support to institutions and individuals in the use of EO methods and data to achieve the SDGs; dissemination of data and information products to advance the provision, access, discoverability and applicability of EO for use with the SDGs; and outreach and engagement activities to promote the consideration and adoption of EO for the SDGs by nations and stakeholders. EO4SDG has also become a focal point for coordination across the breadth of the Group on Earth Observations (GEO) Work Programme including relevant Flagships, Initiatives and Community Activities.

7.1 Introduction

The multidimensional landscape of the United Nations (UN) 2030 Agenda for Sustainable Development requires GEO to engage with numerous UN activities, multi-stakeholder partnerships, emerging initiatives and voluntary commitments from all stakeholders devoted to support the SDG process. GEO is working to ensure comprehensive alignment and engagement of EO with the SDG implementation process through close collaboration with users and stakeholders including, but not limited to: GEO Members, Participating Organizations and Observers; National Statistical Offices (NSOs) and line ministries; and international organizations, UN Custodian Agencies, the United Nations Statistical Division (UNSD), the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM), the United Nations Environment Programme (UN Environment), and the United Nations Convention to Combat Desertification (UNCCD).

Currently, GEO supports the implementation of the 2030 Agenda through:

a) Implementation of the GEO Engagement Strategy, endorsed at the GEO-XIII Plenary meeting in 2016, which identifies the 2030 Agenda as one of the three priority areas for coordinated engagement across the entire GEO community;

b) The EO4SDG Initiative; and

c) A GEO Programme Board-directed initiative that aims to ensure alignment among the GEO Work Programme elements and the GEO priorities, including the SDGs.

EO4SDG participates in the Inter-Agency and Expert Group on Sustainable Development Goals (IAEG-SDGs) Working Group on Geospatial Information (WGGI) and works to enhance its engagement with the UN, expand GEO's current collaborations and ensure alignment with international coordinating organizations, foundations and initiatives, such as the Global Partnership for Sustainable Development

Figure 1: Third Meeting of the IAEG-SDGs Working Group on Geospatial Information, Kunming, Yunnan, China, 8-10 May, 2017

Data (GPSDD), the UN Sustainable Development Solutions Network (SDSN) and the International Institute for Sustainable Development (IISD).

7.2 Engagement with the UN process

EO4SDG has a broad range of engagement with UN groups and agencies in support of Agenda 2030.

WGGI: WGGI aims to demonstrate the value of geospatial information and its contributions to the SDG Indicators and associated metadata. EO4SDG contributed to WGGI reports on **Indicators 6.6.1**, *Change in the extent of water-related ecosystems over time* and **15.3.1**, *Proportion of land that is degraded over total land area*, that: summarized the current status of the two Indicators' metadata; examined existing statistical practices; reported on current UN institutional activities; and described current techniques for geospatial data including EO that can be used to provide information on the Indicators.

EO4SDG also supported WGGI in the development of advice and guidance to the IAEG-SDGs on how geospatial information, EO and other data sources can reliably and consistently contribute directly or support the production of Indicators.

UN Custodian Agencies: UN Environment, Custodian Agency for several Indicators under Goal 6 including **6.6.1**, *Change in the extent of water-related ecosystems over time*, and **6.3.2**, *Proportion of bodies of water with good ambient water quality*, has developed step-by-step methodologies to monitor factors that are associated

Figure 2: Access to safe water and sanitation and good management of freshwater ecosystems are essential to human health, environmental sustainability and prosperity.

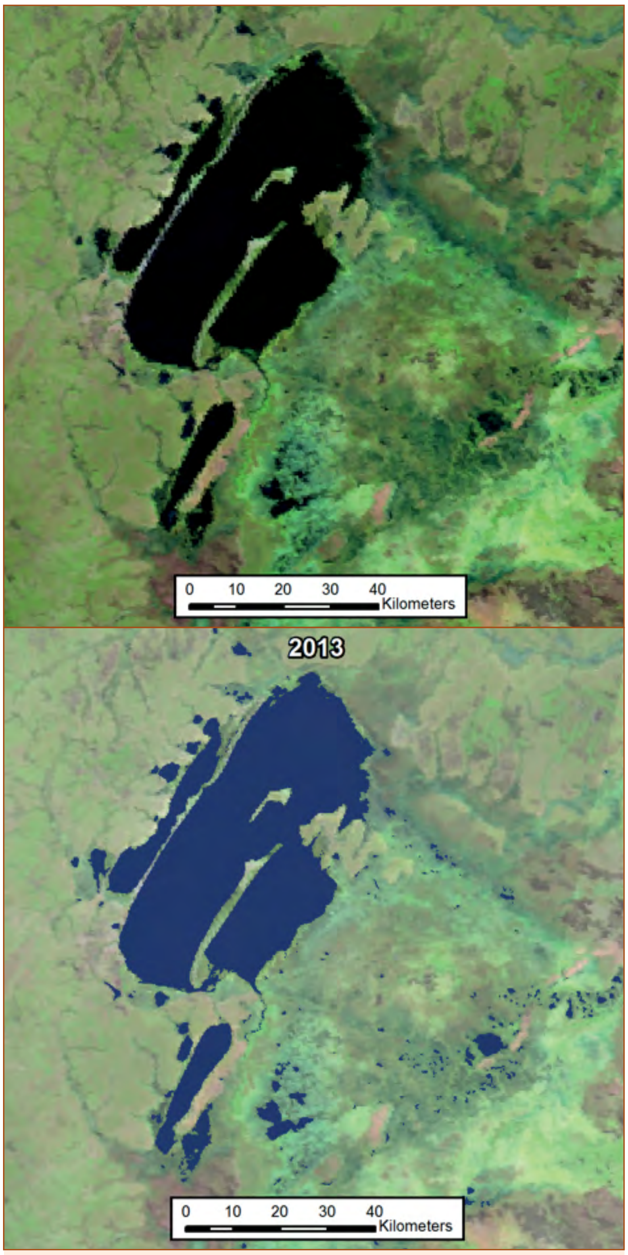

Figure 3: A) False colour composite (6-2-1) MODIS surface reflectance image (MOD09A11) of several lakes, the largest of which is Lake Bangweulu, and associated swamps in Zambia. Imagery is an 8-day composite collected from a period beginning on 7/12/13. B) The annual water dataset, MOD44W C6.1 (Carroll et al., 2017), overlain in blue, showing measured spatial extent of open water for the year 2013

with these Indicators, such as changes in water quality, water quantity and spatial extent. The methodologies provide an explanation of how to monitor these changes over time and include definitions, computational steps and recommendations on spatial and temporal resolutions. In collaboration with space agencies such as NASA, ESA and the European Commission's Joint Research Centre (JRC), UN Environment is seeking to include EO components into Indicator methodologies for national and sub-national level data collection and monitoring that will:

– help generate a reference baseline against which change in spatial extent of water-related ecosystems can be measured and future monitoring can be compared; and

– provide maps and estimates of open water ecosystem extent in square kilometres using moderate and high resolution remote-sensing products, as well as water quality Indicators, such as concentrations of total suspended solids and chlorophyll-a products.

GEO representatives have also been extensively engaged with the UNCCD and the Food and Agriculture Organization (FAO), Custodian Agencies for several Indicators under Goal 15, *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*, in their efforts to develop methodologies for monitoring degraded land through the use of EO techniques. UNCCD efforts relating to land degradation neutrality (LDN) have seen GEO support parties to the UNCCD in implementing the Convention by providing guidance on space-based information and *in-situ* measurements to assist countries in fulfilling the reporting requirements for SDG **Indicator 15.3.1**.

7.3 EO4SDG support to countries in monitoring Targets and Indicators

The principle of national ownership is at the core of the 2030 Agenda to help ensure a people-centric approach that addresses national priorities. It requires countries to be chiefly responsible for collecting information and producing reports on monitoring progress towards the achievement of the SDGs. EO4SDG directly supports countries and pursues pilot projects that aim to develop and deploy uses of EO to support the tracking of, and reporting on, the SDGs. These projects conceive, develop, test and validate relevant methods, building on proven, existing techniques and applications, where appropriate.

Partnering with the GPSDD and national agencies in Colombia, including the National Administrative Office of Statistics (DANE) and the Institute of Hydrology, Meteorology, and Environmental Studies (IDEAM), EO4SDG is devising a work plan to support the use of EO data products and tools to advance the tracking of, and reporting on, the SDGs in Colombia. The government of Colombia has successfully implemented several projects that demonstrate the value of using EO to monitor SDGs. DANE conducted a successful pilot project using EO to examine SDG 11, **Indicator 11.3.1**, *Ratio of land consumption to* *population growth*, using a method that incorporates freely available Landsat images with population statistics data to investigate the relationship between land consumption and population growth in four metropolitan areas (MA), including Barranquilla in northern Colombia. DANE has now measured this Indicator for more than 130 cities in Colombia. As a follow-up step, EO4SDG and partners are now working with DANE to extend the successful method to other countries, ensuring widespread sustained utilisation of EO data to track and monitor Indicator 11.3.1.

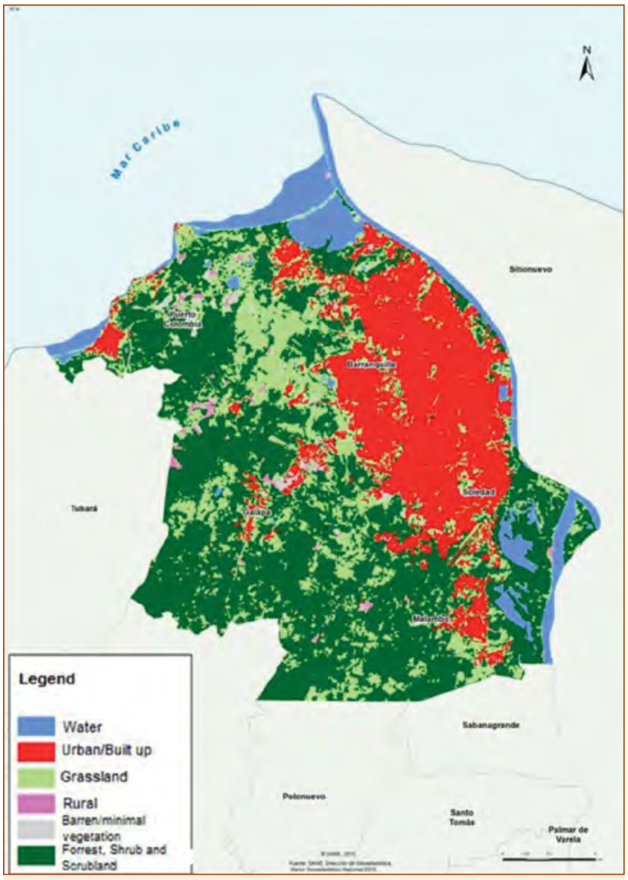

Figure 4: Land cover areas for the Baranquilla Metropolitan Area: year 2015.

Credit: DANE Report

In addition, IDEAM has been using satellite data in their national forest monitoring efforts in support of the nationally led, Reducing Emissions from Deforestation and Forest Degradation (REDD+) effort. Further, IDEAM and the University of the Andes have made considerable progress in learning how to create and use data cubes – time series stacks of analysis-ready data. In collaboration with the Committee on Earth Observation Satellites (CEOS) Systems Engineering Office (SEO), a country-level Landsat Data Cube (consisting of 25,000 scenes) was completed in December 2016.

These efforts demonstrate the value and contributions of EO along with other data types to monitor and implement the SDGs at national level. Colombia is now working with EO4SDG and partners to identify ways to use EO to advance work on these topics and determine other areas of interest where incorporation of EO data can be beneficial. Additionally, DANE is interested in exploring further how EO can support the country's upcoming census, including the need for official, reliable statistics and information about indigenous populations – their number, location, demographics, and agricultural activity, among other items.

In Africa, EO4SDG has also engaged with Kenya's Ministry of Agriculture, Livestock and Fisheries, in close collaboration with GPSDD, to identify areas of EO contributions in support of national priorities and data needs. Coordination with the Governments of Kenya, Sierra Leone, Ghana, Senegal and Tanzania, as well as GPSDD, Safaricom, the African Development Bank and the UN Economic Commission for Africa, has aimed to establish an aspiring agenda to bring together the voices of African governments, local and regional bodies, private sector and civil society across the region to ensure that data becomes an integral part of the infrastructure for sustainable development, supporting improved economic, social and environmental decision-making.

The SERVIR program is a joint venture between the National Aeronautics and Space Administration (NASA) and the US Agency for International Development (USAID) that provides satellite-based EO data and science applications to help improve environmental decision-making in developing nations. In collaboration with AfriGEOSS, a GEO regional initiative that aims to provide the necessary framework for African countries, organizations and international partners to access and leverage ongoing EO-based initiatives across Africa, the SERVIR program is looking to leverage ongoing activities and explore linkages to support government needs on SDG monitoring and reporting efforts, using EO data.

7.4 Partnerships

The EO4SDG Initiative pursues partnerships as a key element of its strategic implementation, leveraging knowledge, resources and skills of partner organizations in collective support of the SDGs. Involvement of the individual GEO Member countries and Participating Organizations is central to the Initiative's activities, including efforts to support the engagement of, and collaboration with, NSOs. The Initiative seeks to enhance GEO's strong relationship with the UN and continuously engages and informs the global EO and geospatial information communities of developments and opportunities. Additional key partners of EO4SDG include development banks, non-governmental organizations, corporations, foundations and civil society.

Engagement and partnership with these entities help build processes, mechanisms and human capacity to include EO in national development plans and to integrate them with national statistical accounts to improve the measuring, monitoring and achievement of the SDGs.

Two examples of key organizations that EO4SDG is involved with, include:

Global Partnership for Sustainable Development Data (GPSDD): GEO has been a key Anchor Partner with the GPSDD, supporting GPSDD's country-level data roadmap process that assists countries with developing and implementing whole-of-government, multi-stakeholder data roadmaps for sustainable development at both national and sub-national levels. EO4SDG is providing resources and expertise to more directly engage with countries on meeting key data gaps and challenges. Country examples include Colombia, Kenya, Senegal and Ghana, among others.

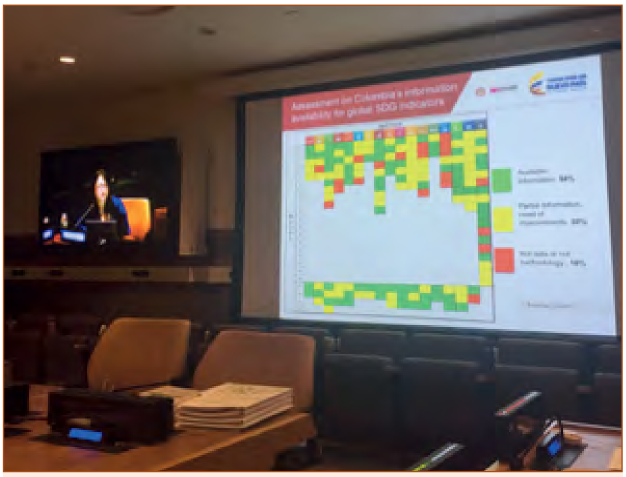

Figure 5: An assessment of the availability of Colombian information available for SDG Indicators (presented at the July 2017 UN High Level Political Forum learning, training, and practice session, co-organized by GEO and GPSDD)

EO4SDG has also been working with GPSDD on assembling a module on *"Earth Observations for the Sustainable Development Goals"* for inclusion in their Data4SDGs Toolbox, which comprises a set of tools, methods and resources to help countries create and implement their data roadmaps for sustainable development.

Examples of pilot efforts, capacity building, as well as outreach and engagement activities, in collaboration with the GPSDD, can be found on EO4SDG's website, eo4sdg.org, under *'What We Do'*. An article by GPSDD can be found in Part 2 of this Handbook.

Sustainable Development Solutions Network (SDSN): GEO participates in the SDSN Thematic Research Network on Data and Statistics, TReNDS, which convenes cross-sector technical and policy knowledge from across the global scientific, development, public and private sector data communities. Its members are leaders whose expertise spans the spectrum of global and national data policies, standards and processes that guide data production, access and use. TReNDS aims to contribute critical insights and offer technical and policy-oriented solutions on the rapidly evolving sustainable development data ecosystem. GEO supported the production and review of a report, *"Counting On the World"*, which focused on recommendations about how to improve the global ecosystem for sustainable development data.

7.5 Concluding remarks

GEO envisions a world, well in advance of 2030, in which uses of EO and geospatial information to support progress on the SDGs are valuable, routine and customary. Realising this vision implies that:

- the global community is aware of, and has timely access to, effective ways to use EO and geospatial information relative to the SDGs;
- countries and stakeholders have developed the skills and capabilities necessary to apply the data and information for effective SDG monitoring and reporting;
- EO provide real, value-added benefits and are recognized for their contributions to support the social, economic and environmental aspects of the 2030 Agenda; and
- there is demonstrated progress on the Goals and broad desire to achieve more.

Finally, to accomplish this vision, focus must be given to the means of implementation and global partnerships among EO providers, stakeholders and countries and in particular for NSOs and line ministries to ensure that countries have the latest information at their fingertips to guide and shape policies.

To this end, EO4SDG and the GEO community has found that successful development and application of EO for SDG data and monitoring support in national and sub-national contexts requires the following elements:

- direct engagement with the UN Custodian Agencies to ensure EO techniques are incorporated in recommended data methodologies and early data studies as they are developed – this is especially important for Tier 3 Indicator methodologies (those under or needing further development);

- both direct and global development data partnership-enabled engagement with national governments;
- facilitation and encouragement for national government ministries and agencies to work together across traditional institutional lines to incorporate EO and data collection techniques beyond traditional statistical practices;
- framing EO and data collection in direct action contexts and examples demonstrating improved human well-being and policy at community and national levels.

