Working Paper Series

SD/WP/13/April 2021 ESCAP Statistics Division

# Big data for environment and agriculture statistics

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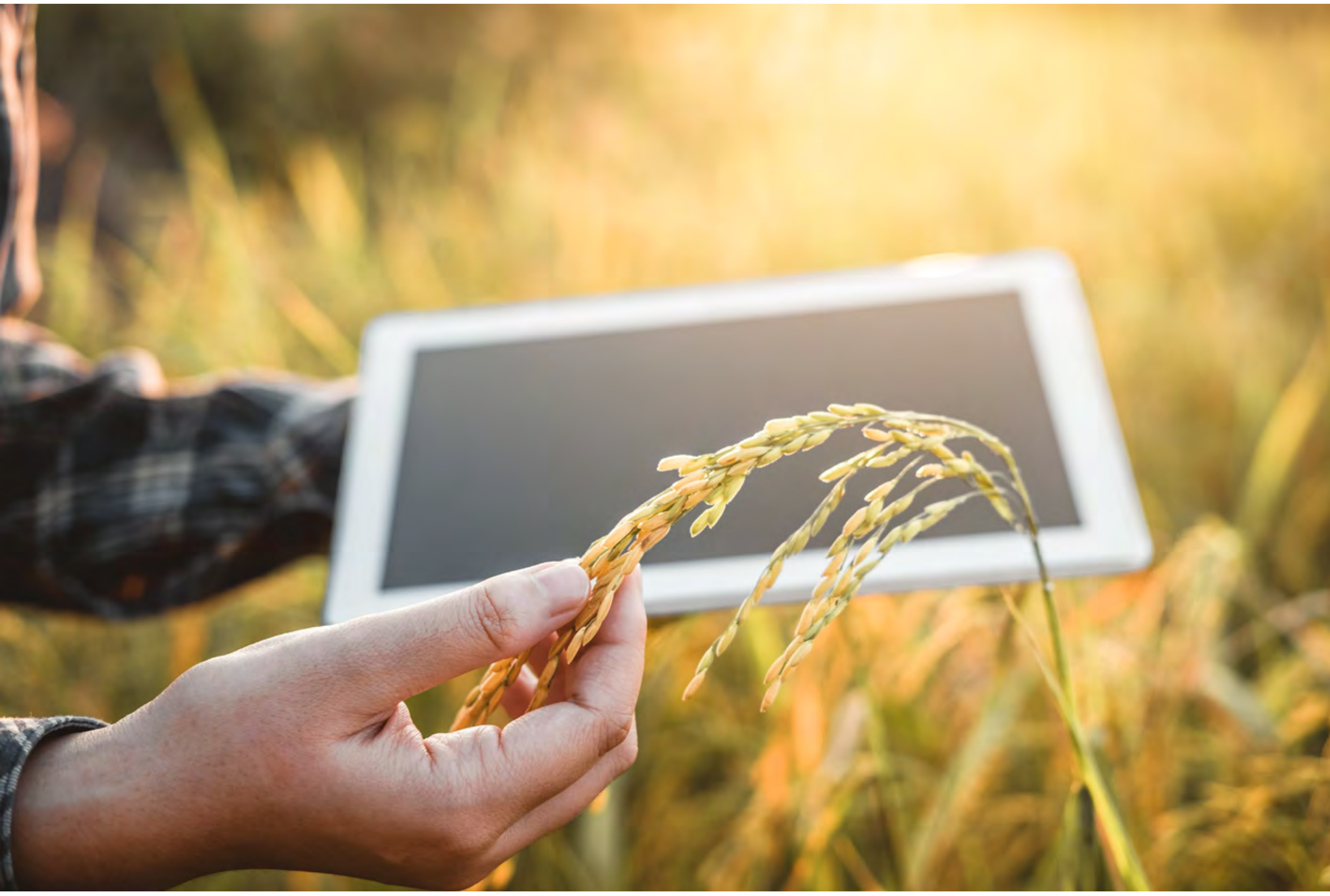

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

## ABSTRACT

This Working Paper gives an overview of how geospatial information and Earth Observation data can be used to produce environment and agriculture statistics and presents specific country examples from Asia and the Pacific. It also provides examples of specific country-led efforts to use Earth Observation data for the compilation of SDG indicators.

This Working Paper is part of ESCAP's series on the use of non-traditional data sources for official statistics.

*Key words: big data, environment and agriculture statistics, Earth Observation data, SDG indicators*

## TABLE OF CONTENTS



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*The Working Paper Series of ESCAP Statistics Division disseminates latest developments and analysis of statistical measurements, methodologies and concepts to users and producers of statistics.*

*The Working Paper is prepared by Irina Bernal, Consultant, UNESCAP Statistics Division, with valuable inputs from Gemma Van Halderen, Director, UNESCAP Statistics Division, Tanja Sejersen, Statistician, UNESCAP Statistics Division, and Rikke Munk Hansen, Chief of Economic and Environment Statistics, UNESCAP Statistics Division. This paper also benefitted from discussions and presentations during Asia-Pacific Stats Cafes held on July 29, 2020, October 14, 2020, and March 15, 2021.This Working Paper is issued without formal editing.*

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*Previous Working Paper Series: https://www.unescap.org/knowledge-products-series/sd-working-papers.*

## What are environment statistics?

Environment statistics covers ten themes: air and climate, biodiversity, energy and minerals, forests, governance, inland water resources, land and agriculture, marine and coastal areas, natural disasters and waste.[1] While environmental statistics are still at an early stage of development in many countries, big data, such as geospatial and Earth Observation (EO) data, coupled with advanced technologies, present opportunities for new ways of producing environment statistics.

The production of environment statistics is guided by the *Framework for the Development of Environment Statistics (FDES 2013)* and the *System of Environmental-Economic Accounting (SEEA)*.[2] FDES 2013 provides an organized structure guiding the scope, collection and compilation of environment statistics, while SEEA provides guidance on integrating economic and environmental data into a single accounting framework, consistent with the System of National Accounts. SEEA covers topics such as agriculture, forestry and fisheries, air emissions, energy, water, land, environmental activity, and material flows.

Both FDES and SEEA can support the reporting on several of the environment-related Sustainable Development Goals (SDGs). SEEA can serve as the basis for the development of coherent environmental-economic SDG indicators, contributing particularly to SDG 6 (Clean Water and Sanitation), SDG 14 (Life Below Water), and SDG 15 (Life on Land).

## What big data sources can support the production of environment statistics?

While environmental statistics are often compiled using administrative data sources, such as land records and information generated from administering environmental taxes and other regulations, governments are increasingly applying geospatial and Earth Observation (EO) data in the production of various environment-related statistics. These data sources are not new and several governments and National Statistical Offices (NSO) in the region have relied on them for decades. Others have recently begun researching potential uses of these data in environment statistics thanks to technological advancements, improved data accessibility and availability of new tools and methods for data processing and analysis.

The importance of earth observation and geospatial information has also been formally recognized for delivering on the 2030 Agenda for Sustainable Development, when countries committed to *"promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including earth observation and geospatial information, while ensuring national ownership in supporting and tracking progress."*[3]

### The Big Data Terminology Soup: Geospatial, Earth Observation, GIS, GPS, and more explained

To provide clarity on the difference between geospatial information and Earth Observation data as well as their interconnection, several definitions and explanations are presented below.

All countries need geospatial information for national development and decision-making and geospatial information provides the integrative platform for all digital data that has a location dimension.[4]

**Geospatial data** combines location information (coordinates), attribute information (characteristics of the object of phenomena), and often temporal information (time or period at which local and attributes exist).[5] Geospatial information is often derived from the **Global**

1 Framework for the Development of Environment Statistics (FDES 2013), https://unstats.un.org/unsd/envstats/fdes.cshtml

2 System of Environmental-Economic Accounting, https://seea.un.org/

3 United Nations, Transforming out world: The 2030 Agenda for sustainable development, A/RES/70/1, paragraph 76,

4 http://ggim.un.org/meetings/GGIM-committee/8th-Session/documents/Part%201-IGIF-Overarching-Strategic-Framework-24July2018.pdf

5 ScienceDirect, Geospatial Data, https://www.sciencedirect.com/topics/computer-science/geospatial-data

**Positioning System (GPS)**, the space-based navigation system that provides location and time information in all weather conditions, anywhere on or near the earth where there is an unobstructed line of sight to four or more GPS satellites.[6]

The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) has identified fourteen global fundamental geospatial data themes and geospatial data layers across environment, economic and social domains to support the SDGs, as illustrated in Figure 1 and Figure 2.

