GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

GEF/STAP/C.57/Inf.06
December 4, 2019

57th GEF Council Meeting
December 17 - 19, 2019
Washington, D.C.

EARTH OBSERVATION AND THE GEF
A STAP DOCUMENT

Earth Observation and the GEF

A STAP document

December 2019

Earth Observation and the GEF

A STAP Document

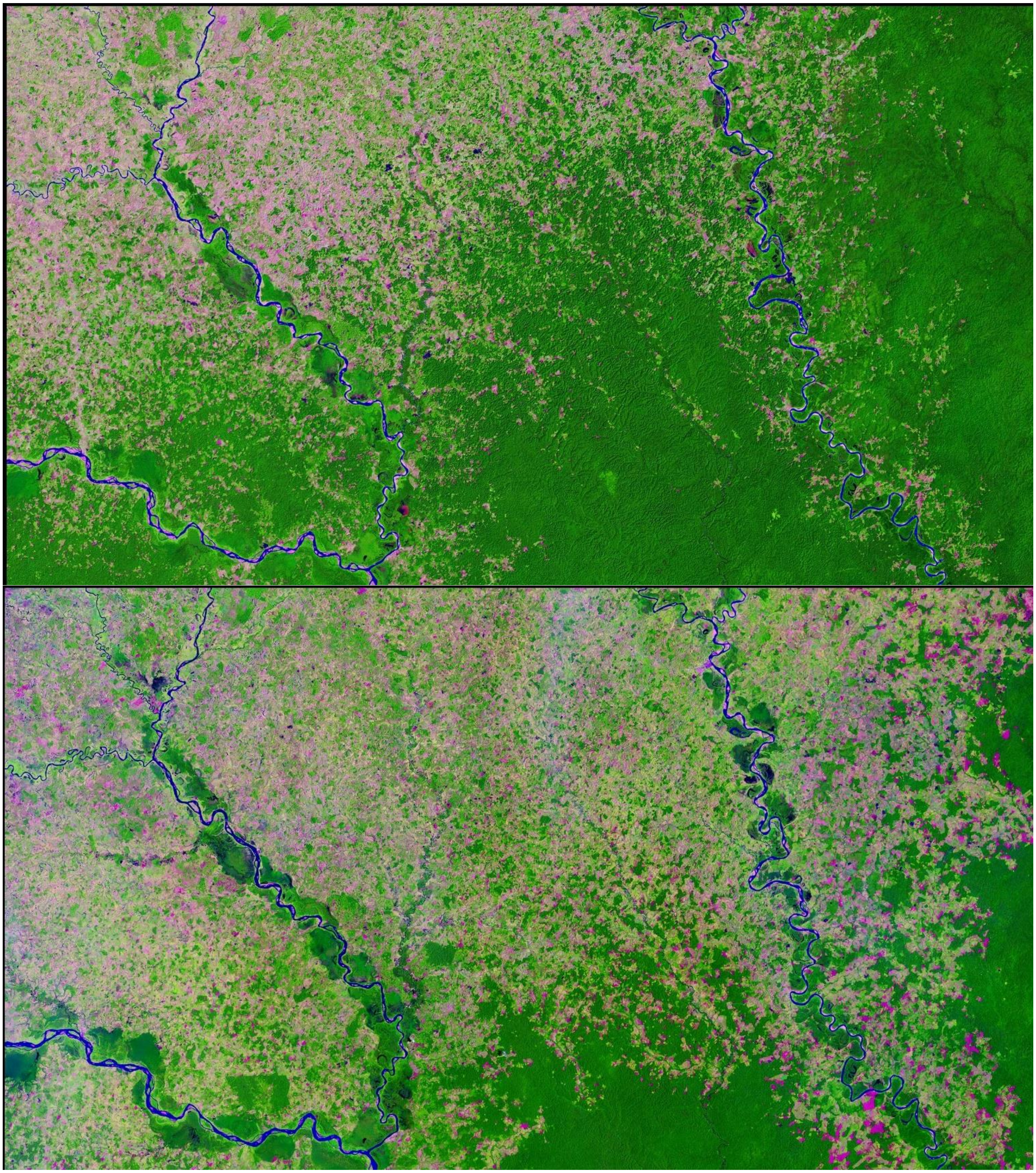


Image: Comparison of Landsat-4 image taken on December 22, 1989 and Landsat 8 image taken on March 11, 2016, shows significant deforestation in Colombia. USGS: Green = forested extent. Light pink = cleared areas.