GEO's EO4SDG experience has provided some indications of the way forward for immediate progress. These include the following:

- specific focus on collaborative work across the development data ecosystem to incorporate EO techniques;
- prioritising integration of EO techniques with national census and newly emerging population data techniques, enhancing the ability of national and sub-national entities to GEO-locate and disaggregate gender and other demographic data;
- improving collaboration and integration of activities across the GEO and CEOS communities to make the most efficient use of intellectual, space-based and *in-situ* observation assets and resources;
- accelerated engagement among GEO and CEOS specialized communities to identify novel data analytics and observations that can result in better metrics and indicators.

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GEO publication *"Earth Observations in support of the 2030 Agenda for Sustainable Development"*:
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data4sdgs.org

UN Sustainable Development Solutions Network (SDSN):
unsdsn.org

SDSN TReNDS Report "Counting on the World, Building Modern Data Systems for Sustainable Development":
unsdsn.org/resources/publications/counting-on-the-world

8

Pan-European Space Data Providers and Industry Working in Support of the SDGs

Europe has two intergovernmental agencies dedicated to satellite Earth observations (EO): the European Space Agency (ESA) develops and operates a diverse range of EO satellite missions including the Sentinel series in cooperation with the European Commission and the Copernicus Programme, while the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) focuses on supply of weather and climate-related satellite data to the National Meteorological Services of Member and Cooperating States in Europe and other users worldwide.

Both agencies provide data streams (making best use of Earth observations, satellite communications and satellite navigation information) with significant potential to assist with the monitoring and reporting for multiple SDGs.

8.1 Pan-European space agencies and sustainable development

ESA has been working in close partnership with UN agencies since the World Summit on Sustainable Development (WSSD) in Johannesburg, in 2002. It supports the UN Environmental Conventions (UNFCCC, UNCCD and CBD) with international partners and financial institutions like the World Bank to promote the use of space data and technologies to support sustainable development activities and programmes.

ESA has developed a programme that comprises EO missions in three categories: meteorological missions, scientific missions (Earth Explorers) and the Sentinel satellite missions for the Copernicus programme led by the European Commission. All three categories of missions have potential to contribute to SDGs.

EUMETSAT's observations of weather, environment and climate, along with its scientific and technical expertise and support to capacity-building also help make the UN's Sustainable Development Goals a reality.

EUMETSAT's primary objective as an intergovernmental organisation, as set out in its Convention, is to establish, maintain and exploit European systems of meteorological satellites, taking into account, as far as possible, the recommendations of the World Meteorological Organization (WMO). A further objective is to contribute to the operational monitoring of the climate and detection of global climatic changes.

EUMETSAT is proud to be contributing to the implementation of the 2030 Agenda through provision of global, accurate, consistent and timely observations of the weather, environment and climate from space and of its involvement in user training and capacity-building projects. The use of its data and products saves lives, prevents economic loss and supports sustainable development and innovation.

8.2 SDG-2: Zero hunger

EO offers an alternative to traditional survey-based methods for forecasting regional and global crop yield. Managing the health of livestock is one path to that goal. ESA co-founded the VGTropics project, an information system to manage animal health data in data-sparse environments like developing countries in Africa. Livestock survey planning, livestock distribution, data analysis and syndromic surveillance are all supported and facilitated by a satellite network, including satellite navigation, GPS units, satellite-based telecommunication services and satellite EO. Thus, VGTropics works to offset weak capacity in some African countries to conduct diagnostics and gather coordinated information. The commercialisation of VGTropics started at the end of 2015. ESA also contributes to the global Group on Earth Observations Global Agricultural Monitoring (GEOGLAM) initiative started by the G20 Agriculture Ministers in 2011.

8.3 SDG-3: Good health & well being

During the Ebola crisis, ESA supported hospitals through the International Charter on Space and Major Disasters and helped laboratories by providing them with satellite data thanks to an inflatable satellite antenna. This technology facilitated rapid and reliable diagnosis. The so-called B-Life system, developed within ESA's Advanced Research in Telecommunications Systems (ARTES) Integrated Applications Promotions (IAP) programme, was used to support the Ebola treatment centre in N'Zérékoré, a remote area of Guinea. B-Life enabled collaboration in real time between on-the-ground emergency teams and St. Luc's Hospital in Belgium, allowing for treatment plans to be modified as patient blood samples were analysed. In December 2014, the B-Life service was registered as part of the European Emergency Capacity Response within the European Mechanism for Civil Protection managed by the European Commission.

Figure 1: The 12th EUMETSAT User Forum in Africa in Kigali, Rwanda, involves more than 160 participants from 51 African countries in a workshop atmosphere

8.4 SDG-4: Quality education

EUMETSAT supports training and capacity-building initiatives in Africa, Eastern Europe and Central Asia.

One example is EUMETSAT's uninterrupted support to a series of highly successful EU-funded capacity building projects (PUMA, AMESD, MESA, GMES & Africa) involving the African Union Commission and regional economic communities in the development of weather, environment and climate information services and an increasingly broad range of applications that are central to sustainable development.

Via its EUMETCast-Africa data broadcast system, EUMETSAT provides access to data from satellites and weather and ocean forecasts information from a variety of sources to more than 550 reception stations deployed across the African continent.

EUMETSAT's record of effective partnership building and multilateral and bilateral cooperation makes it a trusted partner in capacity-building projects facilitating the use of EO data and the building of sustainable communities, industries and environments.

8.5 SDG-6: Clean water and sanitation

In 2002, ESA worked with UNESCO to launch the TIGER initiative to use EO technology for improved, integrated water resources management in Africa. Exploiting this technology fills existing information gaps for effective and sustainable water-resources management at national-to-regional scales. Guided by its own international steering committee, TIGER received the endorsement of the African Ministerial Council on Water. Today, the TIGER initiative aims to support capacity-building activities and development projects in some 42 African countries. Delegates from 19 African and 10 European countries participated in TIGER's 2016 workshop held in Addis Ababa.

8.6 SDG-7: Affordable and clean energy

The dependencies between energy, weather and climate are increasing; while the demand for energy remains temperature-dependent, weather now determines the supply of the renewable part of the energy mix. Therefore, weather forecasts influence day-to-day decisions on energy production while climate data are essential inputs for well-informed decisions on strategic investments in the energy sector, in particular on preferred energy sources and production capacity.

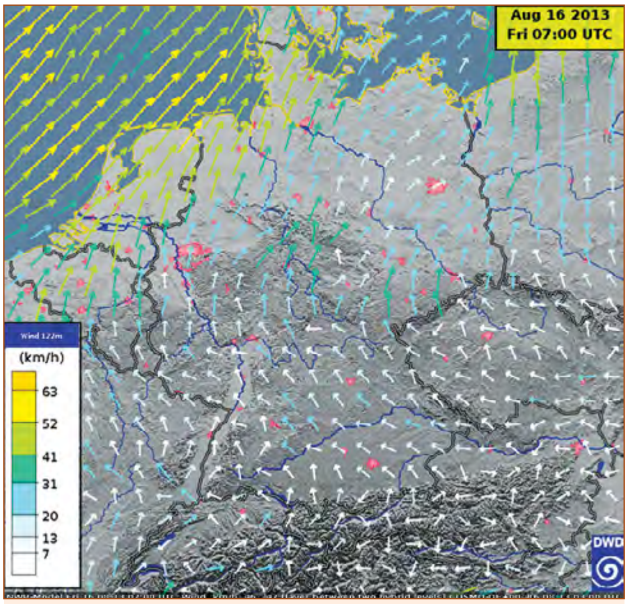

Figure 2: Forecast of surface wind field used to guide operations of wind turbines and predict their energy input to power grids.
Source: DWD

Observations from EUMETSAT satellites have a twofold contribution as they increase the performances of weather forecasts and are used to produce climate records of solar radiation parameters that can aid decision-making in relation to solar energy installations.

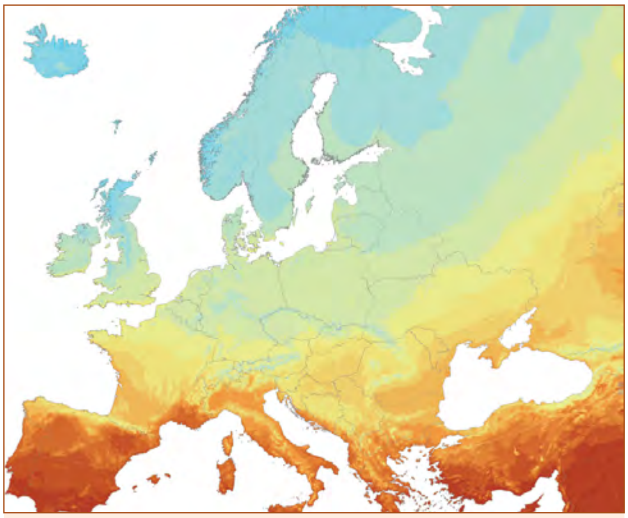

Figure 3: Map of photovoltaic solar electricity potential based on Meteosat solar irradiance climatology
Source: JRC with inputs from CM SAF

8.7 SDG-11: Sustainable cities and communities

Missions like the Copernicus Sentinel satellites provide increased potential to characterise developments at urban scales. With air pollution linked to millions of deaths around the world, it has never been more important to monitor the air we breathe. The Sentinel-5 TROPOMI instrument will be very important to continue the monitoring of our atmosphere by an operational system. Delivering important data on the composition of the atmosphere, Sentinel-5 is set to make a step-change in monitoring and forecasting global air quality. This state-of-the-art instrument will be installed on the polar-orbiting MetOp Second Generation satellite. It will monitor the composition of Earth's atmosphere globally on a daily basis by measuring trace gases – such as ozone, sulphur dioxide, methane and carbon monoxide – and aerosols that affect air quality and climate.

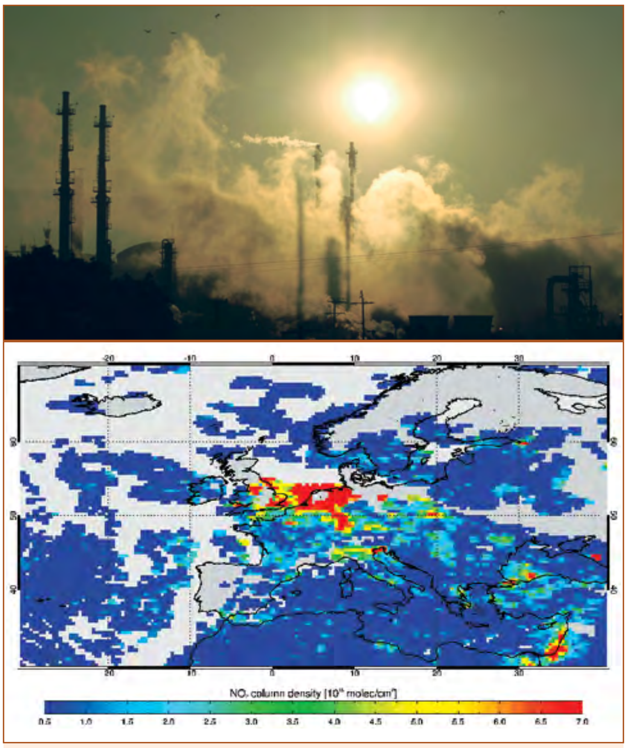

Figure 4: On 1 April 2014, the GOME-2 instruments on-board MetOp-A and -B observed elevated levels of NO2 total column concentration over parts of Germany, Belgium, the Netherlands and the UK

EUMETSAT monitors atmospheric composition from space using its geostationary and polar orbiting satellites, which will in the future carry additional dedicated Sentinel instruments provided by the EU Copernicus programme.

These satellite observations provide key inputs to forecasts of air quality over large urban agglomerations as well as sand and dust storms, in particular in Africa. Public health benefits from the use of this information for regulating traffic or other economic activities and for warning for potential respiratory problems.

In Europe, EUMETSAT data is used by the Copernicus Atmosphere Monitoring Service (CAMS), which provides information on air quality, the ozone layer and harmful ultraviolet radiation to users worldwide.

Figure 5: Copernicus services support coastal zone monitoring and management.

EUMETSAT data and imagery are also used for forecasting dispersion and transport of accidental pollutions and to monitor wildfires and the plumes of aerosols and gases they generate.

8.8 Further SDGs

Satellites have the unique potential for observing systematically and globally 31 of the 50 Essential Climate Variables (ECVs) identified by the Global Climate Observing System (GCOS). Both ESA and EUMETSAT provide significant data in support of SDG-13: Climate action.

For SDG-14: Life below water, EUMETSAT monitors the oceans using its own satellites, Copernicus missions it operates on behalf of the EU and the Jason missions shared with CNES, NASA and NOAA.

The resulting integrated marine data stream provides information about ocean currents, ocean surface wind, sea state, sea ice, sea surface temperature and ocean colour. These data are used directly and ingested in weather and ocean prediction models to provide crucial information for safety at sea, operations of marine infrastructure, fisheries, sustainable use of marine resources and protection of vital marine and coastal ecosystems.

For SDG-15: Life on land, optical imagery can be used to measure the extent of different land cover types and their changes over time, and can be complemented by radar data like those from the Copernicus Sentinel-1 satellites and Japan's ALOS series. In the context of the Global Forest Observations Initiative (GFOI), ESA contributes to the REDD+ Initiative of the UN Framework Convention on Climate Change (UNFCCC) to support the availability of wall-to-wall national coverage of satellite data to provide evidence and accuracy for forest reporting.

8.9 EO industry contributions

Europe has a vibrant value-adding industry that works in novel and creative ways to improve society through the application of EO satellite data. In 2017, the European Association of Remote Sensing Companies (EARSC) decided to focus its 2017 Product Award scheme on how industry might support the SDGs with data from a wide variety of EO sources. The results are the focus of the panel on the pages below.

Industry award: EO data for development

Recognising the need for the processing of an unprecedented amount of data from a wide variety of EO sources and the potential role that industry can play, the European Association of Remote Sensing Companies (EARSC) decided to focus its 2017 Product Award on how industry can contribute to the SDGs. Entrants were asked to address the monitoring of SDG outcomes and support to implementation and to specify which indicators their products were focused on. The winner was a product called **Waste from Space**, developed by Air & Space Evidence.

Waste from Space focused on the identification of unlawful waste dumping in unlicensed locations by using satellite EO data to detect areas of non-standard or anomalous land use. The application uses data from Landsat and Sentinel, although finer spatial resolution commercial data can also be incorporated to improve results.

Unlawful dumping of waste in unsuitably prepared locations can cause significant environmental and public health hazards. Revenues from illegal waste dumping often go to organised crime, frequently in areas with lower income and fewer public resources to bear clean-up costs. The product is intended for law enforcement agencies, aiming to enable early identification of illegal activity and support combatting organised crime (**Target 16.4**). It seeks to help ensure that more waste is subject to environmentally sound lifecycle management (**Target 12.4**), push more waste to be treated sustainably within the circular economy (**Target 12.5**), and ultimately mean much less waste is released illegally into the environment (**Targets 6.3**, **11.6**, and **12.4**).

A total of seven entries were received, and several of the runners-up are summarised below as a further illustration of industrial capabilities.

RAPID, developed by Astrosat, is a situational awareness platform acting as a single point of access for data to address the needs of first responders and others who require situational awareness in critical situations. The product was developed specifically to address **Target 1.5** and was developed with direct societal benefits in mind, with a framework for evaluating impact over several years. Examples of monitoring applications include the aftermath of storms, landslides and coastal erosion, the efficiency and operational status of ports, airports and national rail networks.

Starling, developed by Airbus, seeks to help companies verify their commitments to reducing deforestation across their agricultural supply chain. The number of companies making these commitments has risen by 22% in 2017, in part due to increased public attention, and this service enables companies using or producing palm oil to verify these commitments. Data from the SPOT constellation provide unbiased monitoring, enabling the distinguishing of forest from plantations, as well as small changes in tree coverage. They are complemented by data from radar imagers (e.g., Sentinel-1), which help overcome dense cloud cover in key palm oil landscapes. The product helps to ensure sustainable consumption and production patterns and encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle (**Target 12.6**).

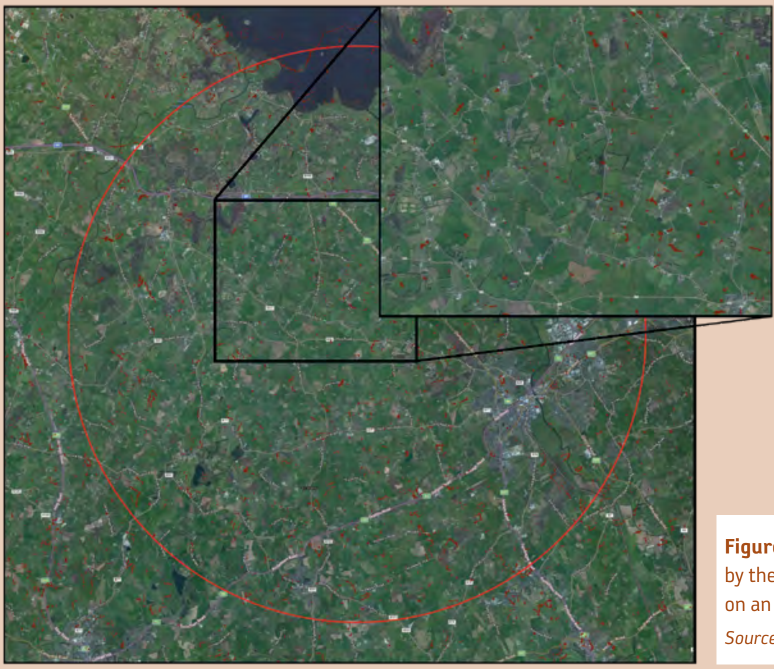

Figure 1: Areas of anomalous land-use identified by the 'Waste from Space' process, highlighted on an image map layer.
Source: Bing Maps

EO-based 3D Virtual Reality Cities, developed by GAF AG, provides photorealistic, high-quality, up-to-date and standardized 2D and 3D GIS-ready spatial information products globally, with resolutions from 30cm to 5m. These products are used as the basis for analysis by many organizations and local authorities in developing countries. Their monitoring support for disaster risk reduction (e.g., vulnerability mapping) and emergency response addresses the participatory, integrated and sustainable human settlement planning and management featured in **Targets 11.1, 11.2, 11.3, and 11.7**.