**Geographical Information System (GIS)** or Geospatial Information System is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. What goes beyond a GIS is a spatial data infrastructure.[7]

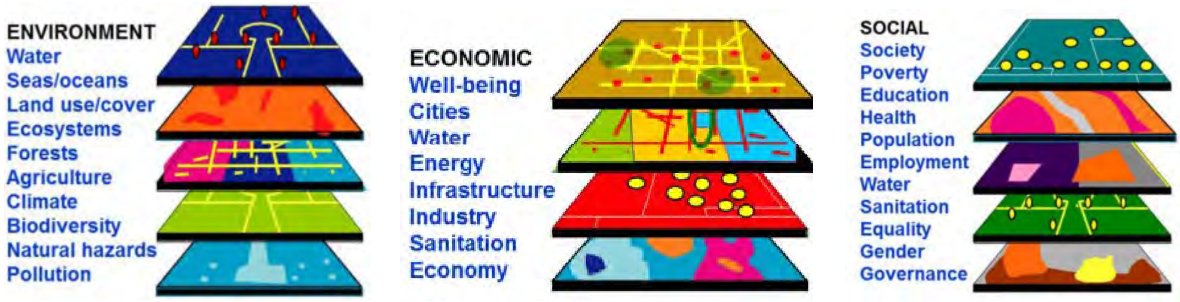
**Figure 1 |** Global Fundamental Geospatial Data Themes


***Source:*** *UN-GGIM*

6 https://sustainabledevelopment.un.org/topics/informationforintegrateddecision-making/geospatialinformation

7 Geospatial Information for Sustainable Development, https://sustainabledevelopment.un.org/topics/informationforintegrateddecision-making/geospatialinformation

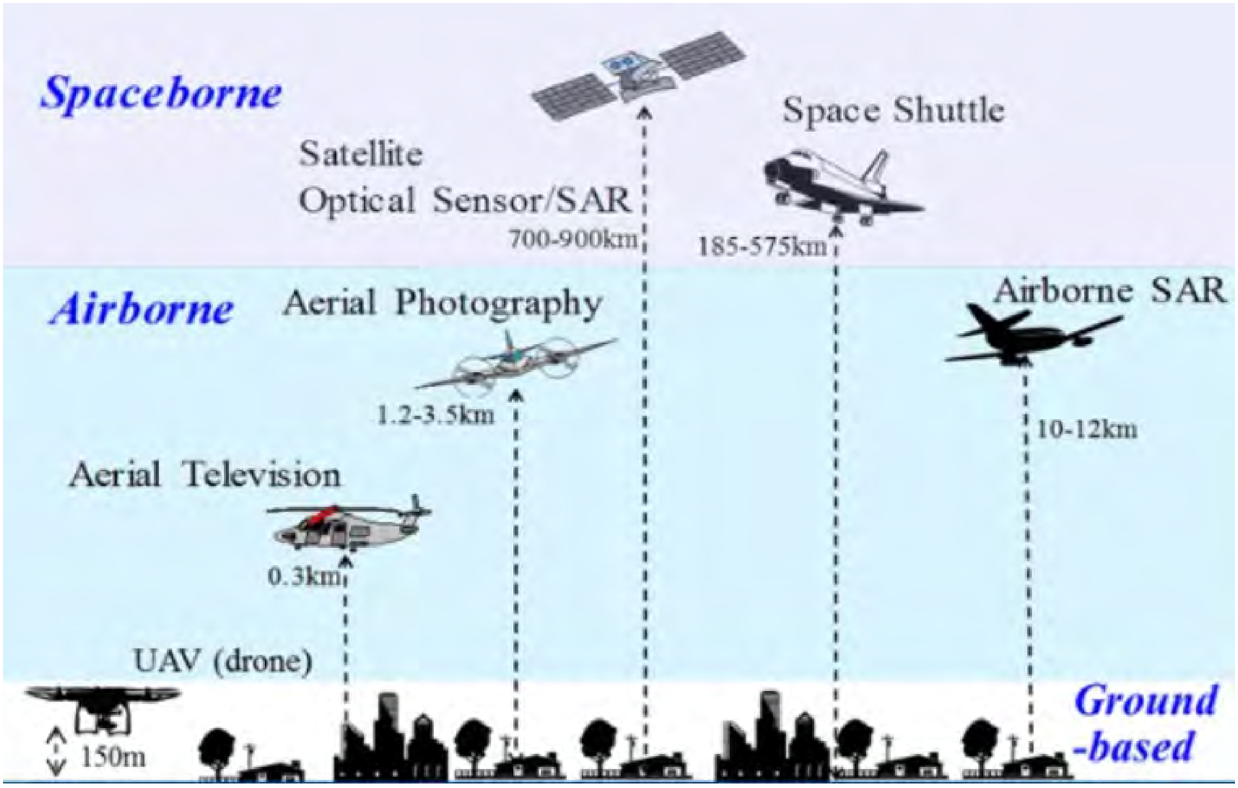
**Figure 2 |** Geospatial data layers supporting the Sustainable Development Goals




***Source:*** *UN-GGIM*

**Earth Observation (EO)** is the gathering of information about planet Earth's physical, chemical, and biological systems via **remote sensing** technologies (ground-based, airborne or spaceborne), usually involving satellites, unmanned aerial vehicles (UAV, also referred to as "drones") or other technology carrying imaging devices, as depicted in Figure 3. Earth Observation is used to monitor and assess the status of and changes in the natural and manmade environment.[8] As Earth Observation data are images of the Earth's surface, they need to undergo pre-processing to correct for radiometric and geometric distortions of data before performing analysis, and are often integrated with administrative data, such as administrative boundaries or elevation during the analysis.

**Figure 3 |** Earth Observation data




***Source:*** *mapscaping.com*

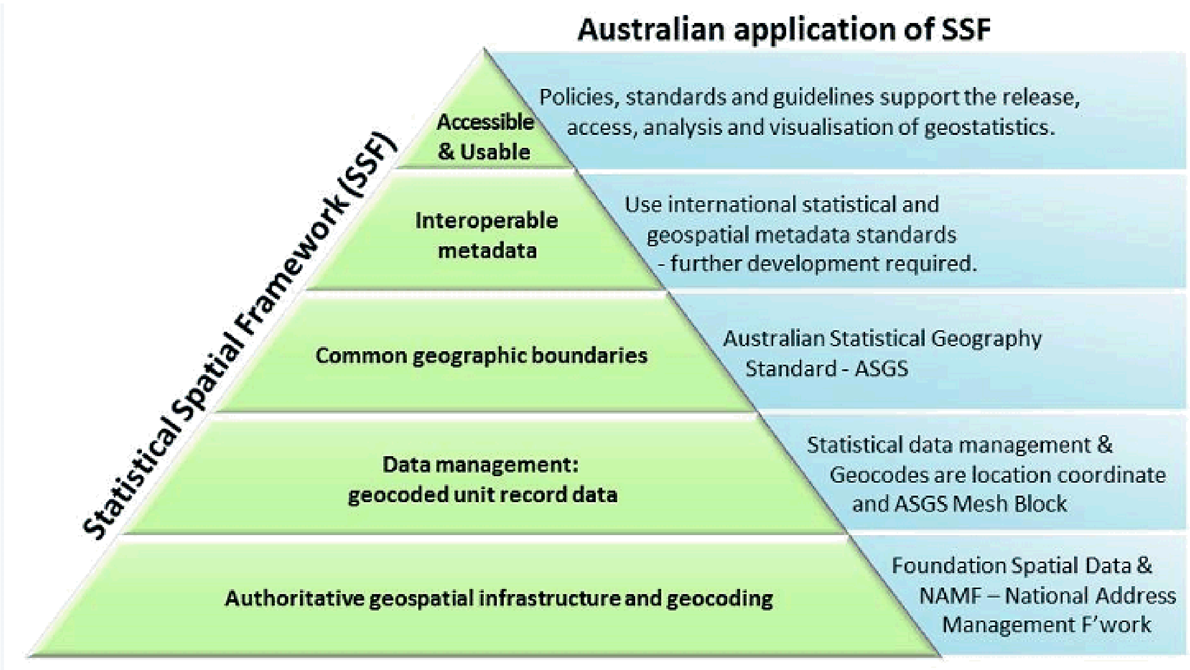
8 EU Science Hub, Earth observation, https://ec.europa.eu/jrc/en/research-topic/earth-observation

## Country experiences and examples

Governments in the region have been actively developing their national geospatial frameworks to guide the use and integration of geospatial information. For example, the Government of Indonesia launched the One Map Initiative to bring together and incorporate land use, land tenure and other spatial data into one database for the country. The Government of Mongolia developed an Integrated Geospatial Information Framework[9] and is reviewing the Spatial data infrastructure law.