Contents

Executive Summary 4

1. Introduction 5

2. Key benefits of Earth observation technology and data 5

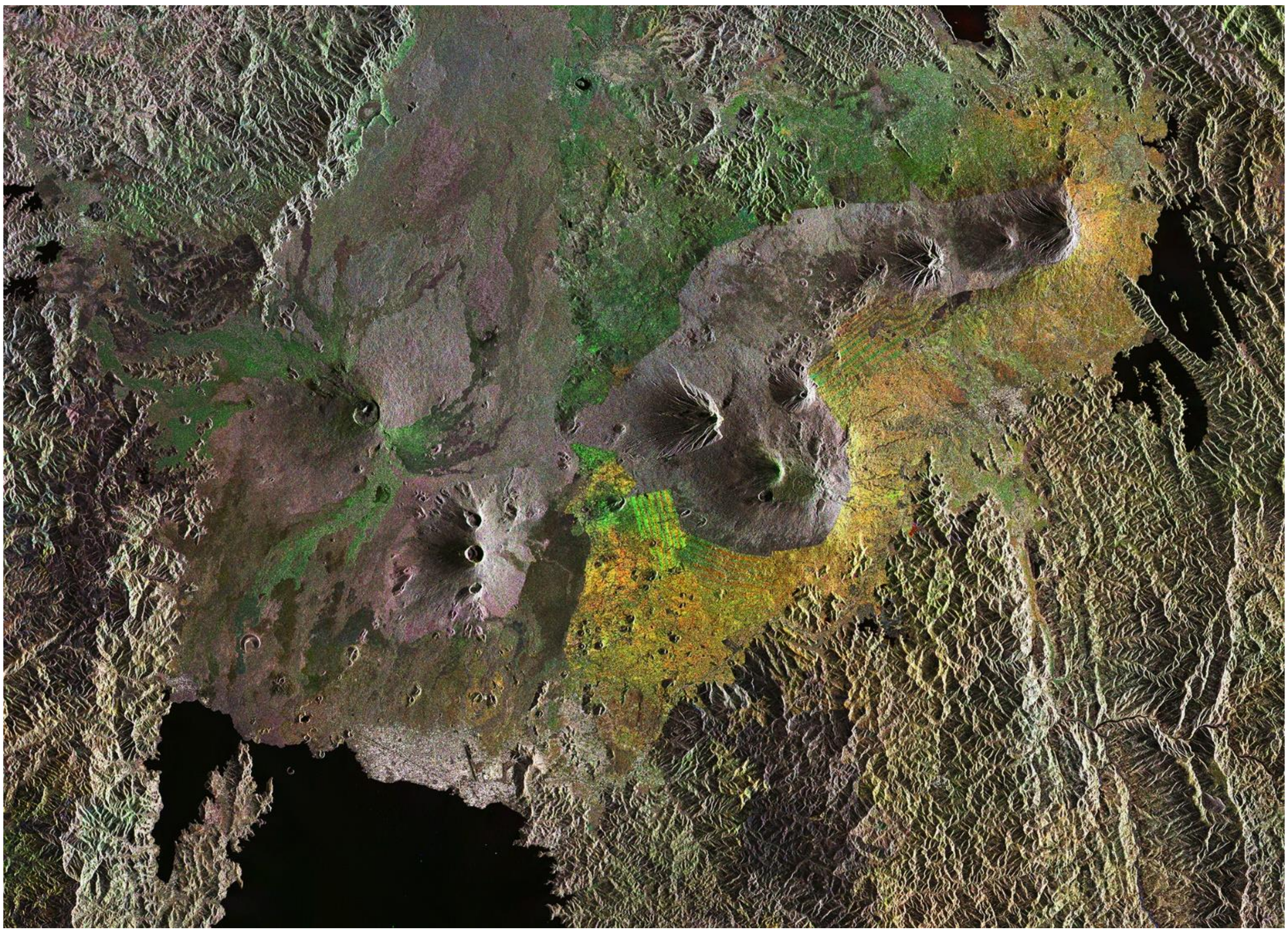
3. Earth observation and the GEF project cycle 6

4. Key characteristics and applications of Earth observation data and technologies 9

5. Trends in Earth observation data and technology 11

6. Improving the GEF's knowledge of the location and impact of interventions 12

7. Conclusions and recommendations 14



Virunga Mountains in East Africa. Sentinel-1 radar composite displays images collected on different dates. The green, orange and yellow colors indicate surface vegetation change outside protected lands. Image: modified Copernicus Sentinel data (2016), processed by ESA, CC BY-SA 3.0 IGO

Executive Summary

In the 28 years since the Global Environment Facility (GEF) was created, a digital revolution has taken place. Data from satellite remote sensing and other Earth observation technology have become much more regular, widespread, less costly and accessible. Together with scientific and technological advances such as cloud computing, machine learning, and data sharing, these data offer more opportunity to observe, monitor, and predict environmental and social phenomena with greater efficiency and precision.

Sometimes known as "Big Earth Data," information is being used to highlight and analyze the extensive and complex ways in which human beings are altering the planet's terrestrial and marine ecosystems, and the atmosphere. Big data analysis produces robust, science-based information which enables a better understanding of what is happening and is indispensable in developing mitigation and coping strategies - "you can't manage what you can't measure[a]." Earth observation data greatly enhance the ability to mine, organize, analyze, simulate, and represent information about the Earth system to allow informed decisions to be made about how to prepare for and adapt to environmental change, and how to sustainably manage and conserve natural resources.

Many GEF projects and programs are using Earth observation data to design, implement, monitor, and evaluate interventions; this document provides links to several case studies. However, the uptake and use of Earth observation technology by GEF agencies is uneven. Since 2017, the Project Information Form (PIF) requires project proponents to provide a map and geo-coordinates of the project's location. A PIF map could benefit from being integrated with information derived from Earth observation, but there remains limited guidance on how this information should be provided. STAP is developing a primer to encourage greater use of Earth observation data and technologies in GEF projects. This will provide: a detailed explanation of Earth observation, including information on data sources and platforms; GEF and non-GEF case studies to illustrate how these data and tools can be used; guidance on how to meet the requirement to provide a project map and geo-coordinates; and recommendations to encourage the use of Earth observation by the GEF. The primer will be available in January 2020 on the STAP website.