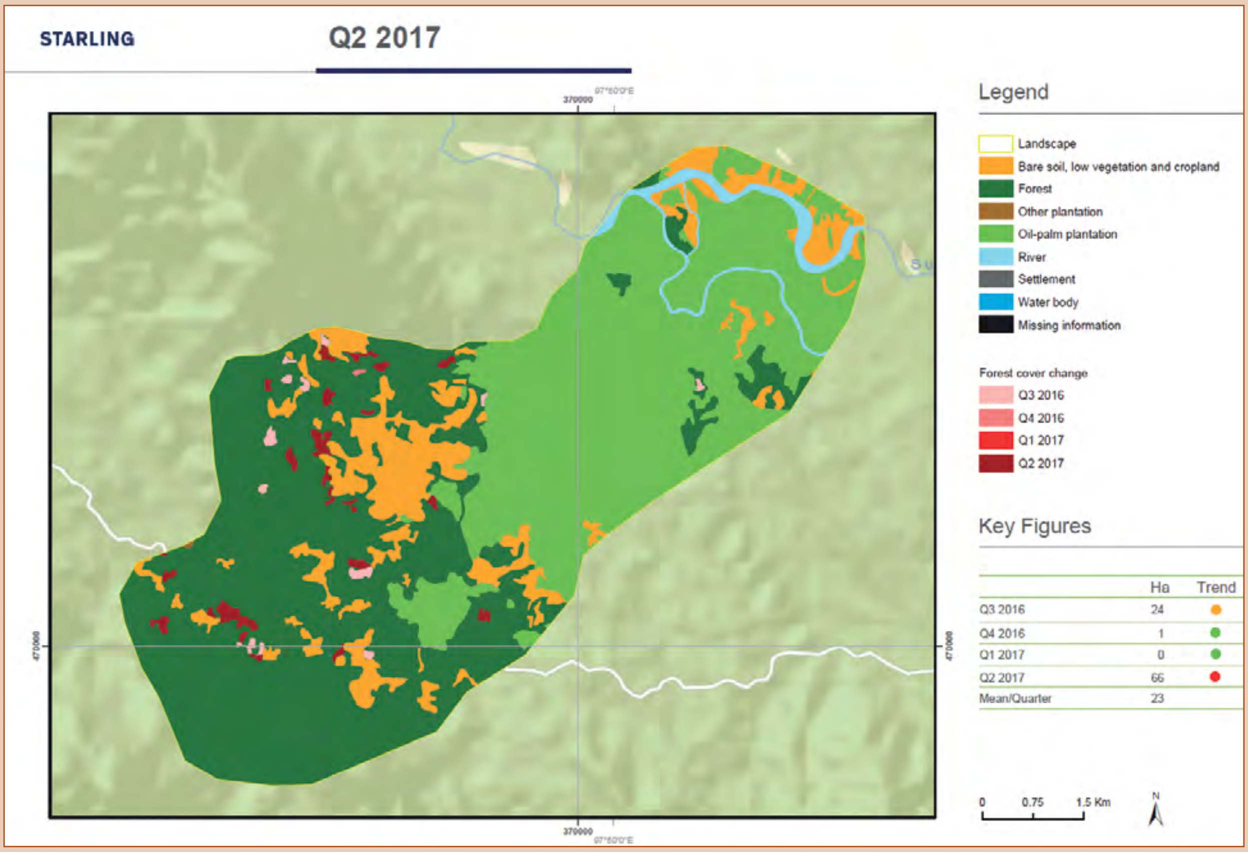

Figure 2: Starling utilises Airbus's SPOT constellation of satellites, which combine large coverage capabilities with 1.5m resolution. Their high-level detail helps companies easily distinguish forest from plantations and identify even small changes in tree coverage.

Credit: Airbus

Figure 3: 0.5m resolution DSM of Kigali, Rwanda.
© GAF AG, contains material distributed by Airbus.

The GAF Elevation Suite has been applied along with Pleiades imagery to derive 3D building models with a resolution on the order of 0.5m for Kigali, Rwanda as part of the ESA EO4SD project. These models can be used with other geospatial products for urban planning and design and for civil administration (e.g., assessment of property taxes and zoning frameworks).

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Further information

ESA SDG activities:
www.esa.int/SDG

EUMETSAT SDG activities:
www.eumetsat.int/website/home/AboutUs/InternationalCooperation/SupporttoUNSDG/index.html

European Association of Remote Sensing Companies (EARSC):
earsc.org

VGTropics animal health system:
business.esa.int/projects/vgtropics

Group on Earth Observations Global Agricultural Monitoring Initiative (GEOGLAM):
geoglam.org

The Global Forest Observations Initiative (GFOI):
gfoi.org

B-Life project:
business.esa.int/projects/b-life

GMES and Africa:
au.int/en/GMESAfrica

ESA TIGER initiative:
www.tiger.esa.int

Sentinel-5:
sentinel.esa.int/web/sentinel/missions/sentinel-5

Copernicus Atmospheric Monitoring Service:
atmosphere.copernicus.eu

9

The Rise of Data Philanthropy and Open Data in Support of the 2030 Agenda

Open data – specifically geospatial open data about our changing planet – plays an essential role by connecting ideas for global stewardship and guiding positive human impact. Nowhere is this more evident than in the area of global development, where more and more governments, non-governmental organizations and businesses are exploring ways to deliver much-needed imagery, data and related geospatial tools to a diverse and expanding community of users to ensure a sustainable future. Whether for food security, humanitarian response, property rights or global health, open data is essential for decision-making and enables the most impactful response to today's critical challenges.

With support from the Bill & Melinda Gates Foundation and Omidyar Network, Radiant.Earth provides users of all levels of sophistication with improved capabilities to discover, obtain, analyse and integrate imagery and data, geospatial tools and knowledge. Topical areas of focus include agriculture, food security, forestry, conservation, environment, global development, global health, humanitarian response, property rights, government transparency and journalism.

9.1 Introduction

Because of the essential nature of data for decision-making, a rise in data philanthropy and open data is taking place on a global scale. Data philanthropy – where for-profit businesses provide commercial data to the global development community free or at reduced cost – is not a new concept, but a proven one that is playing a greater role in global development activities. Perhaps one of the first examples of this is the DigitalGlobe Foundation that, as noted in a recent BusinessWire article, is celebrating 10 years of providing commercial high-resolution data for researchers to solve *"issues that impact the Earth and all its inhabitants."* According to the Foundation (underwritten by DigitalGlobe, Inc.), *"More than 3,000 imagery grants and services delivering hundreds of millions of square kilometers of the Earth valued at more than $14 million have been awarded over 10 years."*

Similarly, Planet has an open call for college students, researchers and professors to apply for access to their "one-of-a-kind" datasets for non-commercial purposes.

Using a different model entirely, Airbus Defence and Space makes information available through their Global Earth Observation Challenge, where entrepreneurs are asked to pitch business solutions in areas such as forest management, agriculture, smart cities and maritime. Selected projects are provided coaching and data vouchers worth €20,000-50,000.

Although implemented differently, the DigitalGlobe, Planet and Airbus efforts demonstrate how commercial providers are further evolving this relatively new area of philanthropy by providing highly valuable imagery and data at no or little cost, all for the benefit of advancing its use and applications to meet today's most pressing challenges. While these commercial businesses cannot be expected to always deliver data for free or at reduced cost, it is through many of these efforts that use cases are proven and advances are happening on the ground, benefiting the industry as well as the broader development community. As efforts increase to deliver on the 2030 Agenda for Sustainable Development, one can readily see the connection and importance of data philanthropy to this endeavour.

Traditional philanthropy is fuelling the rise in open data, supporting game-changing initiatives to expand and accelerate its use in the global development community.

As reported in Reuters earlier this year, *"Some of the world's most influential billionaire philanthropists plan to launch a powerful digital platform to harness the avalanche of data sent from satellites each day – and make it freely available for humanitarian and environmental causes."* The digital platform to which the article refers is Radiant.Earth.

9.2 Radiant.Earth

The Radiant.Earth customer base is diverse and not only recognizes end users and researchers, but also the equally important outreach to and engagement of data providers (public and commercial), value-added companies and cutting-edge developers that enable efficiencies, advancements and the opportunity to reach greater scale. Two foundational principles guide Radiant.Earth: open and neutral. *Open* refers to freely available imagery, data, geospatial tools and educational resources. *Neutral* refers to advocating for all of the growing sources of data, whether it be public or private, satellite, airborne or drone, or from any geographic area.

Through its open-technology platform and robust, proactive community development effort, Radiant.Earth intends to accelerate and expand the use of geospatial resources to improve decision-making by:

- aggregating the world's open Earth imagery;
- connecting users with the best tools, expertise, and solutions;
- improving discovery and analysis of the vast resources of Earth imagery with improved tools (cloud computing, plug-ins, and APIs);
- providing education on the use of the resources;
- serving as a new source for contributing, storing and accessing growing amounts of drone data;
- providing non-profit organizations with services to develop requests for proposals, to conduct technical review of commercial proposals, and to develop proof of concept applications;
- building a community of innovators by creating new opportunities for developers to fuel solutions as a result of better access, more data and a better understanding of the community's needs; and
- providing highly-valuable insights into the commercial marketplace and related policies such as licensing issues.

In short, Radiant.Earth will amplify other's good work – the excellent products, research, contributions and advancements of the numerous and diverse government, business and non-governmental organisations that comprise the broad global development community.

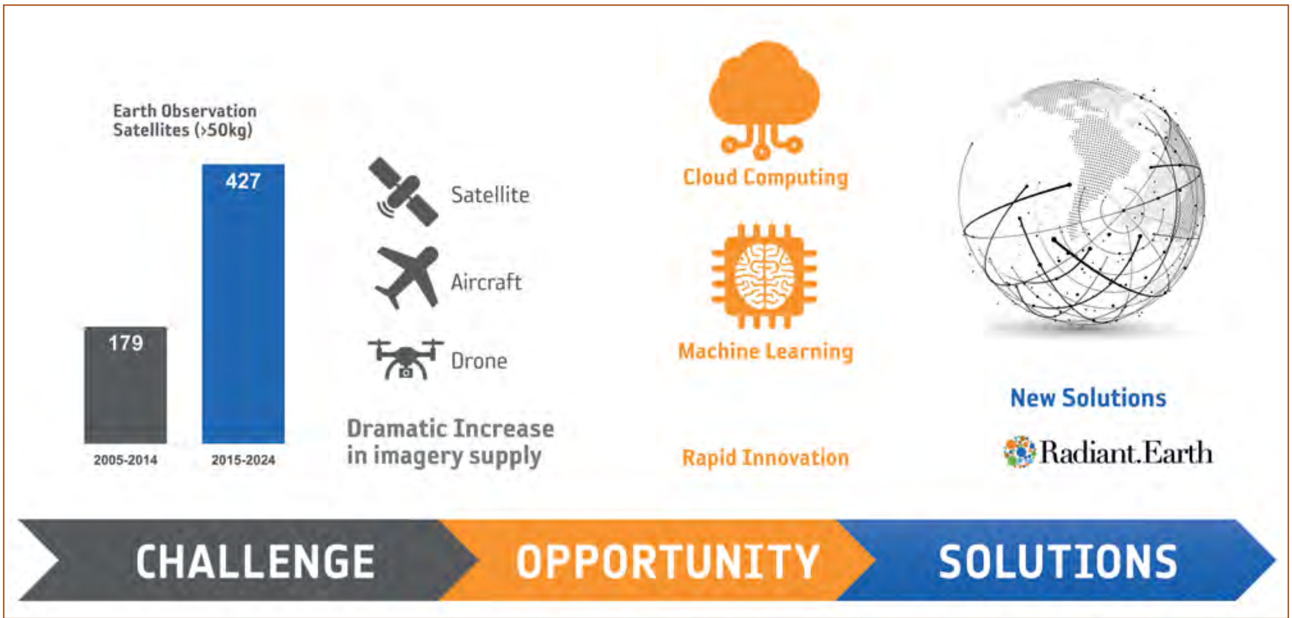

Figure 1: Here's how it works

Figure 2: Food distribution in Kenya
(Anes Sabitovic, unsplash.com, Creative Commons)

It intends to strengthen and compliment on-going efforts, all within a context that is more responsive to global development.

As the old adage states, *"A rising tide lifts all boats"*. Radiant.Earth hopes to be that tide by leveraging today's technology to take what now is a disparate and competitive marketplace filled with many successes, but with several high barriers to entry, and transforming it to one that is more cohesive, collaborative, informed, equipped and responsive to the global development community.

9.3 Partnerships for the future

Strong collaborations with groups such as the Committee on Earth Observation Satellites (CEOS) and the Group on Earth Observations (GEO), which have been at the forefront of open data policy for societal benefit, are key to realizing Radiant.Earth. To that end, Radiant.Earth has established formal working relationships with numerous CEOS Members, including ESA and CSIRO, and has engaged GEO and NASA in planning efforts. In addition, it has established agreements with private sector firms such as Amazon Web Services.

As Radiant.Earth bridges public, private and non-governmental sectors, it is uniquely situated to help deliver on the 2030 Agenda for Sustainable Development, which will require even greater cooperation and communication and will need to address a myriad of fast-paced changes occurring in the marketplace. Many of these changes are happening outside the CEOS community. From new privately-funded satellite constellations to an abundance of drone data, new actors and data sources in the sky and on the ground are rapidly advancing open data strategies and impacts. Cloud computing and machine learning are changing and accelerating analytic capabilities, taking data access and research to new levels. To this end, we have formed partnerships with new actors such as Code for Africa, a membership group with the largest civic technology laboratories and open data activists. All of these capabilities should be harnessed to deliver on the 2030 Agenda.

ESA and Radiant.Earth recently entered into an agreement to facilitate monitoring progress towards the SDGs and enhancing geospatial literacy across the global development community.

Radiant.Earth looks forward to contributing to the 2030 Agenda and leveraging the successes of data philanthropy and open data. Along with the work of groups such as CEOS, Radiant.Earth hopes to provide a new and effective resource for the global development community.

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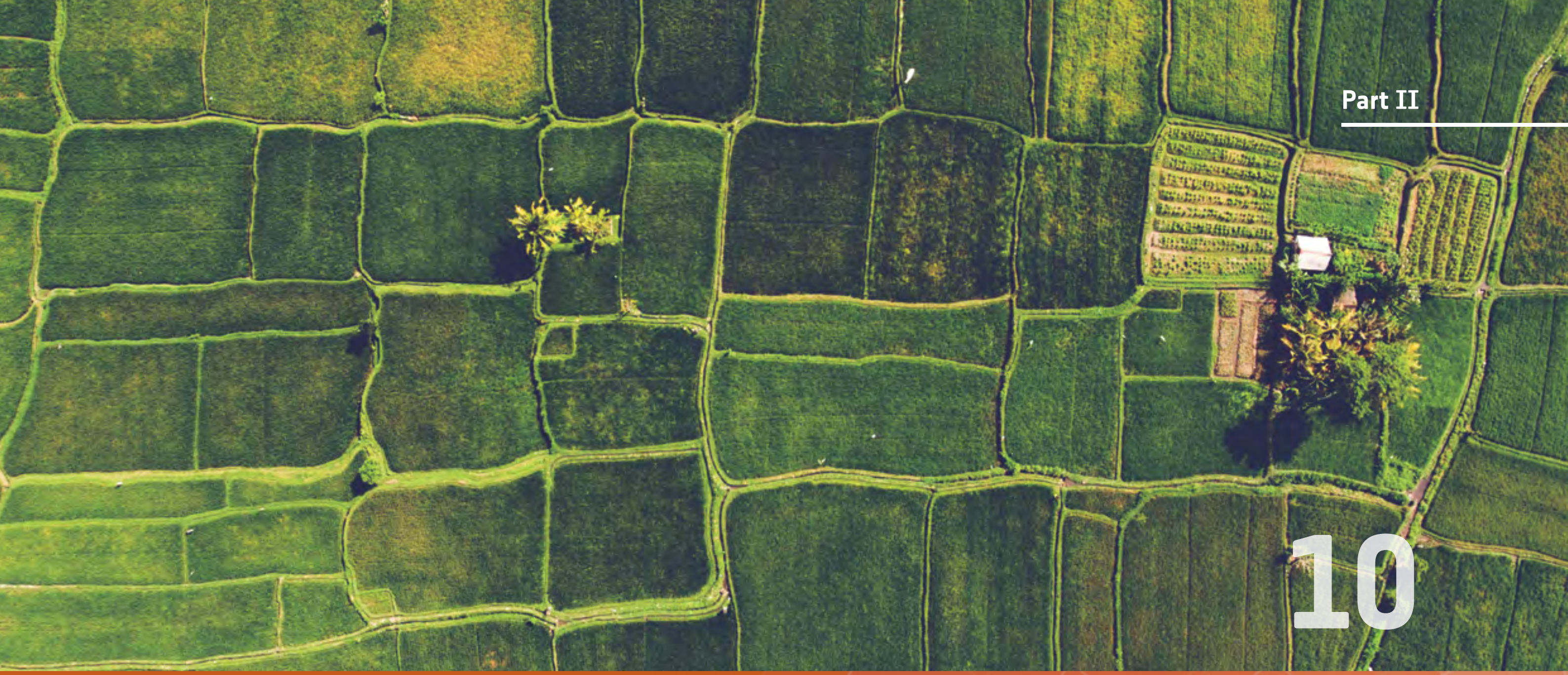

Building a Demand-Driven Approach to the Data Revolution for Sustainable Development

The Sustainable Development Goals (SDGs), and the related implementation and monitoring agenda that governments are starting to address, have increased awareness of the huge demands for data, both to provide the raw material for the monitoring framework and also as an essential part of the infrastructure for delivering the goals. The expectations of governments are high and rising. Running an effective health or education service, understanding how to raise agricultural productivity or how to incentivise investment in new industries all require huge amounts of data for governments and other stakeholders to make effective decisions and implement good policy.