A leader on geospatial and statistical integration, the **Australian Bureau of Statistics** (ABS), has developed an Australian Statistical Spatial Framework with the main attributes depicted in Figure 4.[10] The Australian Framework formed the basis of the global Statistical-Geospatial Framework[11] adopted by two global intergovernmental bodies: the UN Statistical Commission and the UN-GGIM.

**Figure 4 |** Statistical Spatial Framework for Australia




***Source:*** *ABS*

Earth Observation (EO) data has also been actively explored by countries in the region. Many national Space Agencies and Space Programmes are developing frameworks on the use of Earth Observation data for monitoring purposes across areas such as agriculture, environment, and disasters.

In many countries in the region, the national responsibilities for producing environment statistics are shared across multiple institutions, such as the NSOs and specialized ministries (e.g. Ministry of the Environment, Natural Resources, Agriculture, Forests, Waters and Land and others depending on administration), while in others, these responsibilities are unclear or non-existing. Few NSOs in the region have integrated or are exploring the integration of EO into the production of official statistics. However, government agencies are actively exploring EO

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9 Bayarmaa Enkhtur, presentation "Segment V. Operationalizing the Integrated Geospatial Information Framework in Mongolia", https://ggim.un.org/meetings/2020/Virtual_HLF/documents/Bayarmaa_Enkhtur_2Jun.pdf

10 Australian Bureau of Statistics, Statistical Spatial Framework Overview, https://www.abs.gov.au/websitedbs/D3310114.nsf/home/Statistical+Spatial+Framework#:~:text=The%20foundation%20of%20the%20Statistical%20Spatial%20Framework%20for,each%20person%2C%20household%20or%20business%20in%20a%20dataset.

11 The Global Statistical Geospatial Framework, http://ggim.un.org/meetings/GGIM-committee/9th-Session/documents/The_GSGF.pdf

data for the development of environment related monitoring systems, often in collaboration with the national Space, Remote Sensing or Mapping Agencies and Programmes. Thus, many EO-related efforts are concentrated on environmental monitoring and considerably less attention is paid to the use of EO in official statistics.

Integration of EO data into official statistics is confronted with a series of challenges. Satellite imagery needs to be pre-processed to become analysis-ready for statistical purposes. NSOs often lack technical skills for imagery pre-processing, but lately, particularly with the development of the data cubes, access and availability of pre-processed imagery has been growing. Other challenges include technical, human, and financial resources necessary for data storage, processing, and analysis. Despite the technological developments that render EO more accessible, these challenges need to be addressed for a successful integration of EO data into environment statistics. However, in some countries, the Statistics Law also limits the data sources that could be used to produce official statistics, hindering exploration of big data.

Close collaboration between the NSOs, Mapping Agencies, Space Agencies and specialized Environment Agencies could help address many of those challenges. International development partners, such as ESCAP and ADB, as well as the specialized funds and programmes of the UN that are custodians of the environment-related SDG indicators (such as FAO) are supporting the national statistical systems in the use of EO data for environment and agriculture statistics through pilots, trainings and technical guidelines.

The remainder of this paper focuses on specific country examples, from the NSOs and ministries, of using Earth Observation data to produce environment statistics and environment-related SDG indicators. The areas of environment statistics explored are land cover and land use statistics, forest surveys, and agriculture statistics. These examples are followed by a description of the Open Data Cube efforts and access to analysis-ready data at the regional and global levels.

## Land cover and land use statistics

Land cover and land use status and changes refer to information about the coverage of land, and changes in that land and associated activities across time.[12] *Land cover* refers to the (bio)physical coverage on the earth's surface, such as water surfaces, vegetation, buildings, and roads. The types of land cover include different types of crops, grassland, tree-covered areas, mangroves, permanent snow and glacier, water bodies, etc. *Land use* refers to the socioeconomic activities performed on land. There are multiple land uses, and they include activities such as agriculture, forestry, aquaculture, etc. *Land cover and land use change* (LUCC) indicates the changes that occur to the land cover and land use over time.

The SEEA Land Accounts can provide an assessment of the changing shares of different land uses and land cover within a country.[13] SEEA Land Accounts consist of two main types of accounts to record land use and land cover and their links to the economy: 1) **physical asset accounts** – describing changes in land stock associated with human activity and natural processing, 2) **monetary asset accounts** – describing changes to the value of land for agriculture, forestry, human activity, among other usage, due to the revaluation of land.

Traditionally, land cover and land use statistics are collected though administrative data and from *in situ* data collection exercise, meaning that data are gathered through direct observations on the ground. For example, the European Union conducts a three-yearly harmonized regional Land use and land cover survey (LUCAS).[14]

Few NSOs in Asia and the Pacific are integrating Earth Observation data, particularly from satellite imagery, to produce land cover and land

12 United Nations Statistics Division, Manual of the Basic Set of Environment Statistics of the FDES 2013, https://unstats.un.org/unsd/environment/FDES/MS_1.2.1_2.3.1_Land%20Cover_Land%20Use.pdf

13 United Nations, System of Environmental and Economic Accounting, Land Accounts, https://seea.un.org/content/land-accounts

14 Eurostat, Land use and land cover survey, https://ec.europa.eu/eurostat/statistics-explained/index.php/LUCAS_-_Land_use_and_land_cover_survey#How_is_LUCAS_conducted.3F

use statistics. Two prominent case studies presented are from the Ministry of Statistics and Programme Implementation (MoSPI) of India and the Australian Bureau of Statistics (ABS). The third example from Kazakhstan illustrates the collaboration between the Ministry of Agriculture and the Remote Sensing Agency for space monitoring of rational use of land resources. While these case studies provide an understanding of how EO data are used to produce land cover and land use statistics, they do not constitute a complete overview of the regional experience in this area.

- *Improving land statistics with Earth Observation data in India*

The **Ministry of Statistics and Programme Implementation (MoSPI)** of India is one of the few statistical institutions in the region that produces Environment Accounts using remote sensing data. To fulfil its mandate of issuing environmental accounts fit for policy, the MoSPI constituted an Inter-Ministerial Group (IMG) on Environmental Accounting-India comprising the Ministry of Environment, Forests and Climate Change (MoEFCC), Ministry of Jal Shakti, Ministry of Earth Sciences, the National Remote Sensing Center and the Comptroller and Auditor General of India.[15]

The three main datasets on land available in India are **land-use and land-cover** (LULC), **land degraded** by various natural and anthropogenic processes, and the **wastelands** in the country.[16] The land-use and land-cover statistics are maintained by the National Remote Sensing Centre (NRSC) of the Indian Space Research Organization (ISRO) operating under the Department of Space (DOS) through a component on LULC mapping of the Natural Resources Census (NRC). LULC datasets are made available by the National Remote Sensing Centre on a periodic basis on a 1:50,000 scale and on a yearly basis on a 1:250,000 scale.[17] The LULC data are grouped by classes (built-up, agriculture, forest, grass/grazing, barren/unculturable/ wasteland, wetlands/water bodies, snow and glacier).