STAP recommends that: the GEF portal include simple tools to capture and validate geographic data on the location of projects; the GEF facilitate learning about Earth observation and mapping technologies by disseminating the primer and accompanying self-learning materials, and through a workshop with agencies to share experiences; GEF agencies should develop their internal capacity to use Earth observation data and technologies over the project cycle; and the GEF should continue to participate in the global conversations on best practice applications of Earth observation, such as the Group on Earth Observations and the Eye on Earth Summit.

[a] This famous quote is attributed to both quality and process control guru W. Edwards Deming and management consultant and thought leader Peter Drucker.

1. Introduction

Tackling complex, interrelated global environmental challenges requires wide-ranging social, economic, and environmental data and information, including on *what* pressures are occurring, *where,* and *how* they are changing over time. Earth observation technology provides up-to-date knowledge about the Earth's physical and biological systems for multi-disciplinary applications. The technology enables data collection through imaging and non-imaging sensors onboard satellites, airplanes, or drones, as well as deployed *in situ*. Earth observation data can: enhance the visualization, analysis, and communication of environmental issues; and aid decision-making, monitoring change over time, and evaluating results. For example, Earth observation data are routinely used to assess changes in land cover and land use, forest extent, land degradation, and urbanization, as well as the factors which may be driving these changes such as wildfire, road expansion, and natural disasters. The same is true for seascapes, where information gathered by satellites can provide information about ocean bathymetry[b], sea level rise, coral reefs, and coastal erosion.

Earth observation technologies have existed for decades but are now much more accessible due to investment in new systems, lower costs, and policy changes (e.g. open data), as well as improvements in computing power and the Internet, and innovation in data integration and analytical methods. These advances are very useful for GEF projects, and improved knowledge and understanding of Earth observation technology can help agencies to enhance the design, implementation, monitoring, and evaluation of projects.

This is particularly relevant for the Impact Programs (IPs) and Integrated Approach Pilots (IAPs) which take a "landscape approach." Combined with other spatially explicit information, Earth observation data can support greater integration and highlight potential synergies and trade-offs. For examples, these data can help bring together stakeholders to share and evaluate information for decision making using a common Geographic Information System (GIS)[1]. Systematic use and visualization of project data can also help in communicating results and achieving greater transparency, and in evaluating the long-term impact of projects.

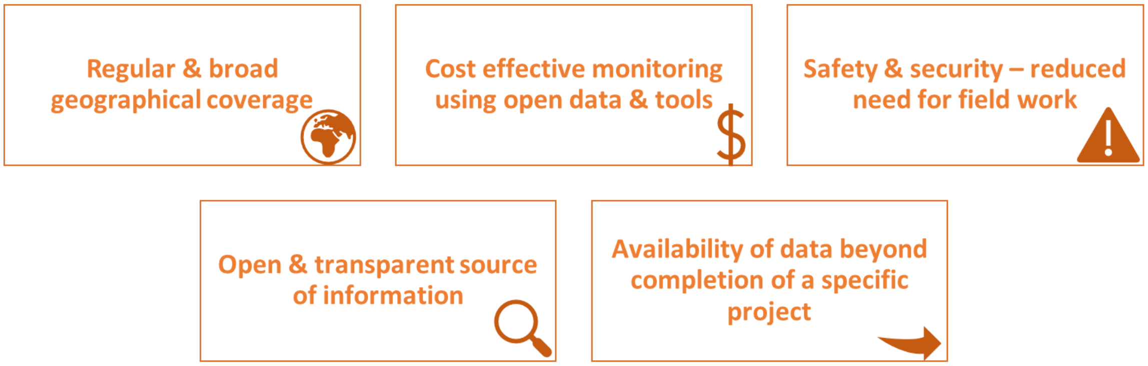
2. Key benefits of Earth observation technology and data

GEF projects require a range of data and information across broad landscapes and time periods that cannot be collected using field-based methods alone. The use of Earth observation technologies can enable, for example, the identification and detailing of biophysical characteristics of habitats, and detection of natural and human-caused environmental change from local to global scales. This type of information can be used to understand past trends, support management decisions, and monitor the impact of GEF projects[2].

Satellite remote sensing is probably the most important type of Earth observation: the key benefits are summarized in Figure 1. While these benefits are generally well known, the greatest value of remote sensing information is typically derived when it is integrated with complementary data obtained using other methods, including qualitative research.

[b] Bathymetry refers to the depths and shapes of underwater terrain. Bathymetric data are used to define the habitat for benthic (bottom-dwelling) organisms and to determine where fish and other sea life will feed, live and breed.