In response to both the increase in the demand for data and to new opportunities on the supply side, the Global Partnership for Sustainable Development Data (GPSDD) was launched during the United Nations General Assembly in September 2015 to support countries around the world and stakeholders across sectors to better harness the data revolution to achieve the SDGs.

10.1 Introduction

One of the most critical conditions for the realisation of the ambitions expressed in the Agenda 2030 will be the more effective and efficient use of dynamic and disaggregated data for improved decision-making, service delivery, citizen empowerment, entrepreneurship, competitiveness and innovation to help achieve and monitor the SDGs and their targets.

This increase in demand has come together with a huge increase in supply, driven by new technologies and the new methods that are now possible. There is a transformative 'data revolution' underway, by means of which

"... new technologies are leading to an exponential increase in the volume and types of data available, creating unprecedented possibilities for informing and transforming society and protecting the environment. Governments, companies, researchers and citizen groups are in a ferment of experimentation, innovation and adaptation to the new world of data, a world in which data are bigger, faster and more detailed than ever before" (A World that Counts, 2014, p.2).

The creation of a partnership like GPSDD had been a recommendation of two reports (*High-Level Panel on the Post-2015 Development Agenda* and *the Inter-Agency and Expert Group on SDG Indicators*) produced under the auspices of the UN Secretary General during the post-2015 development process, which was then taken up by a number of governments, companies and civil society organisations to get the partnership launched in 2015. The GPSDD now has over 250 members including vanguard governments, international agencies, private sector companies, civil society groups, and statistics and data communities from all corners of the world, spanning sectors and disciplines.

The Global Partnership exists to connect different stakeholders working on data, to catalyse ideas and innovations that generate progress and solve problems, and to drive the political changes that are needed if data is to play its role as a key part of the infrastructure for sustainable development.

10.2 Data roadmaps for sustainable development

At the national level, a central pillar of the GPSDD's strategy is to work with governments and other organisations to support their priorities for investments and innovations in data. The GPSDD does this by engaging with them in 'data roadmap processes' that are country-led and take a whole-of-government and multi-stakeholder approach (Figure 1).

Figure 1: The Data Roadmap for Sustainable Development Forum held in Accra, Ghana in April 2017.

Accordingly, the data roadmap, in the current context, can be defined more as a process bringing stakeholders together at the country level to make progress against the SDGs, as opposed to a specific document outlining the path forward. While this is the intent of the process, using a multi-stakeholder approach to drive a strategic process that leads to clear actions over a defined timeframe, countries have used this process to organize, define priorities, connect with relevant partners, and better understand what is happening at the country level. In addition, the data roadmap process as defined by the GPSDD is meant to complement and align to other national development strategies including the National Strategy for Development of Statistics. Countries engaged as part of the data roadmaps process in 2016–2017 include Colombia, Philippines, Senegal, Sierra Leone, Kenya, Tanzania, USA and Ghana.

The GPSDD operates at three main levels:

1) putting data on the political agenda;

2) creating mechanisms to better connect demand with supply; and

3) creating an enabling environment to lessen the friction for data flows.

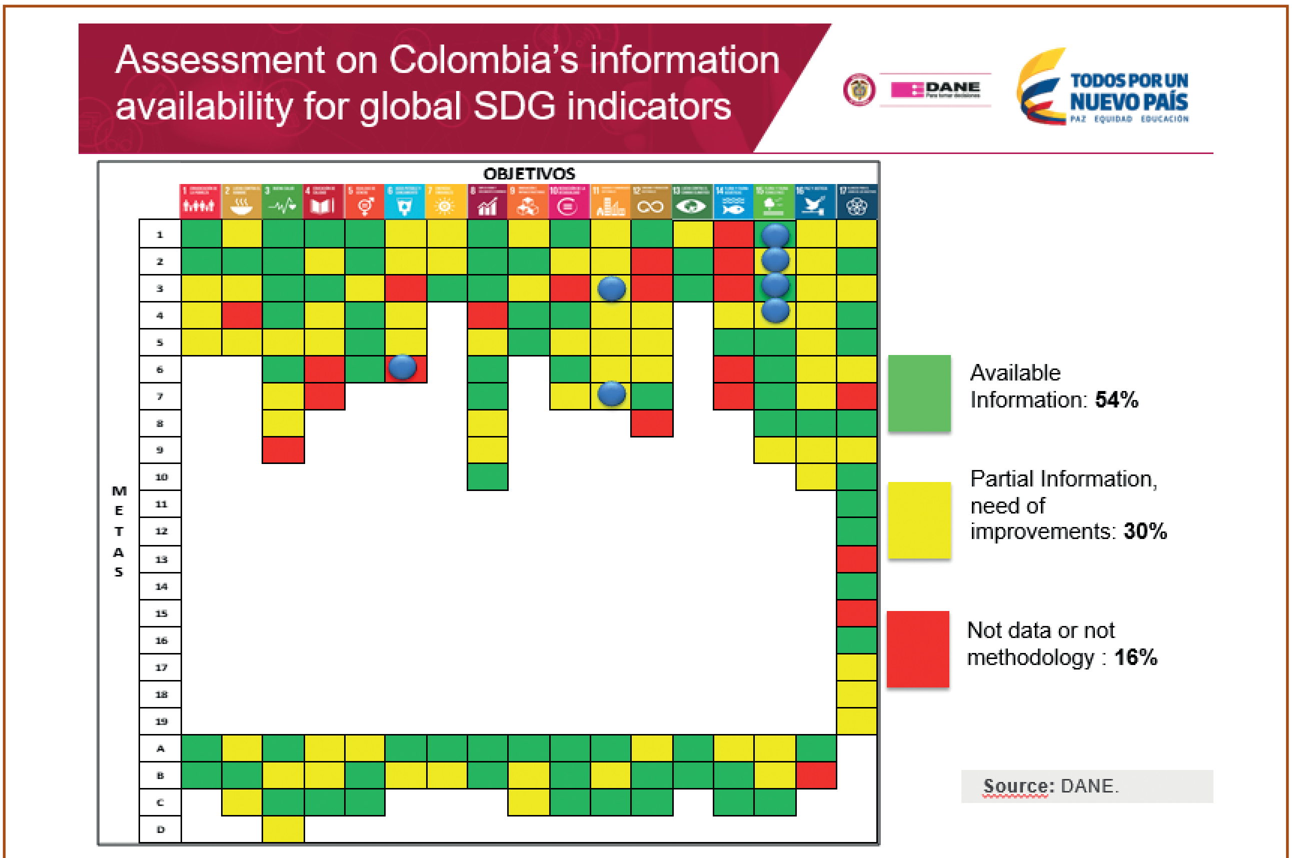

Figure 2: Data gaps assessment matrix for the SDG Indicators developed by DANE for Colombia in 2016.

With these objectives in mind, the data roadmap process is very demand focused. It allows for the better understanding of how countries are addressing the SDGs in relation to their national development priorities; key issues and challenges around data and technology (Figure 2); and how alternative sources of data and new methods in the context of the data revolution can be applied to meet these challenges.

10.3 Country needs – geospatial and EO data

At the country level, the GPSDD has been working primarily with the National Statistical Offices (NSOs), Presidential Offices, Ministries of Planning and Finance, and institutions focused on the rights to information access as the main focal points through which other government institutions and stakeholders across sectors are brought into the process. A number of consistent challenges have been identified, including financing and capacity, interoperability, data-sharing mechanisms, engagement with the private sector, data literacy, and a number of others that will be outlined in a forthcoming report from the GPSDD assessing the data roadmaps process thus far. Of these, issues around data disaggregation, gaps on environmental data, and the use of geospatial and Earth observations (EO) have been identified as major issues that will be addressed by the GPSDD through multi-stakeholder collaborations (Figure 3). In addition, the GPSDD has been assembling a 'Data4SDGs Toolbox' that makes available a number of resources that speak to best practices, guidelines and tools that address many of the common challenges countries are facing within the context of the data revolution.

In early 2017, the GPSDD started working closely with NASA and the Group on Earth Observations (GEO) to more specifically address how EO and *in-situ* data could be applied to data gaps that countries are facing. Many of these are within the broader environmental domain and many of the targets and related indicators are classified as Tier II or III. With the support of NASA, GEO and other organizations including the University of Maryland, CEOS, ESA, CIESIN and University of South Florida, the GPSDD has been working iteratively to identify the need at the country level and match this need with available or developing methods from partner organizations in a way where these methods can be tested and scaled across countries (Figure 3). The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) is spearheading the process to better integrate geospatial methods with national statistics, something that this work at the country level is only further encouraging and aligning to.

For example, in Colombia, the GPSDD worked closely with NASA and the National Administrative Department of Statistics (DANE) to develop a workshop in March 2017, bringing together key institutions to address how EO data could be applied to generate and/or complement environmental information. The workshop included the Ministry of Environment and Sustainable Development (MADS) and the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), both of which had relevant expertise within this domain. Key SDG Goals identified as challenges included Goal 6 – Clean water and sanitation; Goal 11 – Sustainable cities and communities; and Goal 15 – Life on land.

With the help of all of the above institutions, a number of

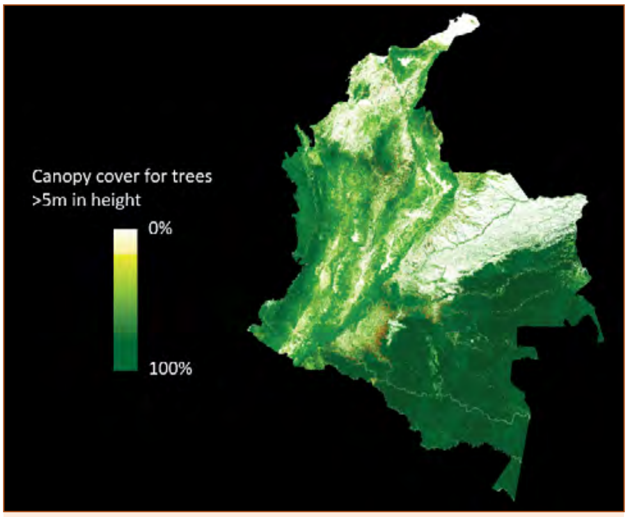

Figure 3: Canopy cover of trees in Colombia >5m in height - Matt Hansen, University of Maryland.

methods were identified that were applicable to strengthen the work already being done in the country, as well as new opportunities to address the needs of Colombia through partner organizations. More importantly, this process also supported the strengthening of institutional ties between the Colombian institutions regarding the dissemination on methods under development and promoting access to a Data Cube already under development at IDEAM with the support of CEOS, NASA and others, from open source code made available by Geoscience Australia and CSIRO. This process provided a great example of both national level and international collaboration, including making innovation more openly accessible.

10.4 Encouraging a data ecosystem approach

At the core of the work with country partners is the advancement of mechanisms for how governments, civil society, private sector and other actors including international organizations, foundations and academia work with one another to achieve the SDGs. It will take more coordination and cooperation across these sectors to fill the data and technology gaps, including the capacity and resources required. There are still fundamental issues when considering the elements needed to encourage a data ecosystem approach, including data sharing and federated approaches at the government level, and the integration of open data and the SDGs to build a more thriving environment that brings in the private sector and civil society as active participants and users of data. Conversely, both the private sector and civil society have valuable data in support of the SDGs that also needs to be made more accessible. For example, efforts are on-going for how mobile data, specifically call data records, can be applied for social good and the SDGs. However, there are many regulatory, privacy and functional models that still need to be developed and tested before this becomes more mainstream. Organizations like GSMA, DIAL, Orange, Dalberg Data Insights, MIT and many others are working on these issues. In the end: an ecosystem approach where the right policies are in place to encourage data sharing and open data; an infrastructure in place that creates a distributed network; and users across sectors that have access to use and innovate against these data developing a new market for social good is the ideal. The SDGs need a framework that supports the reporting and monitoring requirements, while also applying data for action, decision-making and entrepreneurship.

10.5 API Highways

An early activity the GPSDD was involved in was to address the interoperability issues that limit access and use of data. A 'Data Architectures' Working Group was formulated in early 2016 that initially focused on the differences between platforms, rather than an infrastructure that supports the data needs of these platforms. As a result, and based on further feedback from Working Group members, the GPSDD Secretariat experimented with developing a data infrastructure that sought to identify high-value, alternative datasets (geospatial, EO, open data, citizen-generated-data, mobile data) made available via API Highways that could easily be consumed by other applications and platforms (Figure 4). This includes a playbook or key considerations for developing data services.

The intent was to provide an additional "channel" for SDG-relevant data that could be networked with other

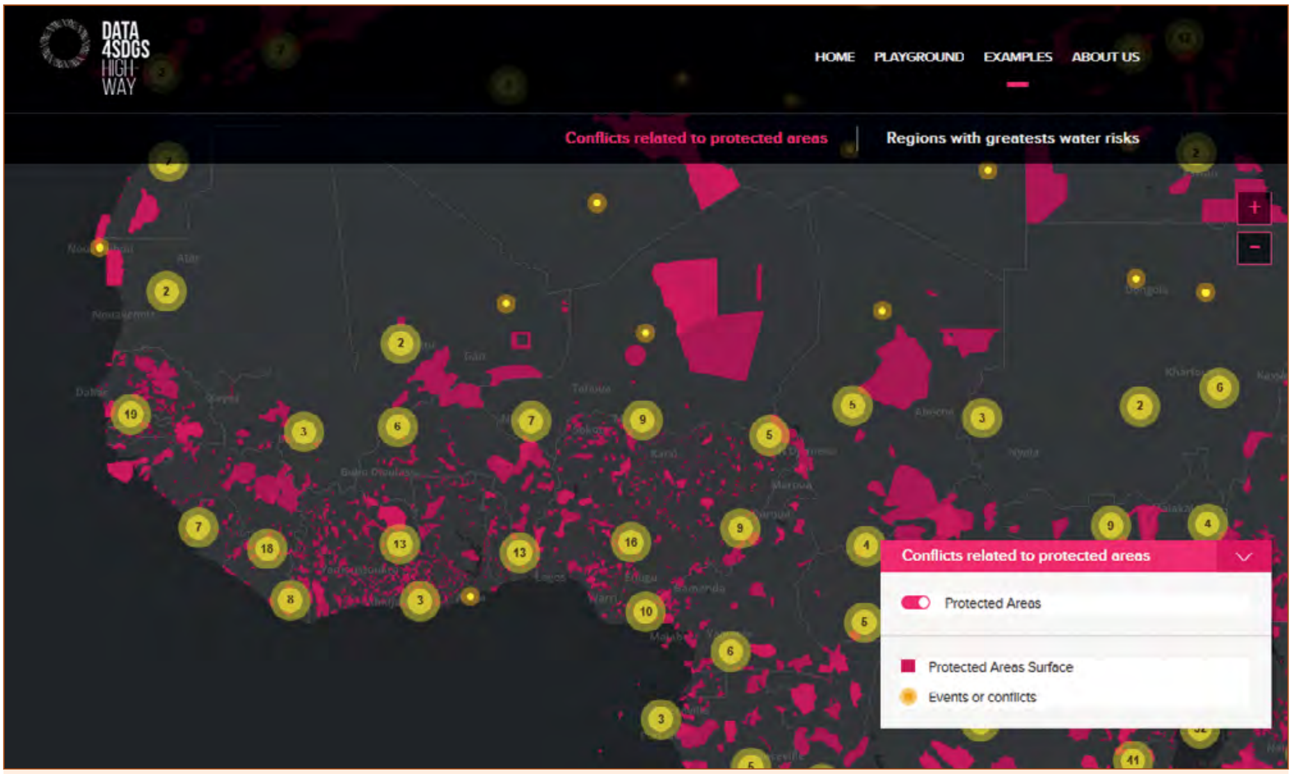

Figure 4: An example of bringing data together via API Highways to visualize where conflict is occurring in relation to protected areas.

data infrastructures and platforms, bringing together both official and non-official data that would further empower the developer ecosystem to create rich apps and visualizations for action and decision-making. Working with GEO, the GPSDD is also testing this infrastructure to make methods and EO data more accessible and thus scalable across countries. For example, GEO, NASA and others are working with UN Environment on the methodology for calculating Indicator 6.6.1 – change in the extent of water-related ecosystems over time. The GPSDD is working with GEO to create a connector from API Highways to its data repository such that the data needed for this indicator can be 'packaged', along with the methods where API Highways can be used as an additional channel to scale the application of this method.

10.6 Conclusion

Over the next 3 years, many countries will be undergoing their national censuses both for population and agriculture. While maintaining the need for household level surveys, there are consistent needs for using alternative methods to make these censuses and sectorial information more dynamic, cost-effective and granular, something where geospatial and EO data have a large role. When coupled with citizen-generated data, mobile data and survey level data, there is immense potential for how these data not only inform national planning, but also citizen-level decision-making.