The national level **land degradation** mapping is conducted by the National Remote Sensing Center (NRSC), in association with the Department of Space and Department of Land Resources (DoLR) and the Ministry of Rural Development (MoRD) at a regular interval since 1986. The "Wastelands Atlas of India" is compiled using remote sensing satellite data at a 1:50,000 scale.[18]

- *Integrating multiple data sources for land accounts, land cover, and monitoring changing vegetation patterns in Australia*

The **ABS** recognizes land use datasets as essential statistical assets for Australia and the Australia and New Zealand Land Information Council recognizes the same datasets as Foundation Spatial Datasets.[19]

The development and maintenance of information on **land use and land management** practices in Australia is promoted by the Australian Collaborative Land Use and Management Program (ACLUMP), comprising multiple actors including the ABS, Geoscience Australia, Department of Agriculture and Water Resources, Bureau of Meteorology, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and others.[20]

In Australia, land use mapping is conducted at two scales: nation scale and catchment scales. Nation scale mapping (1:2,500,000) integrates satellite imagery, agricultural commodity data, and other land information. Catchment scale

15 EnviStats India 2020 : Vol. II – Environment Accounts, http://www.mospi.nic.in/publication/envistats-india-2020-vol-ii-environment-accounts

16 EnviStats India 2020 : Vol. II – Environment Accounts. Land : A finite resource, http://mospi.nic.in/sites/default/files/reports_and_publication/statistical_publication/EnviStats2/b1_ES2_2020.pdf, page 12

17 Indian Geo-Platform of ISRO, https://bhuvan-app1.nrsc.gov.in/thematic/thematic/index.php

18 Department of Land Resources, National Remote Sensing Center, Government of India, 2019, "Wastelands Atlas of India", https://dolr.gov.in/sites/default/files/Wastelands%20Atlas%20-%20Cover%2C%20Preface%2C%20Contents%2C%20Project%20Team%2C%20Executive%20Summary%2C%20Introduction%20-%20Result.pdf

19 Department of Agriculture and Water Resources, Australian Government, Land use information for Australia, https://www.agriculture.gov.au/sites/default/files/abares/aclump/documents/LandUseInfoForAustralia_v1.0.0.pdf

20 Idem.

mapping integrates state cadastre, public land databases, fine-scale satellite data, and other land data.[21] Land use datasets provide the basis for regional and national reporting of land use and land management practices.

The **land cover** dataset is developed and maintained by Geoscience Australia and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). It comprises the National Dynamic Land Cover Dataset for Australia, a series of derived mapping products and technical information. The **Dynamic Land Cover Dataset** of Australia[22] is the first nationally consistent and thematically comprehensive land cover reference for Australia developed from remote sensing. The dataset provides a baseline for identifying and reporting on change and trends in vegetation cover and extent, with data available for Australia since 2001 at two-year intervals. The Dataset is a time series of Enhanced Vegetation Index (EVI) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra and Aqua satellites operated by NASA.[23]

The Ground Cover Monitoring for Australia allows for monitoring and regular reporting on the vegetation cover using satellite imagery.[24] The RaPP Map tool,[25] supported by CSIRO, provides data on vegetation cover, monthly rainfall, monthly soil moisture, and livestock density for Australia global land use. It also serves as a spatial data platform for the Rangeland and Pasture Productivity and is an activity of the Global Agricultural Monitoring (GEOGLAM) initiative of the Group on Earth Observations (GEO). RaPP supported the national reporting of erosion in the Australia State of the Environment 2016 report[26] and provided data to the New South Wales Government's DustWatch program for monitoring wind erosion and caring for soils. The DustWatch programme is a citizen-science program, which relies on the community of volunteers around Australia to record data and observations about dust in their area and share them with the Department.[27]

The ABS has produced several experimental land accounts, each time improving the methods and revisiting the previous accounts. The land accounts are prepared by combining State Valuer General land titles data with Australian Business Register using GIS software.[28] The Data Cube with Landsat imagery developed by Geoscience Australia provides a model infrastructure for time series analysis with consistent methods and resolution. One example of Land Accounts is the Queensland Experimental Land Account Estimates for 2011-2016.[29] This experimental Land Account was developed in line with SEEA.

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21 Australian Government, Department of Agriculture, Water and the Environment, Land use mapping, https://www.agriculture.gov.au/abares/aclump/land-use/land-use-mapping

22 Geoscience Australia, National Land Cover Dataset, http://www.ga.gov.au/scientific-topics/earth-obs/accessing-satellite-imagery/landcover

23 Dynamic Land Cover Dataset, https://data.gov.au/data/dataset/1556b944-731c-4b7f-a03e-14577c7e68db

24 Department of Agriculture, Water and the Environment, Australian Government, Ground Cover Monitoring for Australia, https://www.agriculture.gov.au/abares/aclump/land-cover/ground-cover-monitoring-for-australia

25 GEOGLAM RAPP Map, https://map.geo-rapp.org/#australia

26 Australia State of the Environment 2016, https://soe.environment.gov.au/theme/land

27 New South Wales Government, Community DustWatch, https://www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation/wind-erosion/community-dustwatch

28 Tim Walter, Australian Bureau of Statistics, presentation "Lessons Learned: The ABS Land Accounting Experience", https://www.wavespartnership.org/sites/waves/files/images/Phil_5.%20Lessons%20Learned%20ABS%20Land%20Accounting%20Experience%20Sept2014.pdf

29 Australian Bureau of Statistics, Land Account: Queensland, Experimental Estimates, 2011-2016, https://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/4609.0.55.003Main%20Features12011%20-%202016?opendocument&tabname=Summary&prodno=4609.0.55.003&issue=2011%20-%202016&num=&view=

## Figure 5 | Land Cover map for Australia


***Source:** Geoscience Australia and Australian Bureau of Agricultural and Resource Economics and Sciences*

- *Using satellite data for monitoring rational use of land resources in Kazakhstan*

In the Republic of **Kazakhstan**, the Land Resources Management Committee of the Ministry of Agriculture partnered with the state agency "Kazakhstan Gharysh Sapary", national operator of a High-Accuracy Satellite Navigation System Services and provider of remote sensing products and services, to develop several geoservices based on satellite data. These services focus on space monitoring of the rational use of land resources in the northern regions of the country, identification of unaccounted and free lands, and the assessment of pasture.[30] The monitoring mechanism uses data from national satellites (KazEOSat-1, KazEOSat-2, and KazSTSAT), data from the State Land Cadastre, data from local authorities, and farm animal identification data.

To address the growing interest in the region from the national statistical systems in using Earth Observation data for land statistics, UN ESCAP has been developing technical manuals and training materials to guide them in the integration of Earth Observation data in the production of environment statistics. Among the most recent knowledge products and tools are the *Step by step guide on the use of QGIS and RStudio for Producing land cover change maps and statistics,*[31] and the more advanced guide on *Producing land cover change maps and statistics: Guide on advanced use of QGIS and RStudio,*[32] to guide countries in compiling their land cover change maps compatible with the SEEA reporting. ESCAP Statistics Division has also directly supported the National Statistics Office of Fiji in their successful production of Experimental Land Cover Account using satellite imagery and the above mentioned tools.[33]

## Forest Surveys

Forest surveys are used to collect information about the boundaries of the forest area, the condition of the forest, information about diseases affecting the forest as well as information about logging activities.

At the global level, Food and Agriculture Organization (FAO) oversees the Global Forest Resources Assessment, a global remote sensing survey aiming to improve estimates of forest area change at global and regional scales. In this regard, FAO has established a global network of officially nominated National Correspondents and has been conducting national capacity building in data collection using remote sensing tools specifically developed for this purpose. Collect Earth Online[34] is part of FAO's Open Foris suite of tools developed by NASA and FAO with the support from Google to guide countries in the implementation of multi-purpose forest inventories.

The Forest Resources Assessments process plays a central part in monitoring progress towards SDG 15 (Life on Land) and in particular indicator 15.1.1 (forest area as a proportion of total land area) and 15.2.1 (progress towards sustainable forest management).[35] FAO is the custodian for 21 SDG indicators, including three under SDG 15.

At the national level, forest surveys are usually conducted by the Ministry of Environment, Natural Resources or Forests. Examples from India, Thailand and Kazakhstan illustrate the use of EO data in forest surveys.

