



Land use change monitoring solutions in support of deforestation-free commodities

Practice Guidance

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United Nations Development Programme

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This report is published with support from the Global Environment Facility (GEF) and the Good Growth Partnership (GGP) and in partnership with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

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Contributions

The authors would like to thank the UNDP Climate and Forest team and the UN REDD teams who developed an initial comparative land use change matrix that served as the basis of this review, and in particular Danae Maniatis, Bruno Guay, Clea Paz, Jose Arturo Santos from UNDP and Carlos Riano from FAO.

Invaluable contributions came from the participants of a workshop comparing land use change monitoring systems held in Tarapoto, Peru, during the Good Growth Conference in 2019. We extend our thanks to the participants of the Good Growth Community of Practice, the Green Commodities Community, who who have also contributed to reviewing parts of this paper, in particular: Jairo Serna, Miriam Miranda, Maureen Ballester, Marvin Rojas, Sandra Andra, Satoko Okamoto, Daniel Arturo Castillo Soto, Pedro Amaral, Chami Akmeemana, Pisca Tias, Cornelia Miller, Hayleen Aguilar, Cristian Vargas.

This paper has also been supported by staff at CENAT, CONARE, PRIAS Lab in Costa Rica and to the UNDP team directly involved in this knowledge product research paper: Pascal Fabie, Matias Ferreira, Aleksandra Atallah, Pascale Bonzom, James Leslie, Andrew Bovarnick, and the entire Green Commodities Programme.





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Executive Summary

Deforestation-free value chains require public and private sector decision-makers to monitor the **land cover** dynamics within the production landscapes that supply the world with agricultural commodities.

Experience proves that users require periodic monitoring of both the dynamics between forest and no forest, and between agricultural land cover and **tree forest cover** inside production landscapes. The monitoring of such dynamics is essential to achieve deforestation-free commodity supply chains.

Practitioners who are unfamiliar with Geographical Information Systems but involved in deforestation-free commodities must choose whether to rely on existing openly accessible global forest monitoring services, contracting private service providers, or developing national monitoring systems themselves. This can be a difficult task because of the increased availability of **Land Use Change Monitoring** (LUCM) solutions.

This research paper provides a guide to non-specialized practitioners through a review of the characteristics of a small sample of LUCM solutions from around the world. It focuses on the suitability and usability of these LUCM solutions to monitor if a production area gains or loses tree forest cover from year-to-year as a result of a specific agricultural activity.
































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Having reviewed five service providers and five country systems, the paper concludes that these LUCM solutions:

- Work at different scales, use different methods and pursue different objectives but that all solutions use **Landsat** and **Sentinel** remote sensors that are widely available for free.
- Use **data layers** of agricultural land covers that are less detailed or disaggregated when monitoring land cover at a global scale, and the **algorithms** they use may not identify changes for all the types of ecosystems or tree forest covers.
- Provide useful and valid information, but users must determine beforehand what scope is required in order to choose the level of accuracy of data needed.
- In Brazil and Costa Rica provide greater detail and accuracy than other existing global services.

At a glance, the main characteristics of the reviewed systems are:

LUCM Solution	Annual publication of tree forest cover gain and loss land cover	Annual publication commodity land cover	Published through open access web viewer	Web Viewer allows interaction with layers of property records / concessions	Free Access	Uses Landsat or/and Sentinel Remote sensor data
Global Services & Tools						
Global Forest Watch						
Open Foris-CollectEarth						
MapX						
MapHubs						
Planet						
National Systems						
Costa Rica						
Brazil						
Indonesia						
Paraguay						
Peru						



Why a review of land use
change monitoring solutions
in support of deforestation-
free commodities?

Deforestation-free value chains require public and private sector decision-makers to monitor the **land cover** dynamics within the production landscapes that supply the world with agricultural commodities. It also entails government entities acting quickly on tree forest cover loss associated with agricultural expansion. In both cases, choosing whether to rely on existing openly accessible global forest monitoring services (such as Global Forest Watch, or MapX); or hire a private service provider (like MapHubs) or develop a national monitoring system (such as the Brazilian environmental cadaster system) can be a difficult task.

The resolution and frequency of existing global Land Use Change Monitoring (LUCM) systems can be ideal to determine tree forest cover gain or loss at national or larger scale, but it may not be precise enough to monitor land cover dynamics within smaller territories. Non-specialized users of this information may require monitoring features tailored for specific jurisdictions or functions. In order to verify compliance of a particular unit of production (i.e. farm, plantation or concession) with any sustainability pledge, practitioners may also need land use change systems to be open-access, low cost and to enable interaction with "official" layers of information such as property or concession records, protected areas, or water catchment areas. These nuances, and the increased availability of LUCM services, tools and national systems can be difficult to handle for sustainable development practitioners.