Key 'plays' for building digital services in support of the SDGs

1. Document everything.
2. Consider the Developer Experience (DX).
3. Be an upstanding citizen of the web.
4. Be a part of the community and ask for help.
5. Build trust.
6. Consider the future.
7. Plan for the long tail.
8. Make it easy to use.

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Further information

GPSDD has developed a guidelines document that provides methods for developing a data roadmap process: **www.data4sdgs.org/resources/data-roadmaps-sustainable-development-guidelines**

The Data4SDGs Toolbox assembles resources and methods applicable to common challenges in implementing the SDGs: **www.data4sdgs.org/toolbox**

Current minimum viable product (MVP) of API Highways: **http://apihighways.data4sdgs.org**

GPSDD Data Playbook: **https://gpsdd.github.io/playbook**

Monitoring Guidelines for SDG Indicator 6.6.1: **www.sdg6monitoring.org/news/indicators/661**

11 Environmental Information from Satellites in Support of Development Aid

Development Aid is a complex international system covering a range of financial aid mechanisms (loans, grants) originating from mostly Western industrialised countries to support the economic, environmental, social and political development of developing countries. About 80–85% of developmental aid comes from government sources such as Official Development Assistance (ODA), with the remaining 15–20% coming from the private sector, such as Non-Governmental Organisations (NGOs), foundations and other development charities. As an indication of the overall economic size of this activity, the total net ODA volume in 2016 was around US$143 billion, up 8.9% on 2015 figures.

11.1 Background and context

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. On 1 January 2016, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda officially came into force. These SDGs were adopted by world leaders in September 2015 at an historic UN Summit and will drive development aid priorities over the next few decades. A comprehensive governance process is in place within the UN framework to guide implementation of the 2030 Agenda, including the High-level Political Forum, the UN Statistical Commission (UNSC), the UN initiative on Global Geospatial Information Management (UN-GGIM), and many UN specialised agencies allocated as custodians of individual SDGs.

Many significant developments and changes are taking place in Earth observation (EO) that are bringing this technology from scientific use to a level where it can be used as an operational source of environmental information in a wide range of (non-specialist) domains. In addition, political, public and scientific interest is growing to make better environmental decision-making through the use of EO to address the grand societal challenges that the world is increasingly facing, many of which are linked to initiatives supported by the Group on Earth Observations (GEO).

Over the last decade, several space agencies have started individual initiatives to demonstrate the capabilities and use of EO in the field of development aid with varied stakeholders. These include the International Financing Institutions (IFIs), Multi-lateral Development Banks (MDBs), national aid ministries/departments, NGOs and a range of local government organisations in those developing countries that are the aid recipients. Such initiatives include NASA's SERVIR program, based on a high-level partnership between NASA and USAid, and JAXA's (Japan) active support and engagement with the Asian Development Bank (ADB). Since 2010, ESA has been collaborating on the use of EO-derived information together with leading IFIs, in particular in partnership with the World Bank (WB), the European Investment Bank (EIB), the International Fund for Agricultural Development (IFAD) and the ADB.

11.2 ESA initiatives

ESA has sought to demonstrate the benefits (both quantitative and qualitative) that EO can deliver in wide range of individual development aid projects implemented by the IFIs. EO can provide key environmental information (e.g., land, marine, atmosphere) to support the planning, implementation and monitoring of these projects in the IFI lending operations, many of which are large infrastructure investments. This information is tailored to the specific project requirements defined through close dialogue with the Bank project managers and, as such, is produced by specialist EO service providers (e.g., SMEs in Europe). For more details, see: www.worldbank.org/earthobservation.

These initial experiences have raised interest within the IFIs to explore a longer-term, more strategic approach to the integration of EO in their activities. For example, both the WB and ADB have signed strategic Memoranda of Intent (MoI) with ESA to collaborate more closely in ten priority thematic areas: *Urban Development, Marine Resources & Coastal Environment, Agriculture & Rural Development, Disaster Risk Reduction, Energy & Extractives, Water Resources Management, Forest Management, Ecosystems Services, Fragile & Conflict States, and Climate Resilience & Proofing.*

ESA's Earth Observation for Sustainable Development (EO4SD: eo4sd.esa.int) initiative seeks to scale up the level of activity in each of these thematic areas by carrying out regional demonstrations over a 3-year period in two or three key regions around the world and two or three countries in each region. An important element will be building technical capacity within the government agencies of the countries involved, such that the environmental information derived from satellites can be effectively used in the local operations with a view to their long-term, sustainable usage. In 2016, ESA started larger-scale activities in three thematic domains (Urban Development, Agriculture and Rural Development, Water Resources Management), and plans to start in the remaining seven areas during 2018–19. Requirements for information are being strongly driven by the relevant Bank teams, primarily within the WB, ADB, and IFAD (Figure 1).

11.3 Urban development

Efforts by governments and international development agencies to effectively ensure that urbanisation in developing countries takes place in a sustainable, equitable and inclusive manner are often hindered by lack of data. While it has been established that urban areas across the developing world are expanding rapidly, very often relatively little is known about the ways in which they develop in terms of spatial growth, pattern and associated population density.

Addressing the socioeconomic challenges in urban areas, including the uncontrolled formation of informal settlements, requires up-to-date and accurate spatial information. This

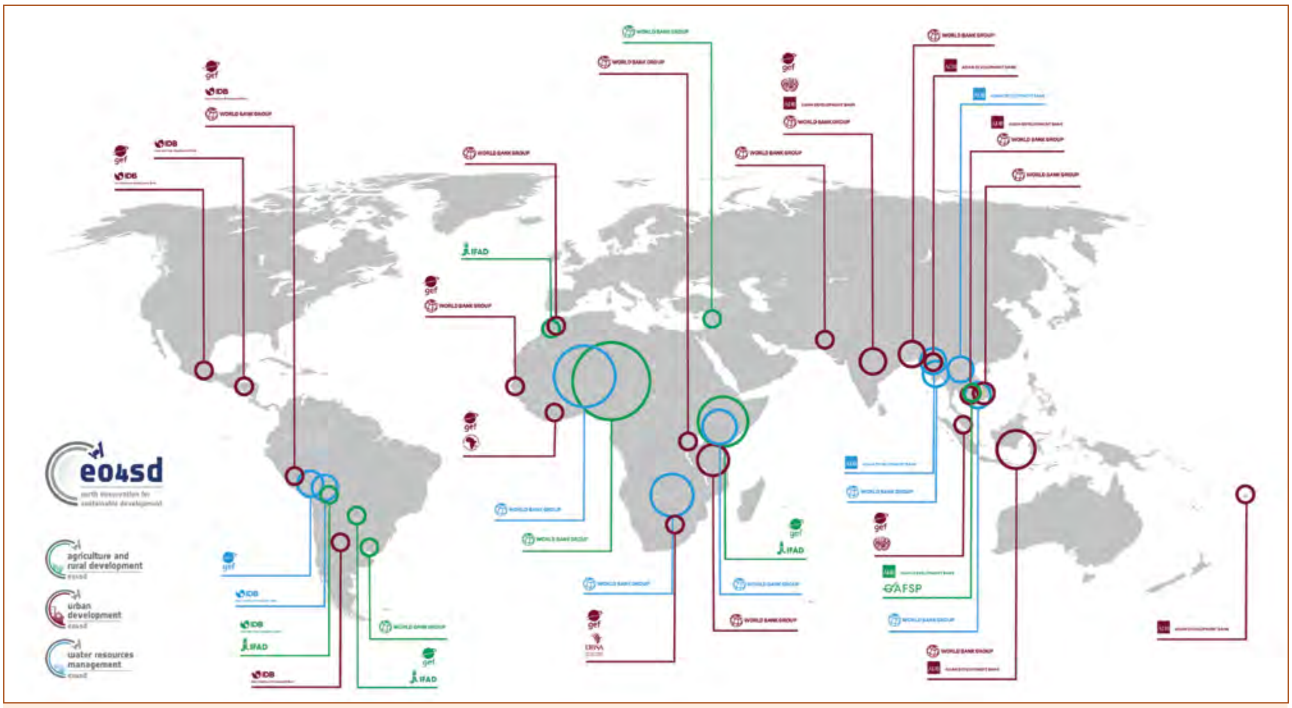


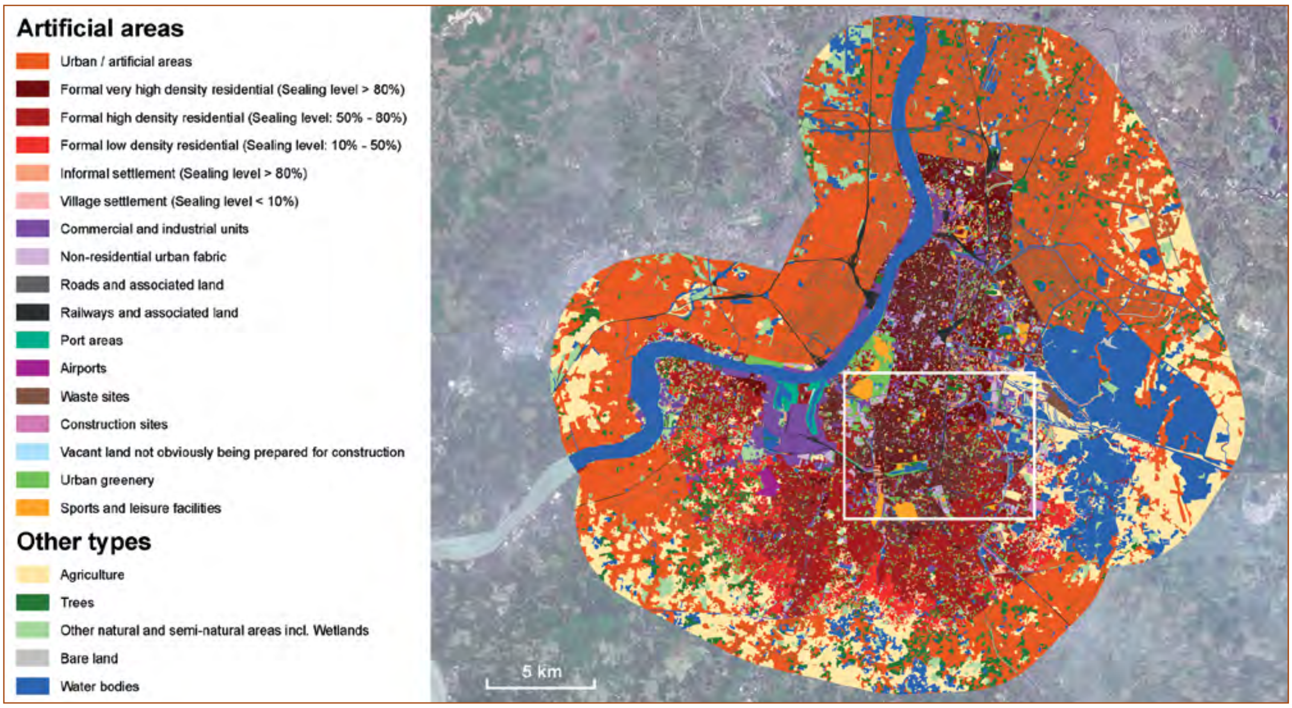
Figure 1: Geographic distributions for the Areas of Interest (AoIs) addressed in the on-going ESA activities in Urban Development, Water Resources Management, and Agriculture & Rural Development.

includes information on the distribution and expansion of urban land and qualitative changes in land use. In this context, satellite data have significant potential to deliver un-biased urban-related information at global, regional and local scales.

Discussions with the IFIs have identified several priority requirements for information to support urbanisation programmes. These requirements can also be illustrated and structured adequately using the World Bank Group's 'plan–connect–finance' framework developed for sustainable urbanisation. The requirements translate into a portfolio of EO products, the details of which can be found at eo4sd.esa.int/urban.

An example is in support of the Kolkata Environmental Improvement Investment Program, implemented by the ADB. This focuses on water supply and sewerage to the municipality, with the main stakeholder being the Kolkata Municipal Corporation (KMC) and also including the Kolkata Metropolitan Development Authority (KMDA) representing 19 municipalities and various state-level administrations.

In line with the Millennium Development Goals followed by India, in June 2015 the government launched three major urban development initiatives, handled by the Ministry of Urban Development (MoUD), in addition to several other programs such as the National Urban Information System (NUIS) initiated in October 2014. In this context, the KMC



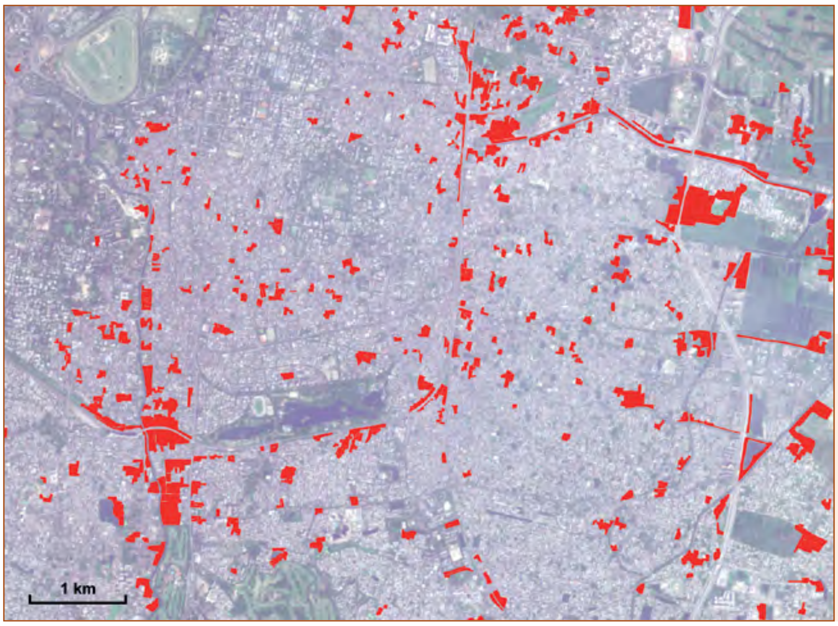


Figure 2: Kolkata, India: Top - Land Use and Land Cover (LULC) for February-March 2017, based on a combination of Pleiades-1A/1B (0.5 m resolution) in the city centre and Sentinel-2 (10 m resolution) for periurban areas. Bottom - informal settlements.

Source: SIRS for ESA/ADB. Contains modified Copernicus Sentinel data (2017). Pleiades data © CNES (2017), distributed by Airbus DS.

leads different projects for improving land-use management and urban planning in a sustainable manner.

In Figure 2, the top panel shows the Land Use and Land Cover (LULC) product for Kolkata. The classification is based on the European Commission's Urban Atlas nomenclature. For the core urban area, the LULC product used very high resolution (0.5m) Pleiades-1A/1B satellite imagery from the period 7–15 February 2017. The peri-urban areas were classified using Sentinel-2A (10m resolution) data, acquired on 16 March 2017, also shown as the background image. The bottom panel shows an extract of the informal settlements class, delineated via visual interpretation, based mainly on attributes of compactness, patch size and building density.

According to Neeta Pokhrel, Senior Urban Development Specialist working in the Kolkata programme, the EO4SD-Urban products can be very helpful for the KMC and other stakeholders for in-depth analysis of the city, both as mapping products and derived geo-statistical indicators. They can contribute to land-use planning (e.g., with precise mapping of informal settlements), better handling of disaster management and supplementing climate resilience assessments.

In support of a similar ADB program, EO-based mapping products were delivered over a number of urban areas in Cambodia's Tonle Sap Basin. The ADB project officer (Sameer Kamal, Urban Development Specialist) explains that the overall goal of the program is to support the government of Cambodia in improving urban services and enhanced climate resilience in participating towns. The program is part of ADB's sequential, programmatic engagement in Cambodia's urban sector. The EO products are being used for both on-going and upcoming ADB projects to (i) inform urban land use and master planning, (ii) support the feasibility studies and detailed designs for specific subprojects, and (iii) prepare assessments of climate vulnerability, risk and adaptation to climate change.