30 Timur Myrzagaliev, presentation "Space monitoring of the rational use of land resources of the Republic of Kazakhstan" at the Regional Inception Workshop on Integrating Statistical Geospatial Data for Land Accounts and Statistics in Central Asia, Tashkent, Uzbekistan, November 2019, https://www.unescap.org/sites/default/files/10.%20Space%20Monitoring%20of%20Rational%20Use%20of%20Land%20Resources%20of%20Kazakhstan.pdf

31 ESCAP, Producing land cover change maps and statistics: Step by step guide on the use of QGIS and RStudio, October 2020, https://www.unescap.org/resources/producing-land-cover-change-maps-and-statistics-step-step-guide-use-qgis-and-rstudio

32 ESCAP, Producing land cover change maps and statistics: Guide on advanced use of QGIS and RStudio, February 2021, https://www.unescap.org/kp/2021/producing-land-cover-change-maps-and-statistics-guide-advanced-use-qgis-and-rstudio#

33 Litia Kurisaqila-Mate, presentation "Compiling Fiji's Experimental Land Cover Account," ESCAP Stats Café, 15 March 2021, https://www.unescap.org/sites/default/d8files/event-documents/Fiji_experimental_land_cover_Stats_Cafe_15Mar2021.pdf

34 Collect Earth, http://www.openforis.org/tools/collect-earth.html

35 FAO, Global Forest Resources Assessment, http://www.fao.org/forest-resources-assessment/en/

In **India**, the Forest Survey of India (FSI), an organization under the Ministry of Environment, Forests and Climate Change oversees the evaluation of forest cover and has been conducting biennial national forest assessment using remote sensing techniques since 1987. Since 2001, the Forest Survey of India has been conducting surveys covering the entire country through the digital assessment. The latest satellite data for nation-wide forest cover mapping are procured from the National Remote Sensing Centre (NRSC)[36] and the results are published in the India State of Forest Report (ISFR).[37]

In Thailand, most of the data related to Land Accounts are derived from administrative records and agriculture census.[38] However, the estimation of the Forest Cover, which falls under the responsibility of the Royal Forest Department of the Ministry of Natural Resources and Environment, is assessed through satellite imagery, particularly the LANDSAT-5TM satellite interpretation imageries with the exclusion of fruit tree orchards and rubber plantations.[39]

In **Kazakhstan**, state agency "Kazakhstan Gharysh Sapary", the provider of remote sensing services, suppliess geospatial data to the Committee of Forestry and Wildlife of the Ministry of Ecology and Natural Resources. On the industry geoportal, the state agency shares satellite images of the national KazEOSat-1 satellite with a spatial resolution of 1 meter for creating forest management plans and maps, producing forest maps and reducing the cost of field work, and making changes to cartographic materials and the electronic database of the State Forest Fund of the Republic of Kazakhstan.[40]

## Agricultural statistics

Agricultural statistics provide information on the production of yield and cultural crops, the extent of arable land and sown area, number of livestock, prices of land and agricultural products. Traditional sources of agricultural and rural statistics include administrative reporting systems, household surveys, and censuses of agriculture. The increasing demand for more granular, timely, accurate and reliable data are pushing national statistical agencies to explore innovative and more efficient methods of collecting agricultural data.

In some countries in the region, the NSOs and Ministries have been integrating EO data with survey data for crop identification and estimation of the area under specific crops. International development partners, such as ADB, are also supporting countries in exploring the use of EO data for agriculture statistics. In addition to contributing to agriculture statistics, EO data are also used in national agriculture-related assessment, monitoring and forecasting systems.

- *Experimental sugarcane statistics with non-survey data in Australia*

In Australia, the ABS collaborates with Geoscience Australia on developing agricultural crop maps and statistics using satellite data.[41] The ABS is collaborating with agricultural experts to co-design methods to integrate existing data from administrative sources and satellite imagery with traditional survey data. One example of this new approach is the experimental sugarcane statistics.[42] Traditionally, sugarcane statistics are produced by the ABS through the annual Rural

36 Forest Survey of India, Forest Cover Mapping, https://fsi.nic.in/introduction?pgID=introduction

37 Forest Survey of India, An Introduction, https://www.fsi.nic.in/

38 National Statistics Office, presentation "State of Land and Land Use in Thailand," Regional expert workshop on land accounting for SDGs monitoring and reporting, Bangkok, 25-27 September 2017, https://www.unescap.org/sites/default/files/Land_statistics_accounts_Thailand_Workshop_25-27Sep2017_0.pdf

39 Ministry of Natural Resources and Environment of Thailand, Forestry in Thailand, http://forprod.forest.go.th/forprod/ebook/การป่าไม้ในประเทศไทย/Forest%20in%20thailand%20eng.pdf

40 KGS, Space Monitoring of forest resources of the Republic of Kazakhstan, https://www.gharysh.kz/monitoringlesa/

41 Australian Bureau of Statistics, Improving agricultural crop statistics using satellite data, 26 June 2020, https://www.abs.gov.au/research/industry/agriculture/improving-agricultural-crop-statistics-using-satellite-data

42 Australian Bureau of Statistics, Sugarcane, experimental regional estimates using new method data sources and methods, 17 June 2020, https://www.abs.gov.au/statistics/industry/agriculture/sugarcane-experimental-regional-estimates-using-new-data-sources-and-methods/2019-20

Environment and Agricultural Commodities Survey (REACS). The experimental sugarcane statistics were produced with new data sources (non-survey data) and methods of production, with potential to reduce reporting burden on farmers. Geospatial validation and outlier adjustments in the production of statistics were based on satellite data-derived maps identifying areas where sugarcane was grown. The experimental estimates were published nine months earlier than those usually produced from REACS. The ABS co-designed this approach with industry experts from Sugar Research Australia (SRA), Australian Sugar Milling Council, Canegrowers, the Australian Cane Farmers Association, and the Queensland Government.

- *Remote sensing for forecasting agricultural output in India*

To address the need for timely and accurate data, the India's Ministry of Agriculture and Farmers' Welfare established Mahalanobis National Crop Forecast Centre (MNCFC) under the Department of Agriculture in 2012. MNCFC was set up to provide in-season crop forecasts and assessment of the drought situation using techniques and methodologies developed by the Indian Space Research Organization (ISRO). The Space Application Centre (SAC), one of the major centers of the ISRO, is already at an advanced stage of experimenting with the approach of remote sensing to estimate the area under principal crops through the scheme known as "Forecasting Agricultural output using Space, Agro-meteorology and Land based observations" (FASAL).[43] Under FASAL, MNCFC regularly generates crop acreage estimation, crop condition assessment and produces forecasts at the district, state and national levels for nine major crops of the country (jute, kharif rice, sugarcane, cotton, rapeseed and mustard, rabi sorghum, wheat, rabi pulses and rabi rice), using both optical and microwave data and the procedures developed by the Space Applications Centre.

Besides FASAL, the National Crop Forecast Center manages NADAMS (National Agricultural Drought Assessment and Monitoring System).[44] NADAMS project provides near real-time information on prevalence, severity level and persistence of agricultural drought across 17 states of India at the district and sub-district levels. The assessment is carried out using rainfall data, Remote Sensing Vegetation Index and Moisture adequacy Index during the Kharif season regularly generating underlying statistics.

- *Remote sensing for crop identification in China*

In China, the National Bureau of Statistics (NBS) deploys remote sensing for crop identification and uses geospatial technology to build the area sampling frame for agricultural surveys[45]. The first agricultural survey vehicle integrated satellite imagery, aero photography from the UAV and field observation generating geospatial samples and estimations of crop area, crop condition and total production. In conducting the agricultural remote sensing survey, the NBS collaborates with the Ministry of Land Resource, National Bureau of Mapping and Geo-Information, the National Geo-Information Center, and private companies. The geo-spatial base data framework includes full coverage satellite imagery, land use census data and other data types, such as geo-referenced statistics, meteorology, phenology, and hydrology data. In addition to monitoring the growth of major grain, the NBS is exploring the application of remote sensing in livestock statistics.

- *Using satellite imagery for maize detection in East Java, Indonesia*

In Indonesia, BPS Statistics Indonesia conducted a study on the use of satellite imagery to detect maize (one of the most important food crops along with rice in Indonesia) field area in East Java Province. The machine learning model with random forest (RF) as the classifier was used to detect maize field areas using multispectral

43 FASAL (Forecasting Agricultural output using Space, Agro-meteorology and Land based observations), https://www.ncfc.gov.in/about_fasal.html

44 NADAMAS (National Agricultural Drought Assessment and Monitoring System), https://www.ncfc.gov.in/nadams.html

45 Yu Xinhua, presentation "Remote Sensing Applications in Agricultural Statistics at China NBS", 2014, https://unstats.un.org/unsd/trade/events/2014/Beijing/presentations/day2/morning/3.%20Remote%20Sensing%20Applications%20in%20Agricultural%20Statistics--Yu%20Xi%20-1.pdf

imagery acquired by Landsat-8, Sentinel-1, and Sentinel-2 satellites.[46] Official statistical surveys published by BPS-Statistics Indonesia are used as the ground truth labels to validate the proposed model. The results of the experiment suggest a promising accuracy in detecting the food crops area.