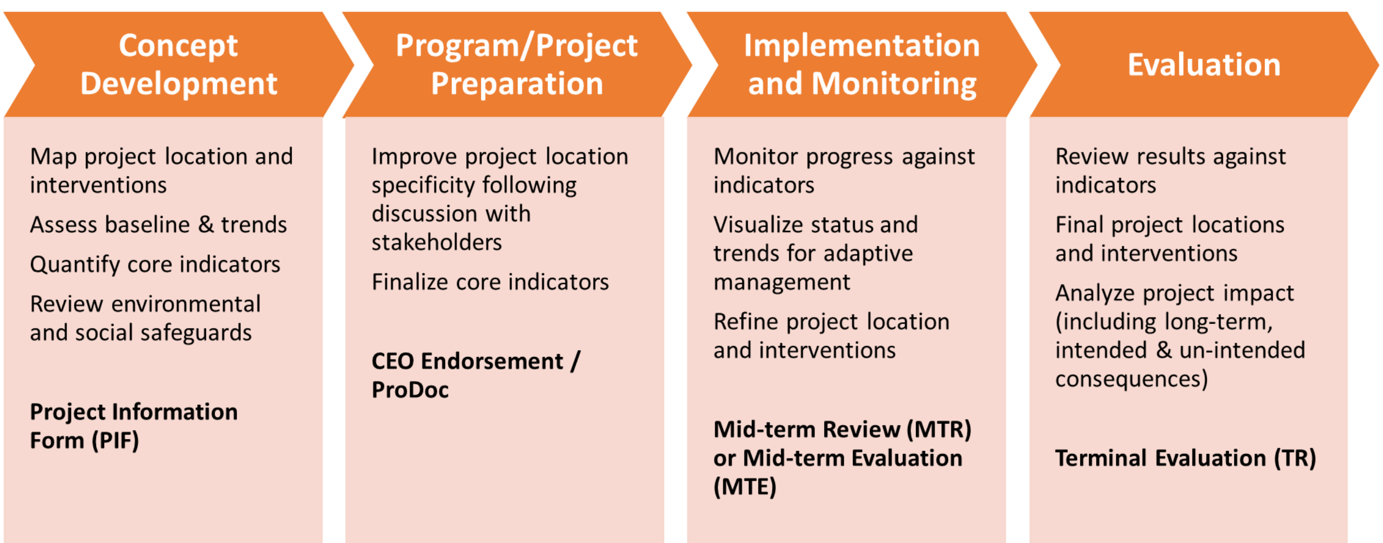
Figure 1 Benefits of satellite remote sensing



3. Earth observation and the GEF project cycle

Earth observation technology is useful at several points in the GEF project cycle, but the appropriate data sources and methods differ depending on the stage of the cycle (Figure 2). Typically, the information requirements and level of effort required in working with these data are less demanding at the concept development and project preparation stages. Information derived from Earth observation data and technology can complement that obtained using qualitative methods. Integrated, mixed method approaches (i.e. data triangulation) can be used to better understand not only the past and current state of a landscape, but also the underlying drivers of change and how interventions can change the current trajectory.

Figure 2 Earth observation and geospatial technologies and the GEF project cycle



Concept development

Developing a GEF project concept requires compiling and analyzing a range of data to ensure an up-to-date understanding of the current status of the project's location. The Project Information Form (PIF) now requires georeferenced data and a map showing the project's location (see Section 6). At this stage, published

information and tools can be easily accessed to explore key issues, trends, and processes to inform the proposed intervention.

It is unlikely that extensive analysis and processing of Earth observation data will be required at this stage, and several useful data portals provide user-friendly access to satellite images (e.g. SentinelHub, NASA Worldview) which enable visualization of up-to-date images. Freely accessible data portals and tools such as Global Forest Watch or Trends.Earth, both of which were supported by the GEF, may provide quantitative data to develop a baseline, assess trends and for GEF indicators[3] (e.g. area of degraded agricultural lands restored; forest and forest land restored; natural grass and shrublands restored; and wetlands, including estuaries and mangroves, restored).

Project preparation

Once the project concept is approved, additional information is likely to be needed for CEO endorsement. For example, supplementary data analysis and quantitative information may be required to further delineate the project's boundaries, and to refine estimates of expected global environmental benefits. The same data portals and tools used in concept development may provide the required information.

For example, the project *Integrated Landscape Management to Secure Nepal's Protected Areas and Critical Corridors* (GEF ID 9437) used forest cover data derived from remote sensing images and spatial analysis to determine baseline information and to identify target areas for project interventions.

Implementation and monitoring

Earth observation data and analysis can be used to support project implementation and monitor progress, including on performance indicators, building on data sources and information gathered for concept development and project preparation.

Evaluation

Earth observation can be useful for evaluation of the extent of a problem or progress in addressing it, for example, by addressing common data-related constraints, such as missing baseline information or insufficient coverage[4]. When combined with other spatial data in a GIS, these data can reveal new insights regarding the interaction between complex environmental and social phenomena. Geospatial data and analysis can help overcome some of the limitations that are encountered in evaluations on a regular basis. The GEF IEO is increasingly using Earth observation data and analysis to verify project outcomes[c] and to assess impact and estimate value for money.

Application Examples

Several GEF and non-GEF projects provide good examples of using Earth observation technology to support decision-making and to detect and monitor environmental conditions and change over time. Figure 3 summarizes several case studies.

[c] See, for example, the following IEO evaluations: Value for Money of GEF Interventions in Support of Sustainable Forest Management (2019); Value for Money Analysis for GEF Land Degradation Projects (2018); Impact Evaluation of GEF Support to Protected Areas and Protected Area Systems (2016).