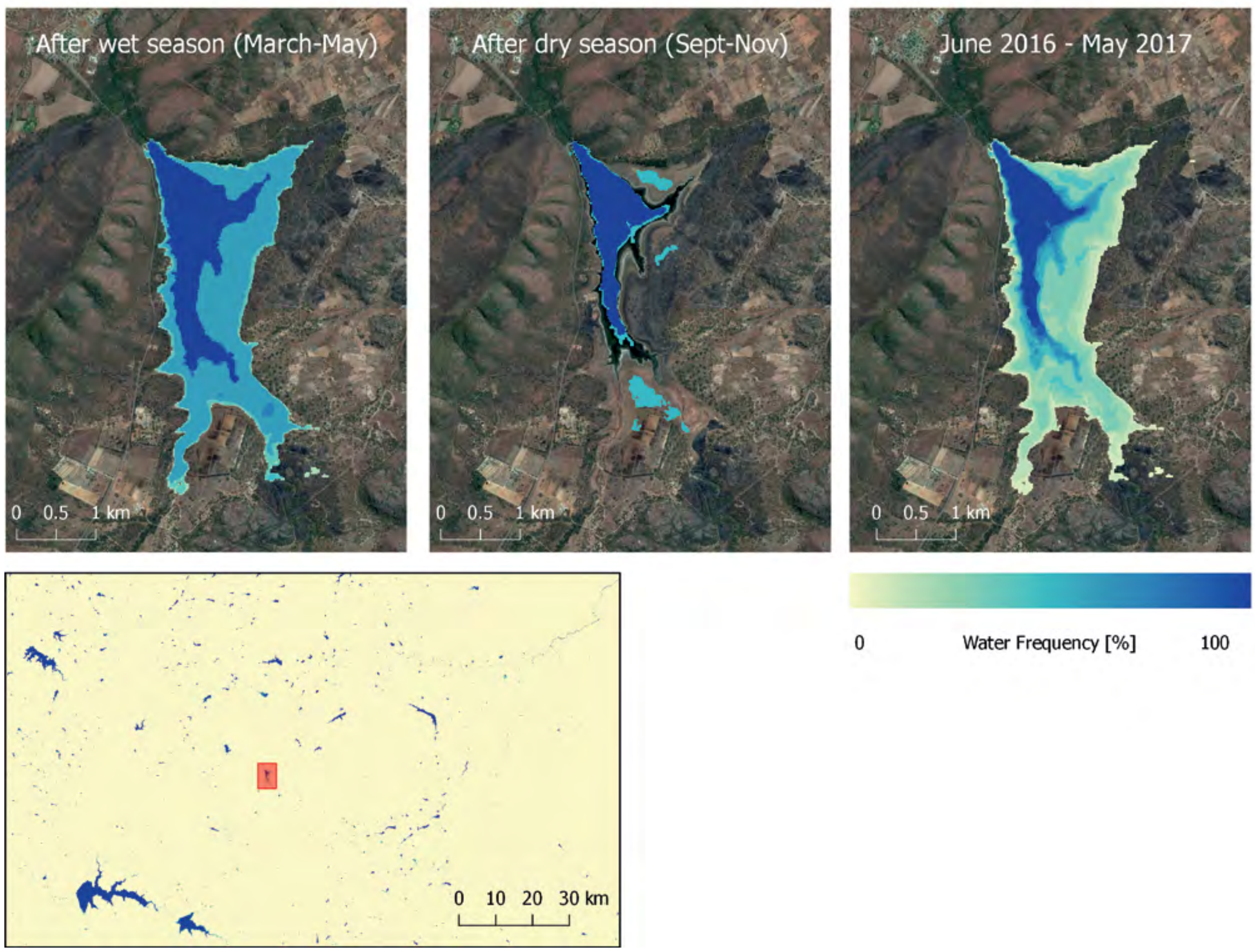


Figure 3: ZRBMP: Water Frequency (June 2016 - May 2017). Seasonal water body dynamics derived from 12-day Sentinel-1 time series in the Zambezi basin.

Source: Contains modified Copernicus Sentinel data

11.4 Water resources management

Comprehensive monitoring of water bodies is essential for national water resources management in support of activities such as drought mitigation, irrigation management and planning of infrastructure investment (e.g. dam constructions). Information on the seasonal dynamics of small water bodies is a high priority requirement for river basin organizations such as the Zambezi Watercourse Commission (ZAMCOM) and its riparian member states (Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe). It is also important for reporting on the efficiency of water use for crop production (SDG Target 6.4).

The government's measurement of water resources in the Zambezi region is limited to major dam resources and river flow stations, representing only a small portion of the overall water resources in the Zambezi countries where substantial amounts of water can be stored privately (e.g., in farm dams). These un-monitored water resources represent a significant gap in information and can contribute substantially to inaccuracies in water resource assessments, thereby increasing supply risk for users dependent on these resources. Assessing the dynamics of the complete set of water resources using regular and systematic EO data over the course of the season provides an efficient tool for planning, decision-making and supply risk reduction.

This information is being actively used in the context of the World Bank's Zambezi River Basin Management Project, the objective of which is to strengthen ZAMCOM's role in promoting cooperative management and development within the Zambezi river basin. Initial financing comes from a multi-donor trust fund (MDTF) for Cooperation in International Waters in Africa (CIWA) for the coming three years. The longer-term plan is to have this complemented by other funding sources for a pipeline of development projects to be implemented over a 10–15 year period.

11.5 Agriculture and rural development

In Morocco, IFAD supports the implementation of the Green Morocco Plan in mountainous areas through the Atlas Mountains Rural Development Project (PDRMA). Agriculture is a strategic sector within this Project both economically and socially. Food supply depends mainly on rainfall with large inter-annual variations, with only 20% of

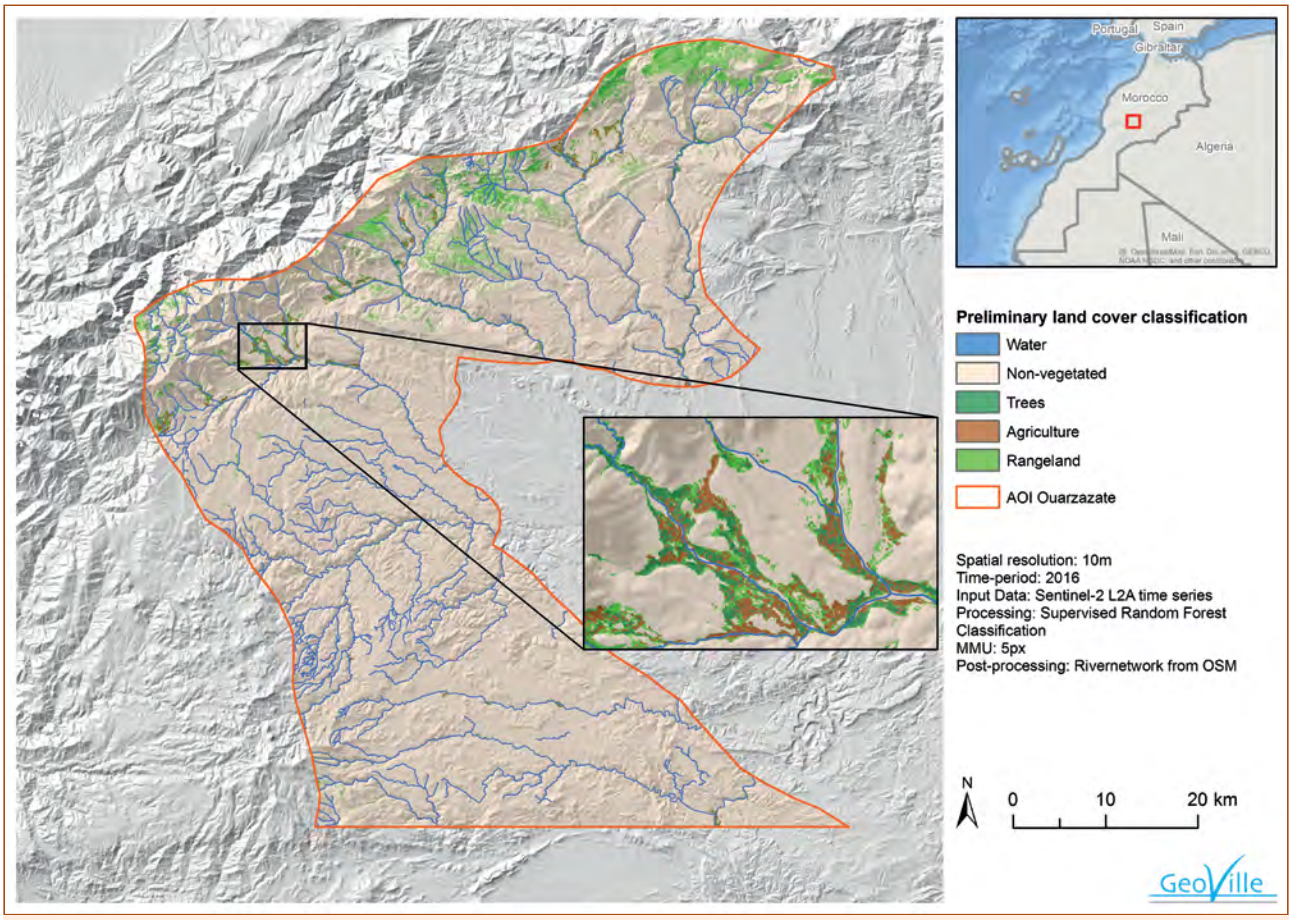
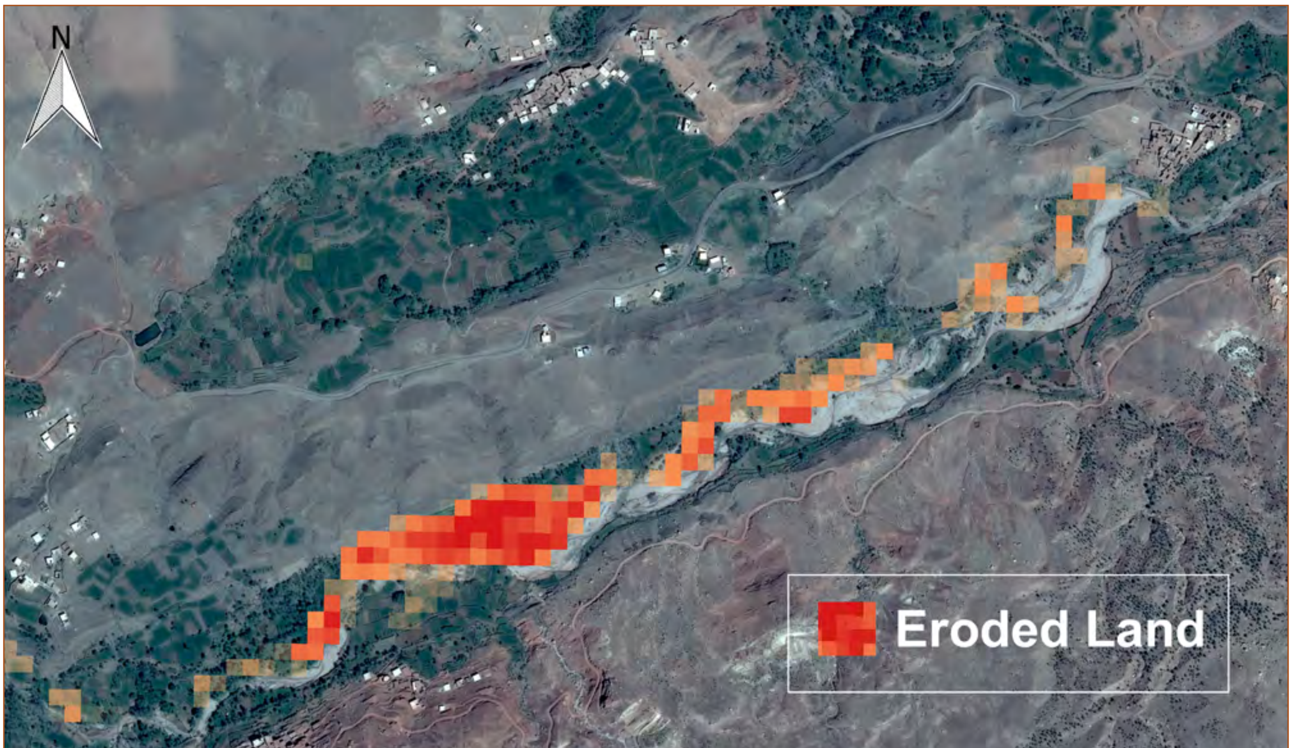


Figure 4: Detailed land cover/use mapping for 2016 in the Ouarzazate region (Morocco) based on Sentinel-2 imagery. Credit: EO4SD Agriculture Cluster.
Source: GeoVille for ESA/IFAD, 2017, Contains modified Copernicus Sentinel data

the croplands irrigated and limited weather risk mitigation and crop improvement opportunities available.

The PDRMA aims to reduce poverty in areas of the Atlas Mountains and increase agricultural production in three provinces of Ouarzazate, Tinghir and Béni Mellal. To understand the connections between rural communities and markets, and to answer key development questions in relation to IFAD activities, a holistic view of the mountainous regions is necessary. Questions include: *How well are the agricultural areas connected to markets? Have bare lands been transformed for agriculture? Can degradation in rangelands be halted? Which areas are most prone to soil erosion? How does the Green Morocco Plan impact the environment?*

EO offers the opportunity to assess the status of natural and agricultural resources, focusing on evolution over time, land regeneration and assessment of improved natural resources management and conservation, contributing to more sustainable income sources for local populations. Land cover assessment enables monitoring of the location, changes and expansion in agricultural areas, for example the planting of fruit trees that is financed through PDRMA. It enables monitoring of changes in the rangelands that stabilise erosion-prone slopes and feed ruminant livestock and the identification of degraded or degradation-prone areas that can become target priorities for land management investment. Soil erosion along rivers and the loss of productive capacity (degradation, overgrazing) of rangelands are the two main issues facing agriculture in PDRMA areas.



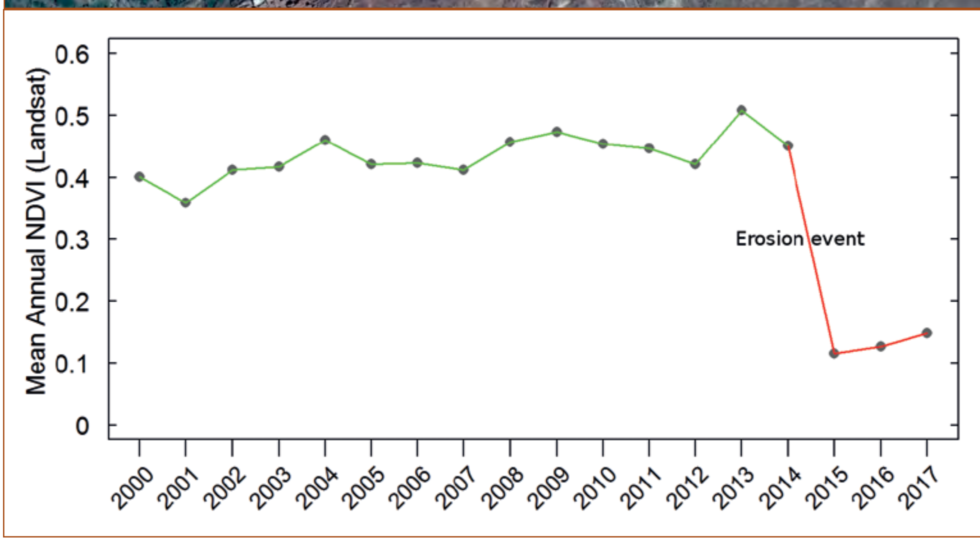


Figure 5: Disappearing agricultural lands due to river erosion near Ighrem N'Ougdal, Morocco.

Source: DHI GRAS for ESA/World Bank, 2017

Long-term time series of vegetation trends provide insights into historic evolution to highlight areas with significant negative trends. Soil erosion maps will combine information about the actual land cover with terrain, soil and rainfall information, indicating areas that are prone to water-based soil erosion, as well as those impacted by drought conditions and/or susceptible to drought. This provides baseline information and serves as a tool for identifying the most needed intervention areas.

IFAD is increasingly committed to better serving its stakeholder groups and demonstrating results; tools like remote sensing can make a significant contribution in this area. For example, during project preparation, there is a need to understand the socio-economic and biophysical baselines, as well as issues that drive environmental and social vulnerability. During results monitoring and impact verification, IFAD strives to improve Monitoring and Evaluation (M&E) methodologies with reliable, consistent and coherent information.

11.6 Benefits that EO can deliver to development aid operations

Through this work, a number of benefits that EO can bring to development operations are beginning to emerge including:

- *Increased efficiencies in existing operations* through better use of resources (economic, manpower, time) with a globally consistent approach to implementation and monitoring activities, thereby reducing supervision costs;
- *Improved definition of future operations* through more informed development planning and methodologies, leading to better technical quality of projects and higher engagement of Client States;
- *Extended capabilities* by supporting policy formulation to allow environmental analysis in a way that is not possible by other means (e.g. impact of climate change); and
- Promoting *better transparency, responsibility and accountability and impact evaluation* through the use of open data.

The perceived potential for EO to support development activities is reflected in the following feedback received from some of the senior IFI partners involved in the ESA activities to date.

"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)

"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 of the Urban Development and Water Division in ADB's Southeast Asia Department and Chief of the ADB Urban Sector Group

"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, Vice President, Sustainable Development, World Bank

11.7 Longer-term perspective

The overall objective of space agency investment in these activities is to 'mainstream' the use of EO-based information into development projects and activities, with the prospect of sustainable transfer into the working processes and activities of the main IFIs. This would mean EO-based information being planned into projects technically and financially as a systematic source of environmental information for all project phases: *Identification, Preparation, Appraisal, Negotiation, and* (most importantly) *Implementation & Impact Evaluation.*

'Mainstreaming' implies a significant capacity building activity to enable the full exploitation of EO, including Bank technical staff and management for the early project phases and (more importantly) the client country recipient (i.e., governments of developing countries) for implementation. Realising this in the complex and rapidly changing development aid system will require long-term, sustained efforts.

Promising initial results are being achieved, and awareness, interest and momentum is growing. At the 31st CEOS Plenary in October 2017, space agencies issued a statement underlining their joint commitment to developing a coherent strategy and approach to promote and expand the use of EO in the domain of Development Aid. It is hoped these efforts will help EO pragmatically work towards addressing the grand societal challenges the world is facing now, and is fully in line with the imperative goal for all governments to maximize the economic and societal benefits of investments in their EO observing systems.