- *Remote sensing for estimating paddy areas in Lao People's Democratic Republic, Philippines, Thailand, and Viet Nam*

The Asian Development Bank (ADB) piloted the use of satellite data to estimate paddy area and rice production in Savannakhet, Lao People's Democratic Republic; Nueva Ecija, Philippines; Ang Thong, Thailand; and Thai Binh, Viet Nam. The implementing agencies for the project included the Center for Agricultural Statistics, Ministry of Agriculture and Forestry in the Lao PDR; the Philippine Statistics Authority in the Philippines; the Office of Agricultural Economics, the Ministry of Agriculture and Cooperatives, and GeoInformatics and Space Technology Development Agency in Thailand; and the Center for Informatics and Statistics, Ministry of Agriculture and Rural Development in Viet Nam. Following the project, ADB developed the handbook *Use of Remote Sensing to Estimate Paddy Areas and Production*[47] along with a web-based training[48] with the tools and techniques, encouraging the NSOs and Ministries of Agriculture to pilot satellite-based techniques as an alternative to existing methods.

## Environment-related SDG indicators

Over half of the SDGs have an environment dimension. Out of the 93 environment-related SDG indicators identified by UNEP,[49] 23 can be supported by or need geospatial data for compilation.[50] Other types of big data, such as mobile phone data and citizen-science data could also contribute to the compilation of the environment-related SDG indicators, but at a lesser extent.

SEEA can contribute to the development of coherent environmental-economic SDG indicators. Several indicators could be partly generated by the SEEA framework, such as SEEA Water Accounts contributing to indicators 6.3.1, 6.3.2, 6.4.2, and 6.6.1; SEEA Land Cover Account and Ecosystem Extent for 6.6.1, 11.7.1, 15.1.1, 15.2.1, 15.3.1, 15.4.2; and SEEA Central Framework Asset Accounts (Fisheries) for 14.1.1.[51]

In the Stats Brief "*Geospatial Information and the 2030 Agenda for Sustainable Development*" ESCAP highlighted the uses of geospatial and Earth Observation data in the compilation on SDG indicators by countries.[52] In the area of the environment-related SDG indicators, only a few countries explored the EO use in their compilation. These examples come for Australia (SDG 6.3.2, 14.1.1), China (SDGs 2.4.1, 6.3.2, 11.2.1, 11.3.1, 11.4.1, 11.6.2, 11.7.1, 14.1.1, 14.2.1, 15.1.2, 15.5.1),[53] India (SDG 11.3.1), New Zealand (SDG 15.4.2), Turkey (SDG 15.4.2) and Japan (SDG 15.4.2). The Stats Brief also presents case studies from countries in other regions.

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46 Wijayanto, Arie Wahyu & Triscowati, Dwi Wahyu & Marsuhandi, Arif. (2020). Maize Field Area Detection in East Java, Indonesia: An Integrated Multispectral Remote Sensing and Machine Learning Approach, https://www.researchgate.net/publication/344906996_Maize_Field_Area_Detection_in_East_Java_Indonesia_An_Integrated_Multispectral_Remote_Sensing_and_Machine_Learning_Approach

47 Asian Development Bank, A Handbook: Use of remote sensing to estimate paddy area and production, April 2019, https://www.unescap.org/sites/default/d8files/knowledge-products/Stats_Brief_Issue27_Dec2020_Geospatial_data_for_SDGs.pdf

48 CARS: Community for Agricultural and Rural Statistics, http://cars.adbx.online/

49 UNEP, Measuring Progress: Towards Achieving the Environmental Dimension of the SDGs, 13 March 2019, https://www.unenvironment.org/resources/report/measuring-progress-towards-achieving-environmental-dimension-sdgs

50 Jimena Juarez, presentation "WGGI's Indicators shortlist: national assessment of the SDG indicators and observations", https://ggim.un.org/meetings/2020/WG-GI-Mexico-City/documents/6.Jimena-Juarez.pdf

51 UNSD developed a matrix of SDG indicators correspondence with the basic Set of Environment Statistics of the FDES 2013, https://unstats.un.org/unsd/envstats/fdes/sdgsind_basicsetmatrix.pdf

52 Stats Brief, December 2020 (Issue no. 27): Geospatial information and the 2030 Agenda for Sustainable Development, https://www.unescap.org/sites/default/d8files/knowledge-products/Stats_Brief_Issue27_Dec2020_Geospatial_data_for_SDGs.pdf

53 Additional SDGs explored by the Chinese Academy of Sciences were identified: SDGs 6.4.2, 6.6.1, 15.1.1, 15.3.1.

In Asia-Pacific, **China** is one of the most advanced in the use of geospatial and Earth Observation data in the area of the SDGs. The efforts are registered at both national and regional levels. At the national level, the Chinese Academy of Sciences conducted pilots compiling SDG indicators using Earth Observation data.[54] At the provincial level, in 2017, China piloted an SDG Local Monitoring project in Deqing, initiative led by the Ministry of Natural Resources of China and Zhejiang Provincial Government, and supported by the National Bureau of Statistics.[55] This was the world's first comprehensive measurement of progress towards the SDGs at the county level using geospatial and statistical data.[56]

The Ministry of Statistics and Programme Implementation (MoSPI) of **India** compiled an experimental compilation of SDG 11.3.1 to understand the populations' growth rate across the million plus cities. The estimates were compiled using the Land Use Efficiency tool (LUE)[57] developed by the Joint Research Center (JRC) of the European Union, and the open and free Global Human Settlement Layer (GHSL). The global layer on built-up surfaces is produced from Landsat images, while the population estimates were nationally adjusted to the population totals from the UN World Population Prospects: The 2015 Revision. The estimates are experimental in nature, as they have been compiled using data available under GHSL, which may differ from the official estimates of population growth and built-up areas in these cities.

In **Japan**, the Geospatial Information Authority stresses the importance of collaboration between Statistics, Space and Geospatial bodies. The Authority has identified its contribution of the Digital Elevation Model and Coastline Data to the Statistics Authority for the compilation of SDG 15.4.2 (Mountain Green Cover Index).[58] In **New Zealand**, the Ministry of the Environment uses Sentinel-2 imagery as a basis for Land Cover database and LUCAS Land Use Map, contributing to SDG indicators 15.1.1 (Forest area as a proportion of total land area) and 15.4.2.[59] In **Turkey**, for the compilation of the same indicator, Turkstat relies on Collect Earth tool, FAO's technical support and collaboration with academia on the calculations of the indicator, registering differences from the custodian agency's results.[60] BPS-Statistics **Indonesia** is researching the uses of different big data sources and is considering the use of satellite imagery for the SDG indicators 15.3.1 (Proportion of land that is degraded over total land area) and 15.4.2.

Increasingly more data and technical resources are available to support the integration of Earth Observation data into the national compilation of the SDG indicators. For example, CSIRO and UNCCD released a Good Practice Guidance for SDG 15.3.1 and Trends Earth released technical guidance on generation of SDG 15.3.1[61] and SDG 11.3.1 (Ration of land consumption rate to population growth).[62]

Guidance on accessing and using satellite imagery in the SDG context is also provided. For example, the UN Statistics Division

54 Chinese Academy of Sciences, Big Earth Data in Support of the Sustainable Development Goals, September 2019, https://www.fmprc.gov.cn/mfa_eng/topics_665678/2030kcxfzyc/P020190924800116340503.pdf and Chinese Academy of Sciences, Big Earth Data in Support of the Sustainable Development Goals, September 2020, https://www.fmprc.gov.cn/mfa_eng/topics_665678/2030kcxfzyc/P020200927650108183958.pdf

55 SDGs Local Monitoring – China's Pilot Practice, https://sustainabledevelopment.un.org/partnership/?p=29982

56 Group on Earth Observations, Member spotlight: China, 7 January 2019, https://earthobservations.org/geo_blog_obs.php?id=336