Figure 3 Selected GEF and non-GEF project case studies using Earth observation data

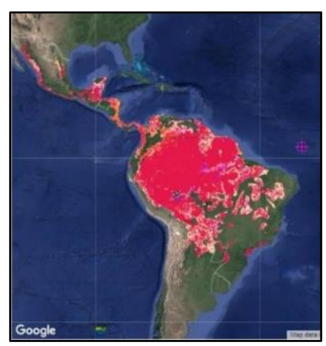
Case studies	GEF Implementing Agency / Lead Organization	Region	Project Phase				Focal Area				IPs			Technologies			
			Concept	Preparation	Implementation	Evaluation	Biodiversity	Int. Waters	Climate Change	Land Degradation	SFM	FOLUR	Sustainable Cities	Spaceborne EO	Airborne/drone	Cloud Platform	Citizen science
Land assessment through mobile and online tools (Open Foris)	FAO	Global			■	■				■	■	■	■	■		■	■
SkyLight Platform to combat illegal fishing	Vulcan	Africa			■			■							■	■	
Mapping land cover for protected area planning in Nepal	WWF	Asia		■	■		■				■			■			
Trends.Earth to map and visualize land degradation trends	CI	Global	■	■	■	■				■		■		■			
Jaguar habitat connectivity characterization	UNDP	LAC		■	■						■			■			
Monitoring of indicators for Food Security	IFAD	Africa		■	■				■	■		■		■			
UN Biodiversity Lab to build capacity of policymakers to use spatial data for conservation action	UNEP, UNDP, CBD	Global		■	■	■	■	■	■	■	■	■	■	■		■	
NASA's Fire Information for Resource Management System (FIRMS) for mapping fire	NASA	Global	■	■	■	■				■	■	■		■		■	
Global Ecosystem Dynamics Investigation (GEDI) mission for forest canopy and structure mapping	NASA	Global	■	■						■	■	■		■			
Global Biodiversity Information Facility (GBIF) and citizen science	GBIF	Global			■		■				■	■	■				■
Global Forest Watch for global forest cover monitoring	WRI	Global	■	■	■	■	■				■			■		■	
Seychelles Marine Spatial Planning	TNC, UNDP	Africa			■		■	■						■			
Satellite-based Sargassum monitoring	CLS, ESA	LAC	■					■						■			
Water resources and wetland monitoring inititatives using Earth observation	NASA, USAID, ESA	Global		■	■			■				■		■		■	■
Global Platform for Sustainable Cities use of Earth observation for Urban mapping	WBG, ADB, IDB, UNEP, UNDP	Global		■	■	■	■			■			■	■			
Forest Monitoring in the Amazon Biome	INPE	LAC		■	■						■			■		■	
Open Data Cube for environmental change analysis	CSIRO	Global	■	■	■	■	■	■	■	■	■	■		■		■	
Forest Monitoring and the Central Africa Regional Program for the Environment (CARPE)	NASA, UMD	Africa		■	■						■			■			

Notes: IP = Impact Program; Case studies will be included in the Earth observation primer to be published in January 2020.

These case studies used Earth observation and other spatial information can assist in the design, implementation, and evaluation of a project. Box 1 summarizes how GIS and remote sensing data were used as inputs to quantify ecosystem services to support prioritization and decision making for jaguar conservation.

Box 1: Ecosystem services provided by the habitat of the Jaguar (*Panthera onca*)

To assess the extent and value of ecosystem services within the jaguar range across Latin America, UNDP, King's College London, and Equilibrium Research used the Co$sting Nature tool and mapped other conservation-related factors including biodiversity, current human pressure on the land, and future threats. Biophysical ecosystem service production and value was calculated at the local, national and global scale. Many geospatial datasets contributed to the assessment, including vegetation information derived from MODIS[d] and SPOT[e] satellite sensors and Landscan population data. Results identified the most important ecosystem services, which include carbon storage; natural hazard mitigation; non-timber forest products; water provisioning; culture-based tourism; and nature-based tourism. The information is used to raise awareness on the importance of jaguar landscapes for achieving sustainable development goals. It is also used to generate political will for greater investment and action in conserving Jaguar landscapes and corridors, in the context of government programs including GEF financed projects.



[d] Moderate Resolution Imaging Spectroradiometer (MODIS) is a sensor on the Aqua/Terra satellites that provides daily global optical and thermal data and spatial resolution from 250 m to 1000 m.

[e] Satellites Pour l'Observation de la Terre (SPOT) is a series of commercial medium resolution satellite sensors. Currently SPOT 6 & 7 provide optical data with a spatial resolution of 6 m.

4. Key characteristics and applications of Earth observation data and technologies

GEF agencies have a lot of experience with Earth observation technology, but it can be challenging for project developers to determine what information is best suited for a given project, because of the many datasets and platforms available.

Understanding how these data may be applicable requires that users to assess their information requirements and then consider the key characteristics of available sensors and systems to determine which is the most appropriate to address their specific needs.

Assess information requirements:

- What is the question to be addressed?
- What is the biophysical information that is required that could potentially be obtained from Earth observation?
- What is the size of area?
- What is most important: spatial detail, large area, high frequency of observation, or long timeframe?
- How will data be integrated with other geospatial or non-geospatial data?

Evaluate how Earth observation can address the requirements:

- What a sensor or system detects
- Coverage and revisit period
- Spatial resolution
- Vintage and time series
- Cost and licence
- Processing applied to products
- Evaluate trade-offs such as data costs, processing and storage costs, and skills and expertise available

A summary of the key characteristics of remote sensing systems – optical, radar, and lidar – can be found in Figure 4, along with the key applications relevant to the GEF.