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Naoufel Telahigue (Country Program Manager, IFAD)

Further information

The World Bank Group (2013): *Planning, Connecting, and Financing Cities—Now.* International Bank for Reconstruction and Development/The World Bank:
http://siteresources.worldbank.org/EXTSDNET/Resources/Urbanization-Planning-Connecting-Financing-2013.pdf

The World Bank Earth Observation for Development:
www.worldbank.org/en/topic/sustainabledevelopment/brief/earth-observation-for-development

EO4SD
http://eo4sd.esa.int

CEOS - Earth Observation in support of Official Development Assistance (ODA): A Joint CEOS Agency Statement for endorsement at 31st CEOS Plenary, Oct 2017:
goo.gl/GBqGEK

SERVIR:
www.nasa.gov/mission_pages/servir/index.html

Asian Development Bank and Earth Observation:
www.adb.org/publications/space-technology-and-geographic-information-systems-applications-adb-projects

Development Assistance & Sustainable Development
oecd.org/dac/financing-sustainable-development

Part III

Exploring Contributions from Satellites in Support of SDG Targets and Indicators

Part III focuses on case studies where satellites make a unique contribution in support of SDG information. Without satellites, we could not hope to possess this information.

End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 2: Zero Hunger

Satellite observations contribute to the production of timely agricultural yield and market information, supporting the effort to limit extreme food price volatility. Satellite measurements can be used to produce baseline maps of crop areas, crop types and growing season calendars. Satellite observations can help detect soil moisture anomalies and even contribute to crop condition assessment; based on these observations, modelling techniques can be employed to forecast yield production and derive market information.

Satellite-based observations used in concert with unmanned aerial vehicles (UAVs) can also support sustainable agriculture via increased production efficiency and crop yields. Precision farming approaches using GPS have been adopted by agricultural sectors in large parts of the world. Associated yield efficiencies can spread as capacity increases and the cost of technology decreases.

Improving market effectiveness through transparency

2.4.1 Proportion of agricultural area under productive and sustainable agriculture. Custodian Agency: FAO

2.c.1 Indicator of food price anomalies. Custodian Agency: FAO

In response to volatility in global food prices, in 2011 the G20 Heads of State endorsed the creation of the Agricultural Market Information System (AMIS), to be supported by the Group on Earth Observations Global Agricultural Monitoring initiative (GEOGLAM). This included a commitment to improve the effectiveness of the market for agricultural commodities via increased information and transparency.

GEOGLAM produces monthly Crop Monitor assessments for 20 AMIS countries that are used by: economists focused on providing early warning of food price shocks and volatility; agricultural ministries; members of

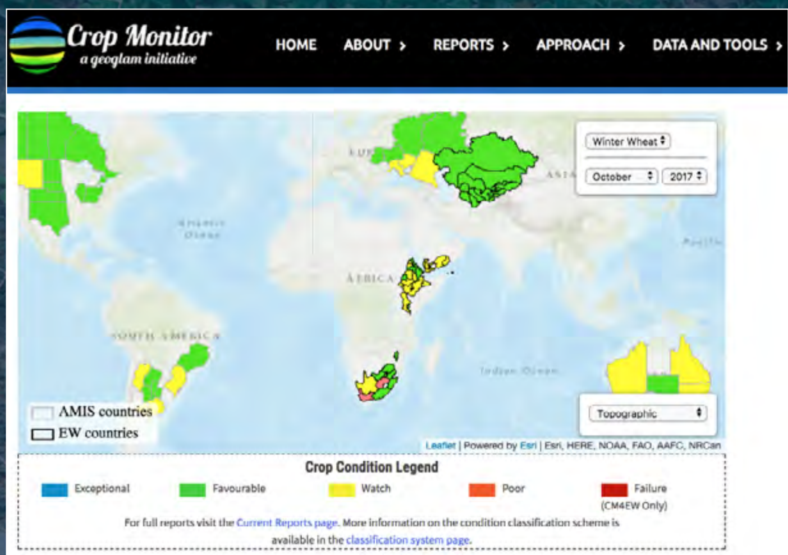

Figure: GEOGLAM's Crop Monitor Portal provides up-to-date reports on crop conditions for both AMIS and in service of Early Warning risk mitigation. *Credit:* ***cropmonitor.org*** industry and research organisations. A Crop Monitor for Early Warning has been developed to identify areas of emerging food supply stress, to support proactive policy decisions and actions and improve the functioning and efficiency of agricultural markets. These reports are generated routinely for a further 40 countries deemed to be vulnerable to crop failures.

Integrated Canadian Crop Yield Forecaster (ICCYF)

Agriculture and Agri-Food Canada (AAFC) is an extensive user of Earth observation data for operational monitoring, looking at agricultural land use, land management practices, soil moisture, near real-time crop condition and monthly crop yield estimates. This information is used across the Canadian government and by industry and researchers. AAFC has worked with Statistics Canada (STC) to develop the Integrated Canadian Crop Yield Forecaster (ICCYF) that integrates climate information, remote-sensing data and other available information (e.g., historical yields, soil maps, EO-derived crop maps) using a physically-based soil moisture budget model and a statistically-based yield forecasting model. In 2016, ICCYF made Canada the first country to release model-based crop yield estimates as official statistics, replacing traditional September farm surveys. It has been recognised across the Canadian community and government as a showcase of the power of Earth observation technology, collaboration and innovative thinking.

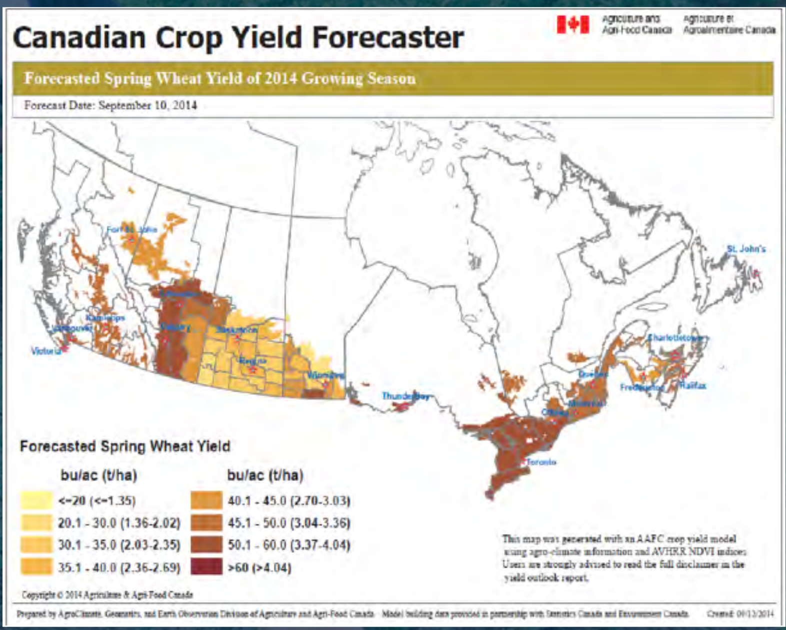

Figure: Weekly NDVI information used to help generate in-season crop yield estimates.
Credit: Agri-Food Canada

Further information, datasets, and methodologies

Goal 2 Description:
http://sustainabledevelopment.un.org/sdg2

Crop Monitor:
https://cropmonitor.org

Crop Condition Assessment Program (CCAP):
www35.statcan.gc.ca/CCAP/en/index

Agricultural Market Information System:
www.amis-outlook.org/amis-about/en

GEOGLAM:
http://geoglam.org

Asia-RiCE:
http://asia-rice.org
GEOGLAM initiative on Asian rice crop monitoring

RAPP Map:
http://map.geo-rapp.org
GEOGLAM initiative on pasture monitoring

JECAM:
www.jecam.org
Developing GEOGLAM monitoring and reporting protocols

Sentinel-2 for Agriculture:
www.esa-sen2agri.org
Supporting exploitation of Sentinel-2 for agricultural monitoring

FAO sites related to SDGs:
www.fao.org/sustainable-development-goals/indicators/241

www.fao.org/sustainable-development-goals/indicators/2c1

6 CLEAN WATER AND SANITATION

Ensure availability and sustainable management of water and sanitation for all

Goal 6: Clean Water and Sanitation

Water and sanitation are at the very core of sustainable development – critical to the survival of people and the planet – and touch on many other areas, including food and agriculture, climate, health, education and poverty reduction. This means that SDG6 *"not only addresses the issues relating to drinking water, sanitation and hygiene, but also the quality and sustainability of water resources worldwide."* Satellites provide repeatable and objective observations of the water cycle with consistency across regions and globally, supporting the implementation and scalability of monitoring systems.

Observations for integrated water resource management

6.5.1 Degree of integrated water resources management implementation (0-100). Custodian Agency: UN Environment

Satellite observations of the water cycle cover a broad range of parameters and at present hydro-meteorological and space agencies around the world are operating or planning instruments to monitor all phases of the cycle.

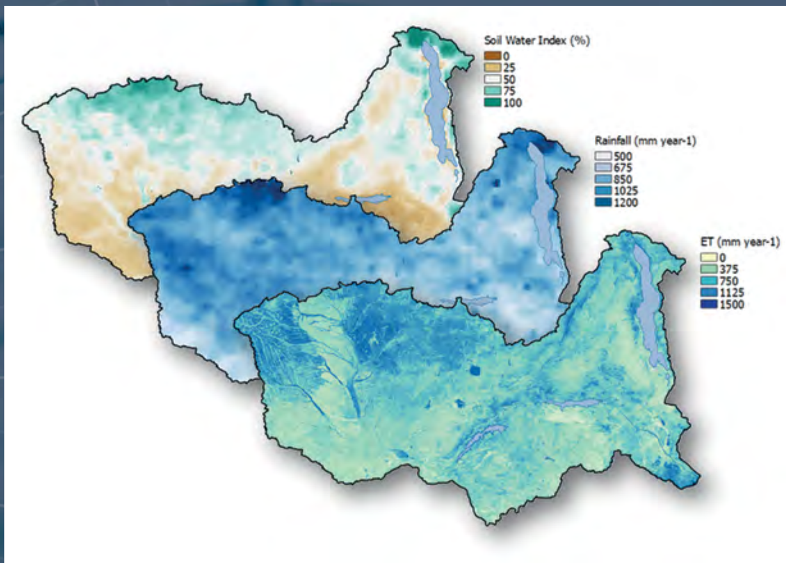

Figure: Hydrological monitoring in the Zambezi river basin using rainfall, evapotranspiration and soil moisture information from multi-source satellite observations.

Credit: ESA TIGER, ***www.tiger.esa.int, FEWS-NET (rainfall); FAO WaPOR (ET) and ESA CCI Soil moisture.***

Satellite capabilities are subject to a range of accuracies, and include the monitoring of clouds, precipitation (rain and snow), soil moisture, groundwater storage, inland water bodies, river and lake surface levels, the cryosphere (e.g., snow, ice, glaciers) and a number of ocean parameters. These observations support holistic management approaches, including hydrological modeling and the implementation of Integrated Water Resources Management (IWRM), identified as a key aspect of sustainable water management in the 2002 Johannesburg Plan of Implementation. The development of IWRM is a focus of water-related overseas development aid disbursements, with water management projects representing 5% of the total ($8.6 billion) in 2015.

One example of Earth observation support of the development of IWRM is the Water Observation and Information System (WOIS), developed as a part of ESA's TIGER initiative in response to the 2002 Plan of Implementation. WOIS helps address problems faced in the collection, analysis and use of water-related geo-information, and the software is available free of charge.

Global surface water monitoring

6.6.1: Change in the extent of water-related ecosystems over time.
Custodian Agencies: UN Environment, Ramsar

The presence of inland and coastal surface water affects human and ecosystem well-being globally. While national and regional inventories, statistical extrapolation and satellite imagery are used to produce surface water snapshots, systematically monitoring long-term changes at high resolution has remained a challenge. Several efforts have been undertaken using the long time series of Landsat imagery (since 1984) to try and address this challenge, including the European Commission's Joint Research Centre's (JRC) Global Surface Water Explorer (GSWE).

Leveraging massive parallel computing capabilities provided by Google Earth Engine, the GSWE maps the location and temporal distribution of water surfaces using 3 million Landsat images, quantifying the extent and change in global surface water monthly over the past 32 years at 30m resolution. The maps show that between 1984 and 2015, permanent surface water has disappeared from an area of almost 90,000 square kilometres, equivalent to slightly more than the area of all the surface water in Europe, though new permanent bodies of surface water covering 184,000 square kilometres have formed elsewhere. Over 70% of the global net permanent water loss occurred in the Middle East and Central Asia, linked to drought and human actions, including river diversion or damming and unregulated withdrawal.

The GSWE provides a freely available dataset to the public, scientists, and policymakers to help countries improve the modelling of surface water, provide evidence of changes in water-related ecosystems ecosystems, and inform water management decision-making including in support of SDG Indicator 6.1.1.

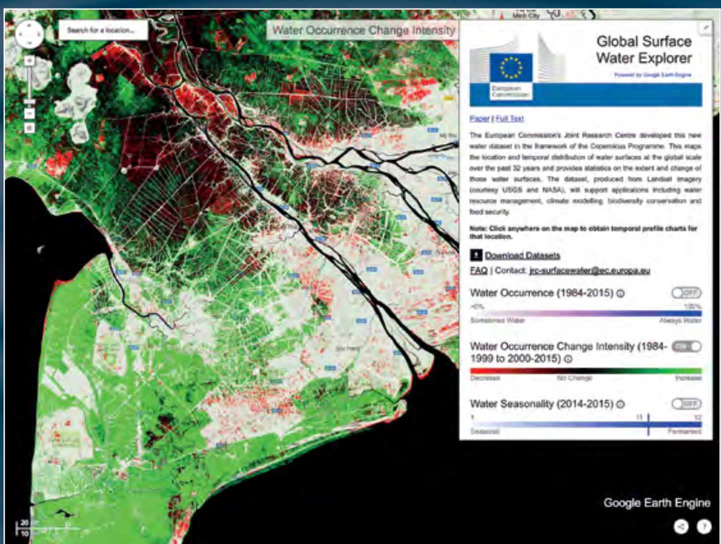

Figure: The European Commission's Joint Research Centre developed the Global Surface Water Explorer using Landsat data to map the location and temporal distribution of water surfaces at global scale over the past 32 years. *Credit: JRC*

Further information, datasets and methodologies

Goal 6 Description:
http://sustainabledevelopment.un.org/sdg6

GRACE Products:
https://grace.jpl.nasa.gov/data/get-data
Global water storage products

Global Surface Water Explorer:
https://global-surface-water.appspot.com

Global Terrestrial Network – Hydrology (GTN-H):
www.gtn-h.info
Links existing systems for integrated water cycle observations

ESA TIGER Water Observation Information System (WOIS):
www.tiger.esa.int/page_eoservices_wois.php

UN Water SDG6 Support:
www.sdg6monitoring.org

ESA hydrology TEP (H-TEP):
https://hydrology-tep.eo.esa.int
Community of scientific users, river basin organisations and service providers

GEO Wetlands initiative
geowetlands.org
Supporting the protection, conservation and sustainable use of wetland ecosystems

Hydroweb:
ctoh.legos.obs-mip.fr/products/hydroweb
Continental hydrology using satellite observations

IWRM Data Portal:
http://iwrmdataportal.unepdhi.org/iwrmmonitoring.html

Make cities inclusive, safe, resilient and sustainable

Goal 11: Sustainable Cities and Communities

Increasingly satellite monitoring is possible at spatial and temporal resolutions suitable for urban applications. Data can be accessed on a free and open basis, enabling products specifically derived for urban planners, and with supporting tools and platforms that greatly increase the accessibility and usability of observations. Two important urban management topics where satellites are making a growing contribution are urban growth and air quality.

Mapping urban growth

11.3.1: Ratio of land consumption rate to population growth rate.
Custodian Agency: UN-Habitat

A number of global urban extent datasets derived from satellite observations have been developed such as the Global Human Settlement Layer (GHSL) and the World Settlement Footprint 2015 (WSF2015).

The GHSL provides global spatial information about human settlements over time (1975, 1990, 2000 and 2014), generated from Landsat data, including built-up area, population density, and settlement maps.

The WSF 2015 will be available at the start of 2018 and will be the first global layer generated at 10m spatial resolution based on both optical and radar imagery (i.e., Landsat-8 and Sentinel 1). It will allow the precise delineation of human settlements in urban, peri-urban and rural areas over the entire globe. The WSF evolution dataset estimating the global settlement growth from 1985 and generated from Landsat-5/7 imagery will follow.

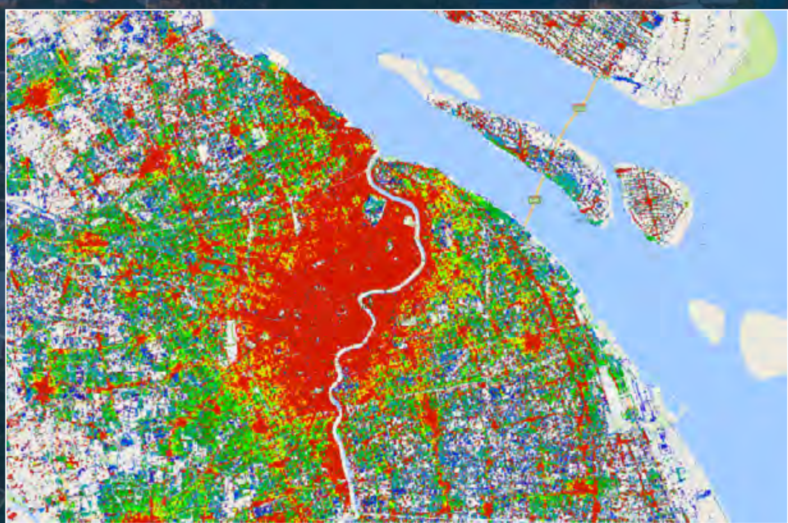

Figure: WSF Evolution over Shanghai, China. Red corresponding to 1985 urban extent, yellow-green-blue growth to 2015. *Credit: DLR*

The WSF suite is freely and openly released for exploitation via the Urban Thematic Exploitation Platform (U-TEP), a Big Data infrastructure offering online processing and analytics services for urban applications. The U-TEP seeks to provide an end-to-end analysis platform for a broad spectrum of users – both expert and non-expert – to produce and extract urban information (e.g., indicators) needed for sustainable urban management.