57 European Commission, GHSL – Global Human Settlement Layer, https://ghsl.jrc.ec.europa.eu/tools.php

58 Hidenori Fujimura, presentation "Partnerships Activities for Geospatial-Statistical Integration", UN-GGIM-AP WG3 webinar on "Integrating Geospatial Information and Statistics, answering SDG's Challenge, 7 October 2020, https://speakerdeck.com/hfu/partnership-activities-for-geospatial-statistical-integration?slide=7

59 Group on Earth Observations, Country Use Case of EO Use for SDG Indicator, New Zealand, https://eo4sdg.org/wp-content/uploads/2020/04/NZ_15.11_15.4.2.pdf

60 Ovunc Uysal, presentation "Mountain Green Cover Index (MGCI): A baseline calculation case for Turkey", Workshop on Statistics for SDGs, Geneva, 17-18 April 2019, https://unece.org/fileadmin/DAM/stats/documents/ece/ces/ge.32/2019/mtg2/S_2_4_Mountain_Green_Cover_Index__MGCI__Turkey.pdf

61 Trends.Earth, SDG Indicator 15.3.1, http://trends.earth/docs/en/background/understanding_indicators15.html

62 Trends.Earth, SDG Indicator 11.3.1, http://trends.earth/docs/en/background/understanding_indicators11.html

Marketplace[63] guides users on accessing via Amazon S3 the Landsat 8 data, which is available since 1972 and generated daily. Additionally, *Specifications of land cover datasets for SDG indicator monitoring*[64] have also been compiled and are available as open data with corresponding sources.

## National and regional open data platforms and Open Data Cubes

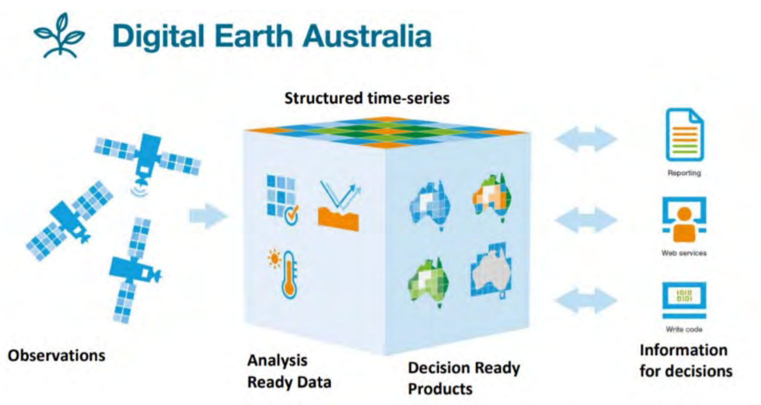
From NASA's MODIS and Landsat Data, which are used in almost any environmental discipline, to the European Union's Earth Observation Programme Copernicus, Earth Observations from satellite imagery are growing in coverage, resolution, and accessibility. Nevertheless, despite the wealth of satellite data collected over the past 40 years, little has been effectively put to good use. The main challenge has been transforming images into analysis-ready data, while correcting for atmospheric effect and continental drifts and lining up those images through time. Effective use for decision-making and development of new products requires data preparation performed by remote sensing specialists before statisticians can proceed to the analysis.

Digital Earth Australia addressed this issue by transforming satellite observations into analysis-ready data and making them available in the Open Data Cube (ODC), which has emerged as an Open Source Geospatial Data Management and Analysis Software. The project was born out of the initiative *Unlocking the Landsat Archive* of the Australian Geoscience Data Cube (AGDC) and is supported by six institutional partners: Geoscience Australia (GA), NASA / Committee on Earth Observation Satellite (CEOS), United States Geological Survey (USGS), CSIRO, Catapult Satellite Applications, and Analytical Mechanics Associates (AMA).[65]

The ABS collaborates with Geoscience Australia on using satellite imagery for remote sensing and compiling environment statistics, and multiple products have been developed from the Open Data Cube. Some of the examples include the Map of Wet Lands, showcasing changes in water content through time, which could be generated for every single wetland in the country and performed every five days; Map of Waterbodies[66], a total of 295,903 waterbodies, and the world's first continent-scale map of surface water; Water Quality Monitoring tool; Measurement of changes in agriculture field productivity; Coastal Change over time. The advantage of these tools is that they can produce an equivalent of a routine census, rather than a survey, with a monitoring capability for environment statistics.

The analysis-ready satellite imagery is stored in the cloud and all the applications are documented online with an open access on opendatacube.org.

**Figure 6 |** The stages of satellite imagery processing at Digital Earth Australia




***Source:*** *Geoscience Australia*

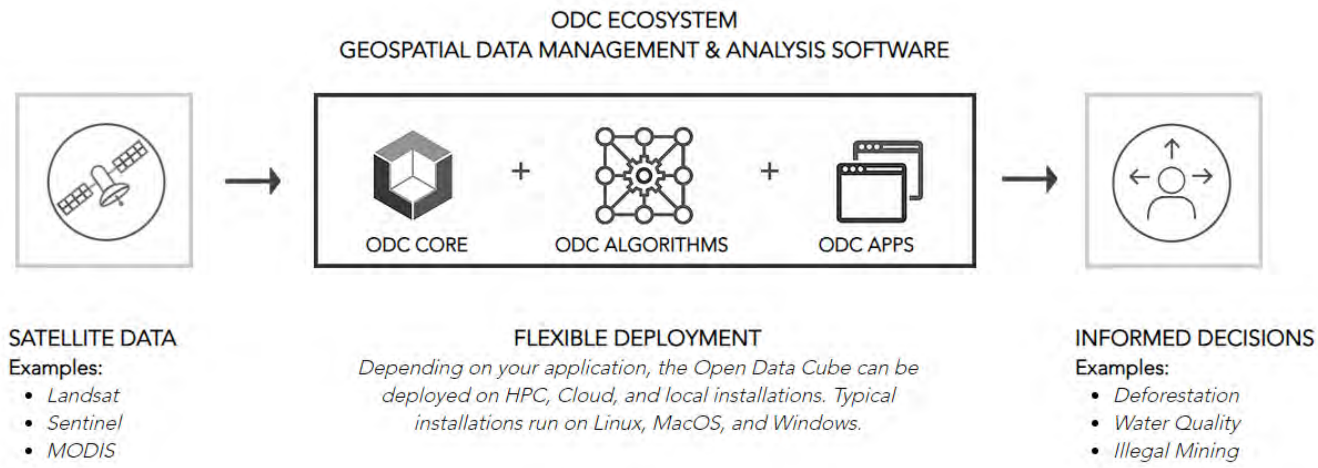
63 UN Statistics Division Marketplace, https://docs.opendata.aws/landsat-pds/readme.htm

64 Global Observation for Forest Cover and Land Dynamics (GOFC-GOLD) Land Cover Project at Wageningen University http://ggim.un.org/documents/Paper_Land_cover_datasets_for_SDGs.pdf

65 Open Data Cube, https://www.opendatacube.org/about

66 Geoscience Australia, DEA Waterbodies, https://www.ga.gov.au/dea/products/dea-waterbodies

**Figure 7 | The Open Data Cube Ecosystem**




***Source:*** *opendatacube.org*

The ease of data access coupled with the utility of the Open Data Cube, led to the development of the Open Data Cube in other continents. Digital Earth Africa[67] provides Earth Observations for policy making covering the entire continent. Another one currently under development with support from CSIRO and the Pacific Community is Digital Earth Pacific, focusing on marine and water-related aspects, covering climate change impacts, coastal change, coral bleaching, maritime surveillance, marine water quality, agriculture, water, and vegetation.[68] This was the quickest data cube, taking 3.5 hours to generate for all of Vanuatu. Furthermore, in addition to the Open Data Cube, the collaboration between GeoScience, Energy and Maritime Division of the Pacific Community, University of Sydney, and Geoscience Australia resulted in PacGeo - an open access geospatial data repository providing geophysical, geodetic, and marine spatial data sets covering the Pacific Island Countries.[69]

Another example in the region is the Vietnam Open Data Cube launched by the Vietnam National Space Center (VNSC). The platform provides information services on coastal change, forest, NDVI anomaly, urbanization, water detection and water quality. The Open Data Cube is VNSC's core data architecture for becoming the Earth Observation provider in Vietnam.