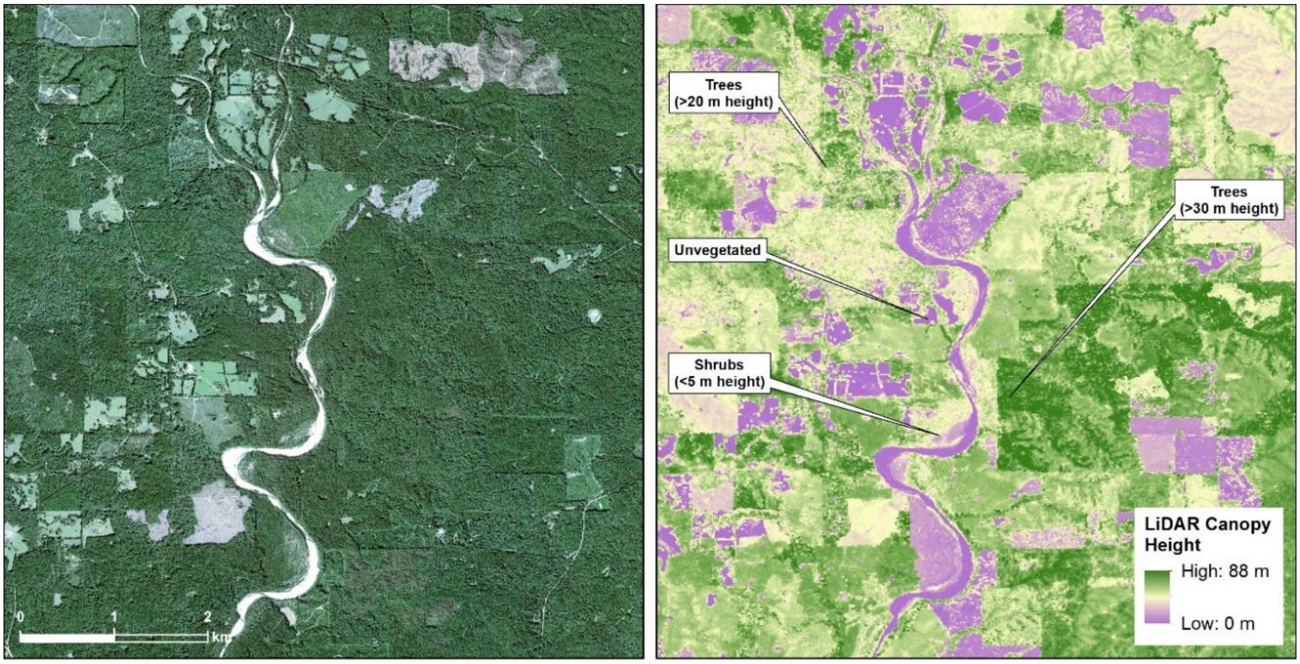
Figure 5 shows how the type of information collected at the same place can vary depending on the sensors used (e.g. lidar versus true color digital camera on board of an airplane). Lidar systems generate a dense dataset of highly accurate georeferenced elevation points – often called a point cloud – that can be used to create three-dimensional representations of the Earth's surface, and features such as vegetation canopy height. Additional technical information about optical, radar, lidar systems will be provided in the forthcoming primer.

Figure 4 Key characteristics and applications of satellite Earth observation systems

		Forest/Vegetation/ Soils	Freshwater	Coastal/Oceans
Optical				
	Key properties	• Sensitive to vegetation health • Reflectance from vegetation and soil surface • Limited sensitivity to vegetation structure	• Sensitive to chlorophyll and suspended matter • Penetration of water column up to 20-30 m* under optimal conditions	• Sensitive to chlorophyll and suspended matter • Penetration of water column up to 20-30 m* under optimal conditions
	Key applications	• Land cover and land use types and change • Forest types • Crop types	• Surface water extent and variability • Wetland classification • Surface water quality (eutrophication)	• Bathymetry (clear waters) • Water quality (chlorophyll and suspended solids) • Coastline change (erosion, deposition) • Coastal habitat (e.g., mangroves, marshes, coral reefs)
Radar				
	Key properties	• Some penetration of vegetation canopy and soils • Sensitive to vegetation structure	• No penetration of water • Sensitive to water surface roughness	• No penetration of water • Sensitive to water surface roughness
	Key applications	• Forest cover change (clear cuts) • Forest biomass*	• Surface water extent and variability • Wetland classification	• Coastal habitat (e.g., mangroves)
Lidar				
	Key properties	• Penetration of vegetation canopy • Limited penetration of soils • Sensitive to vegetation structure	• Penetration of water up to 20-80 m* under optimal conditions	• Penetration of water up to 20-80 m* under optimal conditions
	Key applications	• Forest biomass • Forest structure • Topography • Flood risk	• Bathymetry • Bank/shoreline change	• Bathymetry • Coastline change (erosion, deposition)

* depending on wavelength and environmental factors

Figure 5 Lidar canopy height model (right) compared to aerial photo (left)



Source: Hatfield Consultants using true color aerial photos (2016) and lidar data (2016) from Mississippi Automated Resource Information System.