These global datasets of urban extent, thanks to the use of Big Data analytics platforms like the U-TEP, enable the production of evidence-based knowledge on the properties of human settlements such as area, shape, imperviousness, greenness, pattern and network of settlements and in the future even volumes of building. When combined with information on population they constitute a major source of data to inform the SDG indicator 11.3.1 on land consumption rate.

World Health Organization Data Integration Model for Air Quality Monitoring

11.6.2 Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted). Custodian Agency: WHO

Air pollution represents a significant environmental risk to health, and is also linked to climate change and ecosystem damage (e.g., via acid rain) through the release of CO_2, black carbon (soot), sulphur dioxide, nitrogen oxides, and other greenhouse gasses. Monitoring the release of this pollution and its impact on air quality in the urban environment are keys to better-informed policies and assessment of the sustainability of development decisions.

The World Health Organization (WHO) is the custodian agency for SDG Indicator 11.6.2, using a variety of observations, including ground and satellite measurements, as inputs to models to estimate human exposure to harmful particulate matter of a diameter less than 2.5 micrometres, known as PM2.5. The WHO maintains an air quality database to support reporting and has recently developed the Data Integration Model for Air Quality (DIMAQ) that incorporates data from a variety of sources in order to provide estimates of exposures to PM2.5 at $0.1^{\circ} \times 0.1^{\circ}$ globally.

At the country level, the United States' AirNow system provides the public with real-time air quality observations, forecasts and health information. The system started in 1998, when air quality data was not easily accessed and a national real-time dataset was unavailable, and has since encouraged and supported air quality monitoring efforts around the world. The system makes operational use of data from multiple satellite instruments to supplement measurements from ground-based monitors, which increases the accuracy of PM2.5 air quality forecasts.

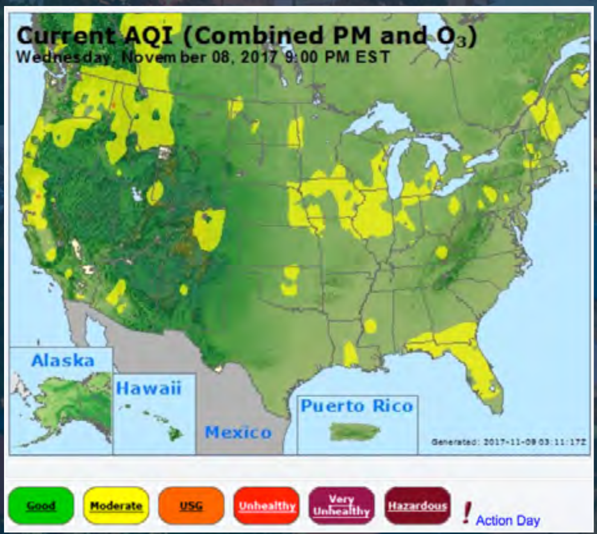

Figure: Air Quality Index (AQI). *Credit:* **AirNow.gov**, *US Government*

Further information, datasets, and methodologies

Goal 11 Description:
http://sustainabledevelopment.un.org/sdg11

ESA Urban TEP (U-TEP):
https://urban-tep.eo.esa.int

JRC GHSL:
http://ghsl.jrc.ec.europa.eu/how.php

GEO Human Planet Initiative:
http://ghsl.jrc.ec.europa.eu/HPI.php
Observations for a comprehensive understanding of the human presence in support global policy processes

WHO Interactive Air Pollution Maps:
http://maps.who.int/airpollution

WHO Global Urban Ambient Air Pollution Database:
www.who.int/phe/health_topics/outdoorair/databases/cities/en

AirNow:
https://airnow.gov

Conserve and sustainably use the oceans, seas and marine resources

Goal 14: Life Below Water

Satellite imagery can contribute to the to the monitoring and sustaining of marine resources, and features in the plans of SDG 14 custodian agencies and supporting activities. This includes the monitoring of Coastal Eutrophication and Floating Plastic Debris Density, as well as the regulation and monitoring of illegal fishing activities. Satellites can help to address the challenges of the vast scale, and the difficulty in accessing many areas of the world's oceans.

Great Barrier Reef World Heritage Area

14.1.1: Index of Coastal Eutrophication and Floating Plastic Debris Density. **Custodian Agency: UN Environment**

The eReefs Marine Water Quality Dashboard provides operational near real-time information on water quality for Australia's Great Barrier Reef. Remote sensing provides measurements of marine indicators (e.g., chlorophylla levels, suspended sediments and dissolved organic matter) that can help marine park management assess ecosystem health and inshore water quality. Observations from NASA's Aqua satellite have provided accurate, regionally tuned water quality information, allowing managers and policymakers to inform, assess and improve the outcomes of their management decisions.

Satellites routinely and systematically provide observations of chlorophyll-a on the ocean surface. Chlorophyll-a is a key indicator of microscopic green algae (phytoplankton), and while phytoplankton are a natural part of the reef ecosystem, elevated levels signal elevated nutrient levels, especially nitrogen. These increased nutrient levels can interfere with the balance of the ecosystem, and can lead to coral bleaching and die-off. Typical sources of nitrogen include runoff from excess fertiliser being applied to crops and sewage contamination from urban areas.

Satellites contribute to informed decisions around the management and regulation of fertiliser usage and sewage management, meaning the overall health of the Reef can be managed for preservation and assessed on a systematic, quantitative and transparent basis.

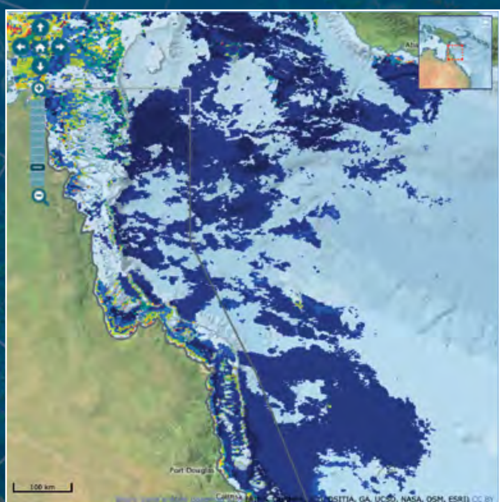

Figure: Screenshot of the Marine Water Quality Dashboard operated by the Australian Bureau of Meteorology, which provides near real-time information of remotely-sensed water quality in the Great Barrier Reef based on methods developed by the CSIRO.
Credit: CSIRO

Illegal, unreported, and unregulated fishing

14.6.1: Progress by countries in the degree of implementation of international instruments aiming to combat Illegal, Unreported and Unregulated fishing. Custodian Agency: FAO

The annual value of Illegal, unreported, and unregulated (IUU) fishing is estimated to be up to $US23.5 billion with a catch totalling 26 million tonnes – one-fifth of the total annual catch worldwide. IUU undermines efforts to enforce regulations intended to conserve the ocean ecosystem. For example, species of fish that have been over-exploited are thus in short supply, which increases the price and in turn increases the incentive to circumvent limits put in place to protect stocks.

Ensuring compliance with the rules and regulations can be time and resource intensive or infeasible. Maritime patrols are costly, inefficient, often dangerous, and can be ineffective. Land-based monitoring is unable to mitigate vessel-to-vessel transfers at sea and can be circumvented. Satellite-based monitoring offers a synoptic solution and, when combined with a number of different data sources, can be an effective means for detecting IUU fishing.

Satellite monitoring is used by OceanMind, a not-for-profit organisation working to increase the sustainability of fishing globally through actionable insights into fishing activity and vessel compliance. OceanMind combines position and heading information from ship-based Automated Identification Systems (AIS), satellite imagery and details about a vessel's history, licenses and ownership. It employs machine learning to rapidly and automatically assess vessel behaviour using these observations, flagging suspicious activities for follow-up by enforcement authorities. Both optical and radar satellite imagery is employed, providing an all-weather, day-and-night monitoring capability in support of Indicator 14.6.1.

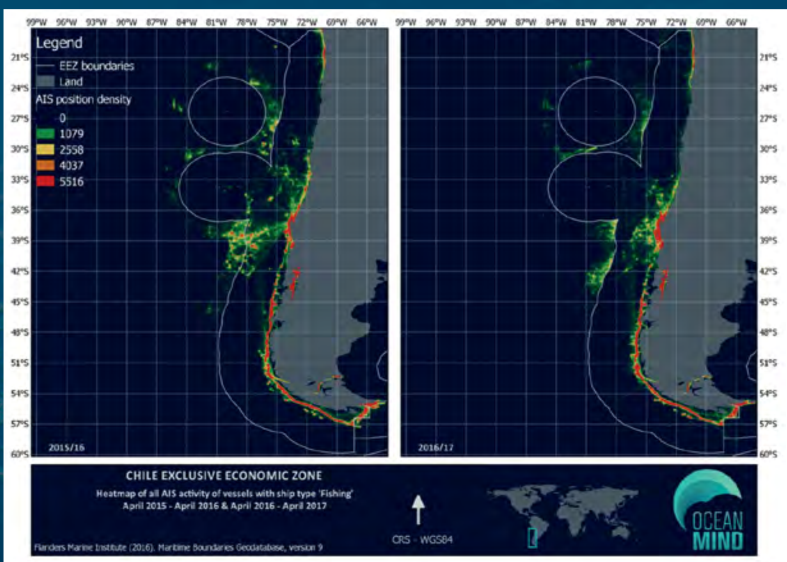

Figure: Fisheries monitoring in Chile's Exclusive Economic Zone using satellite imagery and machine learning. *Credit: OceanMind*

Further information, datasets and methodologies

Goal 14 Description:
http://sustainabledevelopment.un.org/sdg14

eReefs Marine Water Quality Dashboard:
www.bom.gov.au/marinewaterquality

eReefs Marine Water Quality Dashboard:
www.bom.gov.au/environment/activities/mwqd/info.shtml

eReefs Satellite Data and Processing:
https://research.csiro.au/ereefs/remote-sensing/data-processing

OceanMind:
www.oceanmind.global

GEO AquaWatch:
www.geoaquawatch.org
Promoting global capacity of EO-derived water quality data, products, and information

ESA CoastColour:
www.coastcolour.org
Remote sensing of the coastal zone

Copernicus Marine Service:
http://marine.copernicus.eu
European Marine capability, core-knowledge base, and catalogue of services

FAO site on SDGs:
www.fao.org/sustainable-development-goals/indicators/1461

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 15: Life on Land

Satellite Earth observations (EO) are unique in their ability to provide consistent and comparable information on global land cover. Imagery may be used to measure the extent of land cover types and their change over time. This is complemented by radar imagers that can provide further information on vegetation type, soil moisture and biomass and can measure day-and-night, in all weather conditions, and 'through' some forest canopies.

Satellite EO is a fundamental tool for deriving statistics on deforestation and land use change and is critical to monitoring the Indicators of SDG Targets 15.2, 15.3 and 15.b from local to national, regional and even global scales – in some cases allowing the assessment of trends over long historical archives.

Land degradation

15.3.1: Proportion of land that is degraded over total land area.
Custodian Agency: UNCCD

Land degradation is a process of change over time in vegetation cover, water resources, soil erosion and salinity. Time series of coarse to moderate resolution EO data can be applied globally to reveal environmental changes and target hot spots, and is used by national, state, and municipal governments to manage their land use. Standardised methods are being developed to allow consistent derivation of three sub-Indicators for Indicator 15.3.1:

- land cover and land cover change (see ESA Landcover CCI);

- land productivity; and,

- carbon stocks above and below ground.

The UN Convention to Combat Desertification (UNCCD) commissioned a series of Good Practice Guidance reports to help countries select, process and analyse datasets to report against these sub-Indicators, with EO closely integrated into the recommended methods.

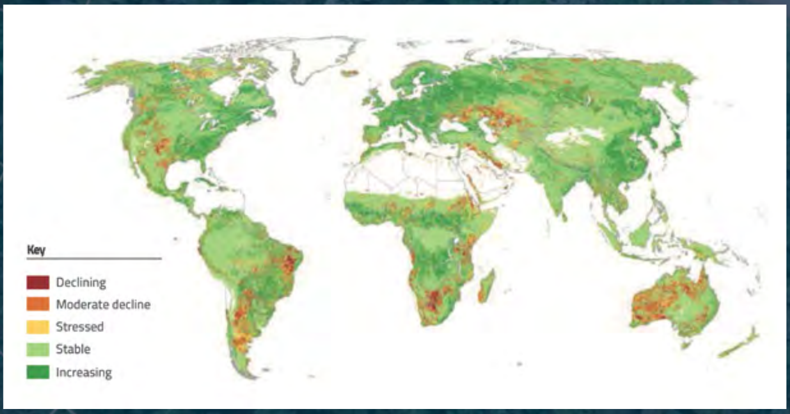

Figure: Land Productivity Dynamics (LPD) map 1999 to 2013 showing 5 classes of persistent land productivity trajectories during the observation period. *Credit: JRC*

Forests

15.2.1 Progress towards sustainable forest management.
Custodian Agency: FAO

15.b.1 Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems.
Custodian Agency: UN Environment

At the global level, FAO has been carrying out its Forest Resources Assessments (FRA) at 5–10 year intervals since 1946. From 1990, information collected through country reporting has been complemented by remotely-sensed data, supported by a growing archive of satellite imagery and new software for image processing and interpretation.

The World Resources Institute's Global Forest Watch (GFW) uses wall-to-wall national coverage satellite EO data (Landsat) to provide spatially explicit information at the pixel level (30m). Information is presented via an online forest monitoring and alert system empowering forest management stakeholders to create custom maps, analyse forest trends, subscribe to alerts or download data for their local area or the entire world.

The REDD+ initiative of the UN Framework Convention on Climate Change (UNFCCC) looks to provide financial incentives for countries to maintain and sustain forests in an effort to reduce emissions from deforestation and forest degradation, foster conservation and management of forests, and enhance forest carbon stocks.

In support of REDD+, the Global Forest Observations Initiative (GFOI) aims to guarantee availability of wall-to-wall national coverages of satellite data and to provide countries with Methods and Guidance Documentation (MGD) that will facilitate reporting consistent with the relevant IPCC Good Practice Guidelines. GFOI's MGD advice is available in English, Spanish and French (www.gfoi.org/methods-guidance/) and via a new online tool – REDDCompass – that guides users through the core themes, concepts and actions involved in the development of National Forest Monitoring Systems.

Figure: Forest Change in the Congo from Global Forest Watch. *Credit:* ***www.globalforestwatch.org***

Further information, datasets and methodologies

Goal 15 Description:
http://sustainabledevelopment.un.org/sdg15

FAO FRA:
www.fao.org/forest-resources-assessment/en

Global Forest Watch:
www.globalforestwatch.org

GFOI MGD:
www.gfoi.org/methods-guidance

REDDcompass:
www.reddcompass.org

GFOI Space Data Portal:
www.gfoi.org/space-data/space-data-portal

Refer also to the ABS/CSIRO article in Part II of this Handbook for details of their work with the Australian Dynamic Land Cover Data and its use for the production of official statistics in Australia.

ESA LandCover CCI Project:
www.esa-landcover-cci.org
http://maps.elie.ucl.ac.be/CCI/viewer/index.php

ESA Forestry TEP (F-TEP):
https://forestry-tep.eo.esa.int

ISRIC Database:
www.isric.org
World Soil information

Global Soil Partnership:
www.fao.org/global-soil-partnership/en

FAO site on SDGs:
www.fao.org/sustainable-development-goals/indicators/1521

CEOS and the Sustainable Development Goals

To highlight the potential role for Earth observations in supporting the global Indicator framework for the Sustainable Development Goals (SDGs), CEOS has established an *Ad Hoc* Team on Sustainable Development Goals (AHT-SDG). This group has aligned its engagement with the SDG agenda through the intergovernmental Group on Earth Observations (GEO), and sometimes deal directly with the custodian UN agencies as well as with individual countries through their National Statistical Offices (NSOs) and relevant ministries.

The Team has taken stock of the UN processes in place for the SDG implementation and of the existing participants and stakeholders, and now focuses its activities around the unique role that CEOS should play as a coordination body of satellite EO efforts in support of the realisation of the SDGs. This includes a focus not only on the SDG Indicators that have been defined to monitor progress towards the SDG Targets, but also ways to explore how EO can complement traditional statistics and help define other indicators with innovative methodologies using EO satellite data.

The objectives of the group have been defined in Terms of References document (available online (at http://ceos.org/ourwork/ad-hoc-teams/sustainable-development-goals/documents) to:

- Actively support the GEO Initiative on SDG (EO4SDG)
- Coordinate the efforts of CEOS agencies and communicate CEOS support to other SDG stakeholders.
- Provide a forum for sharing and communicating EO best practices in support of the SDGs, providing easy access to methodological developments, tools and platforms, and discoverability of global/regional data sets.
- Analyse new opportunities for satellite-based EO to support SDGs Targets and Indicators (new methods, data, indicators).
- Engage with other relevant authoritative stakeholders outside the UN system, who provide support to the SDGs.
- Use CEOS assets and bodies to build user capacity at all levels of the SDG implementation.

Further reading and contacts can be found on the CEOS website:

http://ceos.org/sdg

EO Handbook Online

The full text of this report is available on the Earth Observation Handbook's website at **www.eohandbook.com/sdg**. A supporting database of the satellite missions, instruments and measurements is available at **database.eohandbook.com** and contains powerful search and presentation tools, with the ability to export customised tables and timelines in support of analyses of current and planned provision of observations in support of different applications and measurements.