At the regional level, ESCAP, as the Secretariat of UN-GGIM-AP, has begun a ten-year initiative from 2020 to 2030 to provide member States with an integrated geospatial data hub through the operation of an Asia-Pacific geospatial information platform across countries. It aims to promote the sharing and use of geospatial information services and products among member states, strengthen UN-GGIM-AP geospatial data sharing platform and provide advisory services and capacity building programmes to ESCAP and UN-GGIM-AP member states. On 16 October 2020, ESCAP organized an initial exploratory 'Regional Workshop for Promoting the Asia-Pacific Geospatial Information Platform', to discuss concept, possibilities and challenges of such an information platform.[70]

67 Digital Earth Africa, https://www.digitalearthafrica.org/

68 Stuart Minchin presentation "Digital Earth Australia, Africa, and Pacific: Big Earth Data for Sustainable Development" at ESCAP Stats Café on October 14, 2020, https://www.unescap.org/sites/default/files/Digital_Earth_SPC_Stats_Cafe_14Oct2020.pdf

69 PacGeo, http://www.pacgeo.org/

70 UN-GGIM-AP, Regional Workshop for Promoting the Asia-Pacific Geospatial Information Platform, https://www.un-ggim-ap.org/meeting/regional-workshop-promoting-asia-pacific-geospatial-information-platform

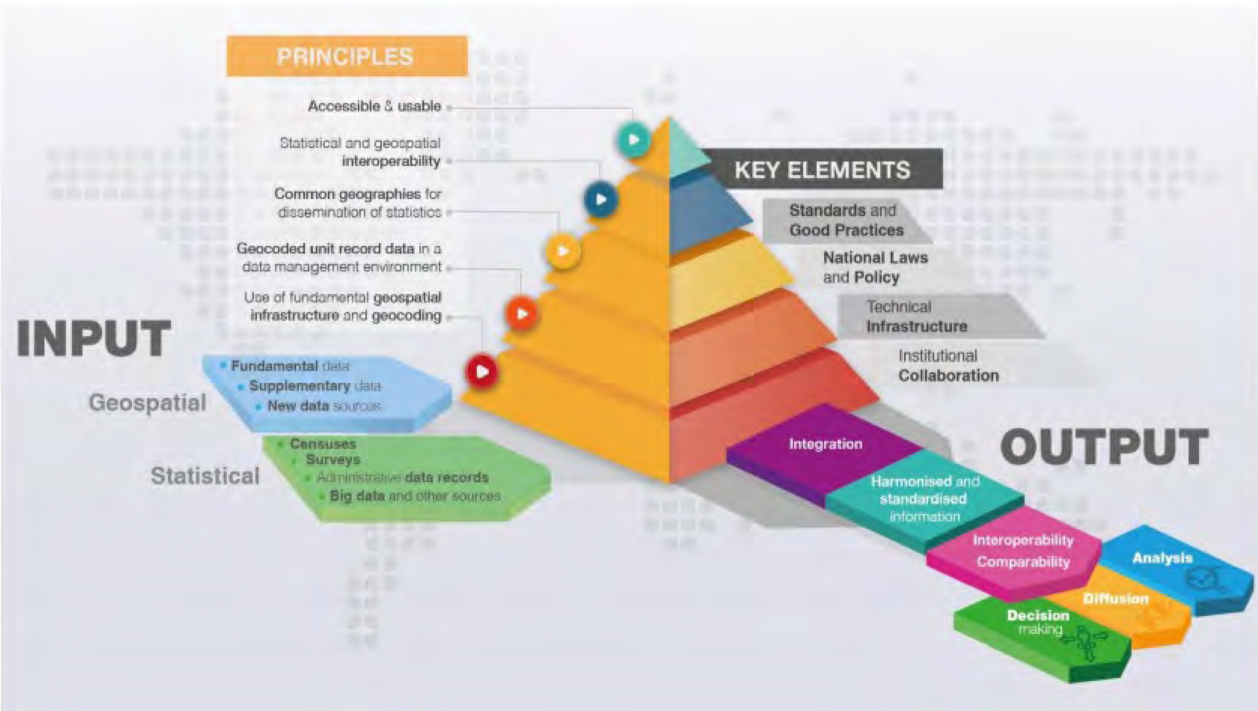
## Global and regional efforts in integrating geospatial and environment data

Multiple actors and communities at the global, regional, and country levels are using big data for environmental monitoring and statistics, and in particular geospatial data and Earth Observations.

At the global level, the UN Committee of Experts on Big Data and Data Science for Official Statistics (UN-CEBD) includes a Task Team on Earth Observation Data (EO),[71] which explores the applications of EO for official statistics, in particular agricultural statistics and land cover and land use statistics. Other pilot projects of the Task Team cover crop density mapping, crude oil inventory and spatial and statistical analysis of historic climate data. To inform countries about the EO potential for statistics, Task Team released a Guide on *Earth Observations for Official Statistics*.[72]

Another UN global effort is the Expert Group on the Integration of Statistical and Geospatial Information,[73] which was established by the United Nations Statistical Commission (UNSC) and the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). The Expert Group adopted the *Global Statistical Geospatial Framework (GSGF)*[74] in 2019. The GSGF relies on five fundamental principles and permits the production of standardized and integrated geospatially enabled statistical data to facilitate data-driven decision-making.

**Figure 8 |** Global Statistical Geospatial Framework.




***Source:*** *UN-GGIM, UN Statistical Commission: UN Statistics Commission, Global Geospatial Information Management Secretariat, The Global Statistical Geospatial Framework.*

71 Earth Observation data, Task Team of the UN Committee of Experts on Big Data and Data Science for Official Statistics; Mission and Strategies, https://unstats.un.org/bigdata/task-teams/earth-observation/index.cshtml

72 Satellite Imagery and Geospatial Data Task Team report, Earth Observations for Official Statistics, 2017 https://acems.org.au/sites/default/files/ungwg_satellite_task_team_report_whitecover_0.pdf

73 UN-GGIM, http://ggim.un.org/UNGGIM-expert-group

74 Global Statistical Geospatial Framework https://unstats.un.org/wiki/display/GSGF/Part+1%3A+The+Global+Statistical+Geospatial+Framework

The Group on Earth Observation (GEO)[75] is an intergovernmental partnership working to improve the availability, access and use of open Earth Observations to impact policy and decision making. GEO's priority engagement areas area the SDGs, Paris Agreement, and the Sendai Framework for Disaster Risk Reduction.

Both UN-GGIM and GEO have regional activities in Asia and the Pacific. The Regional Committee of United Nations Global Information Management for Asia and the Pacific (UN-GGIM-AP)[76] is one of the five regional committees of UN-GGIM[77] and it represents National Geospatial Information Authorities of 56 countries in Asia and the Pacific Region. UN-GGIM serves as a body for global policymaking in the field of geospatial information management. The Asia-Oceania GEOSS (AOGEO)[78] was formed along with initiatives in other regions. AOGEOSS is co-led by Australia, China, and Japan and has 12 task teams, among which AO-DataCube, Ocean and Island, Asia-RICE, monitoring and evaluation of drought in Asia-Oceania region.

## Conclusion

Earth Observations and Geospatial information are changing the way statistics are produced. Statisticians and environment specialists can measure different and new things, with data obtained regularly with full coverage and at lower costs than previously.

Yet the uptake of Earth Observation data for environment statistics remains low, with only few countries having integrated this big data source into the production of environment statistics, particularly land and agriculture statistics, or experimenting with it. Other government agencies are active in using Earth Observation data for environmental monitoring in collaboration with national Space or Remote Sensing Agencies. National Statistical Offices are encouraged to approach such agencies to build capacity and to explore EO data for environment statistics.

ESCAP is actively supporting national statistical systems in the region in the use of Earth Observation data for environment statistics through manuals and tools guiding the use of geospatial technologies for Earth Observation data analysis, as well as sharing country experiences at Stats Cafés and big data-related Stats Briefs and Working Papers. Support from other specialized organizations, such as UNSD, ADB and FAO, and global groups such as UN-GGIM and the Group on Earth Observations is also available.

75 Group on Earth Observations, https://earthobservations.org/geo_community.php

76 Regional Committee of United Nations Global Geospatial Information Management for Asia and the Pacific, https://www.un-ggim-ap.org/

77 United Nations Committee of Experts on Global Geospatial Information Management, http://ggim.un.org/

78 ASIA-OCEANIA Group on Earth Observations (AOGEO), https://aogeo.net/en/staticpages/index.php/aogeo