Earth observation can address many information needs, and it is optimal when complemented with other methods including qualitative research. One of the challenges in relating geospatial technologies to qualitative data is the difference in temporal and spatial scale of information[5,6]. For example, remote sensing images can cover broad areas on a regular basis, whereas socio-economic information may be for specific locations and times (e.g. household surveys) or generalized regions and time periods (e.g. census). Indicators of socio-economic development may take time to appear in the landscape for remote sensing technologies to be able to capture evidence of that development (e.g. agro-forestry and revegetation strategies).

The cost of Earth observation data has declined dramatically with much data available free under an open data license, but users must also consider the costs of downloading, storing, and processing of big data, including human resources.

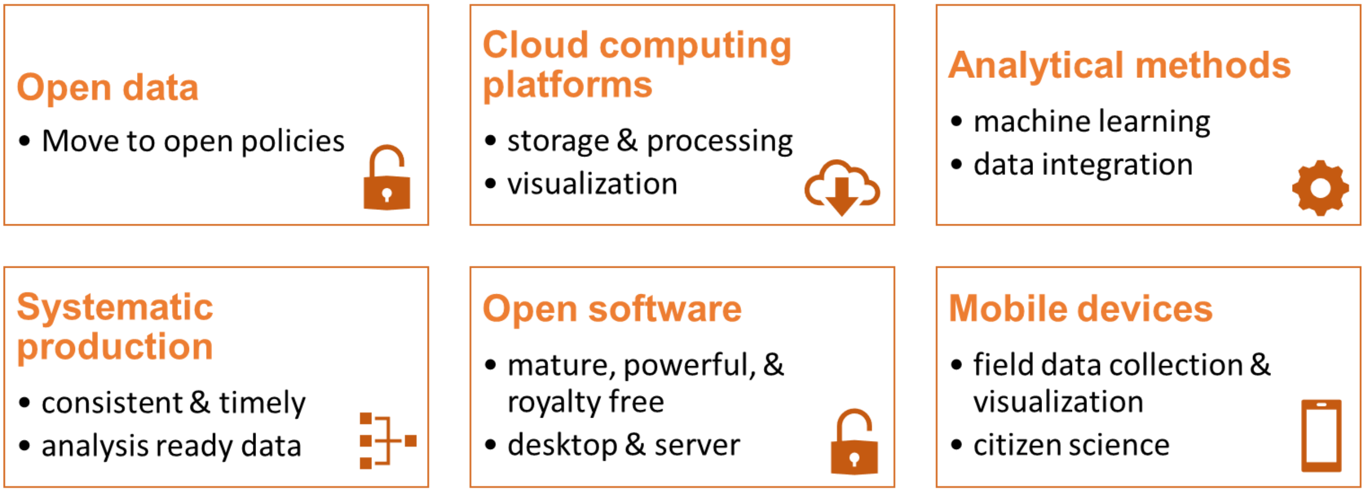
5. Trends in Earth observation data and technology

It can be challenging to keep track of trends in Earth observation technology, especially during a period of rapid development in information and communications technology, including computing capacity, location-enabled and Internet-connected mobile devices, and the numerous services associated with them.

Figure 6 highlights the key trends in remote sensing, including the move towards open data and open software, and the increasing availability of data to more users, rather than being restricted to highly-trained users. New approaches to using Earth observation data have evolved, with access to cloud data storage and processing environments. These can include commercial data provided on a subscription basis.

Two well-known Earth observation cloud computing platforms are Google Earth Engine and Sepal, which, at present, are available at no cost to users. For more advanced users, cloud computing systems from Amazon Web Services, Microsoft Azure, and the European Commission supported Data and Information Access Services (DIAS) also provide access to a large amount of Earth observation data.

Figure 6 Trends in Earth observation technology



6. Improving the GEF's knowledge of the location and impact of interventions

Systematic information on the location and impact of GEF interventions can improve decision-making, accountability, and transparency. However, like all types of data, geographic data needs to be managed to protect privacy and meet security requirements.

The benefits of collecting and sharing geographic information on GEF projects include:

- Better understanding of the geographic context and spatial extent of GEF projects; currently, the GEF portal shows only the name of the country in which the project is located;
- Accessible information on past and current GEF project locations can help users to identify synergies, avoid potential duplication of effort, and coordinate to maximize the impact of GEF investment;
- Better monitoring of projects during the implementation phase, which could help projects to adapt to changing conditions; and
- Robust and precise evaluation of project impacts.

The GEF's current guidance on providing geo-referenced information and a map in PIFs recommends using geonames.org to provide geolocation ID numbers to standardize the format in which data are provided. Alternatively, latitude and longitude of one point in the project area is requested. While providing project location information is mandatory, uneven implementation of the guidance can result in poor quality maps with project locations not identified and no regional context; and basic map elements not included, (e.g. scale bar, north arrow, legend), and GeoNames geolocation ID or coordinates not being provided or being inaccurate.

All GEF agencies systematically collect information on projects that can be geo-referenced. Some agencies go further and collect GeoNames or coordinates of a bounding box (a pair of longitude and latitude coordinates that define a box that covers the project area). Since agencies are collecting and using project geolocation information, it would be reasonable to expect that GEF-7 PIFs include accurate geo-location information.

To ensure that implementing agencies provide consistent and high-quality project geo-location, the following harmonized approach to fulfilling the guidance should be followed, which addresses recommendations by the IEO[9].

Global projects:

a. *Specify the project is global, no GeoNames required.*

Multi-country projects:

a. Whole countries are the project area:
   - *specify country names and GeoNames ids*
b. Sub-areas of countries are the project area:
   - *specify country names and GeoNames ids*
   - *specify* province/state names and GeoNames ids

Example:
A multi country project in Vietnam and Lao PDR focused on the River Ma Transboundary Basin and Coastal Areas. The country and province GeoName ids are provided.

- Countries: Vietnam (1562822) and Lao PDR (1655842)
- Provinces: Thanh Hóa Province (1566166), etc. so that all provinces with activities are listed.

Single country projects:

a. Whole country is the project area:
   - *specify country name and GeoNames id*
b. Sub-area(s) within country are the project area:
   - *specify country name and GeoNames id*
   - *specify province/state names and GeoNames ids*

Example:
A single country project in Brazil addressing Sustainable Forest Management in the states of Amazonas and Rondonia. The country and province GeoName ids are provided.

- Countries: Brazil (3469034)
- States: Amazonas (3665361), Rondonia (3924825)

For any project in a **sub-area** of country or multi-countries (e.g. a protected area), provide the bounding box in decimal degrees.

Example:
A project in Brazil addressing Sustainable Forest Management in the states of Amazonas and Rondonia. The latitude and longitude of the bounding box are provided in decimal degrees.

Upper left -74.03502, 2.340589
Bottom right -56.047211, -13.72352

A project map should be provided in the PIF with the following elements: Title; Scale bar (using the International System of Units); Coordinate System and datum; North arrow; Graticule (a latitude, longitude grid overlay); Inset map showing context of project location in country/region; Legend, including identification of project sites as needed. All elements must be readable, and maps are recommended to have minimum 150 dots per inch and minimum 10-point font for text.

7. Conclusions and recommendations

Enhanced satellite Earth observation capabilities, recent policies on open and free access to data and tools, and advances in algorithms and data processing are facilitating widespread use of Earth Observation data at scale, and beyond the specialized scientific community. These developments offer opportunities for improving the robustness of environmental data and indicators[7], large landscape coverage, and the ability to determine scientific baselines more accurately and to monitor change over time, including after project completion.

Several GEF agencies already use geospatial information and Earth observation technology in their projects and have a designated lead person for geospatial technology to advance its use. The PIF requirement on mapping and geocoding is also encouraging agencies to provide spatial data for their projects. The IEO has recommended that the GEF make greater use of spatially explicit data for projects addressing protected areas[8], biodiversity[9], land degradation[10], and more precision in recording and reporting project location will help in the monitoring and evaluation of progress and results[11].

STAP supports these actions and suggestions and further recommends:

1. Updating the GEF portal to provide fields and simple tools to capture and validate geographic data on the location of projects, such as an interactive map to draw the bounding box for a project area. This would help agencies to update information over the GEF project cycle to support project evaluation and the communication of project impacts.
2. Facilitating learning through the development of an Earth observation primer and accompanying self-learning package, and by holding a workshop with agencies to share experiences for improving the use of Earth observation technology and geospatial data.
3. Encouraging the agencies to continue to develop internal capacity to use Earth observation data and technologies throughout the project cycle, and to share Earth observation science and tools to provide opportunities for others to benefit from successes.
4. Participating in the global conversations on best practice applications of Earth observation and the emerging digital ecosystem for the planet[12], such as such as the Group on Earth Observations and Eye on Earth Summit.

References

[1] See, for example, Lehmann, A. *et al.,* (2017). Lifting the Information Barriers to Address Sustainability Challenges with Data from Physical Geography and Earth Observation. *Sustainability* 9: 858: 1 – 15.
[2] Lech, M., *et al.,* (2018). Improving International Development through Geospatial Data and Analysis. *International Journal of Geospatial and Environmental Research*, 5(2).
[3] Global Environment Facility (GEF), Guidelines on Core Indicators and Sub-Indicators. ME/GN/02. Updated on March 11, 2019.
[4] Lech, M., *et al.,* (2018). Improving International Development through Geospatial Data and Analysis. *International Journal of Geospatial and Environmental Research*, 5(2).
[5] McCusker, B., & Weiner, D. (2003). GIS representations of nature, political ecology, and the study of land use and land cover change in South Africa. In Political ecology: an integrative approach to Geography and environment-development studies. New York, NY: The Guillford Press.
[6] Rindfuss, R.R. *et al.*, (2004). Developing a science of land change: Challenges and methodological issues. *PNAS* 101(39): 13976 – 13981.
[7] Organisation for Economic Cooperation and Development (OECD) (2017). *Earth Observation for Decision Making.*
[8] Global Environment Facility Independent Evaluation Office (GEF IEO), Impact Evaluation of GEF Support to Protected Areas and Protected Area Systems, Evaluation Report No. 104, Washington, DC: GEF IEO, 2016.
[9] Global Environment Facility Independent Evaluation Office (GEF IEO), Biodiversity Mainstreaming 2018. Washington, DC: GEF IEO, 2018.
[10] Global Environment Facility Independent Evaluation Office (GEF IEO), Land Degradation Focal Area Study. Washington, DC: GEF IEO, 2018.
[11] Global Environment Facility Independent Evaluation Office (GEF IEO), Value for Money Analysis of GEF Interventions in Support of Sustainable Forest Management, Washington, DC: GEF IEO, 2019.
[12] UN Environment (September 2019). Building a digital ecosystem for the planet. Foresight Brief.