Most institutionalized and widely used forest monitoring systems that are tied to environmental conventions, such as the REDD+ related articles of the UNFCCC, are insufficient to verify if a production unit (e.g. farm, plantation, concession) is deforestation-free on a given year. The main outputs of these systems are forest carbon inventories, and national tree forest cover maps. Official forest carbon records are reported through the publication of Biannual Reports (BUR), and UNFCCC National Communications. These instruments provide transparent accounting of carbon stored in forests for eventual emissions reductions transactions and as measure of compliance with National Determined Contributions (NDCs) and other UNFCCC commitments. The resolution and frequency of formal systems is aimed at determining forest or no forest land covers at a national scale. This is rarely enough to monitor tree forest cover dynamics within specific commodity production landscapes, or within specific production units (farms, plantations, concessions). Also, and as complex institutional tools go, formal forest carbon accounting and mapping is understood and utilized mainly by a very specialized audience.

As a result, non-specialized users of information about the dynamics of forest and agricultural cover, such as staff from commodity producers, buyers, financial institutions, multilateral agencies and civil society organizations, require additional monitoring features to study the impacts on tree forest cover of specific commodities being exported to world markets and being sold under pledges of 'zero net deforestation' or 'deforestation-free'. Experience proves that these users require periodic monitoring of both the dynamics between forest and no forest, and between agricultural land cover and tree forest cover inside production landscapes. The monitoring of such dynamics is essential to achieve deforestation-free commodity supply chains.

New technologies have triggered the emergence of LUCM solutions that complement existing formal forest carbon accounting systems. The new LUCM solutions have expanded monitoring into production landscape and include new features like the publication of data layers of tree forest cover gain or loss; or of land cover of commodity plantations. New features also include the use of more useful remote sensors, increasing range and periodicity of imagery that can be processed. One very important contribution to the expansion of global services and systems is the availability of Sentinel-2 and Landsat-8 images for free¹.

The increased availability of LUCM solutions can be overwhelming for development practitioners, technical staff from financial institutions, or senior managers from commodity buyer companies, who are unfamiliar with Geographical Information Systems (GIS) but involved in processes aiming for deforestation-free commodities.

This research paper aims to provide answers to these questions by reviewing the main characteristics of a few LUCM solutions from around the world.

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¹ To download free Landsat imagery: <https://ers.cr.usgs.gov/register>
To download free Sentinel imagery: <https://scihub.copernicus.eu/dhus/#/home>

For each reviewed solution it attempts to answer the following common questions of practitioners when designing and participating in interventions related to forest cover:

What global services, national systems and existing tools, can facilitate verification of production units free of tree forest cover loss or gain on a regular basis?

May any practitioner access these services and systems? At what cost?

Should we use an existing global service or national system to monitor target tree forest cover in a given jurisdiction? Is it enough? Do we need to hire a private company to conduct transparent monitoring of a production landscape? What is needed to develop such a system at a national or jurisdictional scale? Must additional methods and tools be used to verify if production units are deforestation-free?

Can the solution be used to monitor if a selected production area gains or loses tree forest cover from year-to-year as a result of a specific agricultural activity?

How practitioner-friendly is the solution?

These questions are addressed through the following categories of classification:

<div>1</div> NOT SUFFICIENTLY FRIENDLY	<div>2</div> FRIENDLY BUT CAN IMPROVE	<div>3</div> VERY USER FRIENDLY
Classification	Definition	
<div>1</div>	<ul style="list-style-type: none"> Access to the digital platform after searching for the name through a search engine (google, yahoo, etc) is not immediate or intuitive. The platform does not allow direct entry to the geospatial viewer. The platform strictly requires registration before you may use it. The platform does not include an option to translate information into different languages. The platform does not provide easy visualization of the data layers: Activation and deactivation button not designed for intuitive use. The platform does not provide visible development functions, such as changing the base map, generating polygons or creating location points. Data layers do not include metadata, or only include general information about the specific layers. Allows downloads of data layers only GIS viewing formats and the download function is difficult to understand. 	
<div>2</div>	<ul style="list-style-type: none"> In order to use it correctly, users must possess specific technical knowledge. Access to the digital platform after searching for the name through a search engine (google, yahoo, etc) is not immediate, it takes some time to find. The platform allows for direct entry to a geospatial viewer, but may only be used after registering. The platform does not require registration to use it, however, if you don't register you will have less functions available to use. The platform provides visualization of the data layers in an intuitive way and without an activation and deactivation button. 	

Classification	Definition
2	<ul style="list-style-type: none"> The platform has visible, but not very intuitive functions, such as for changing the base map, generating polygons, or creating location points. The data layers include metadata and technical information, but it is insufficient, or the language is complicated for all users to understand. Allows for downloads of data layers formats to view in GIS such as KML and KMZ that may be used in Google Earth. The download option seems complicated and difficult to understand.
3	<ul style="list-style-type: none"> Access to the digital platform after searching for the name through a search engine (google, yahoo, etc) is immediate and intuitive. The platform has a visible tab to enter the geospatial viewer. The platform may be translated into different languages. The platform provides visualization of the data layers in an intuitive way and includes an activation and deactivation button which is clearly visible. The platform includes visible functions, such as changing the base map, generating polygons, creating location points. The data layers include metadata and technical information, a summary of the data is well explained without technical concepts which can be consulted in an agile and intuitive way. Allows for downloads of data layers in many different formats and the download option is designed in an intuitive way. In order to use it correctly, users do not need to have specific technical knowledge, other than previous knowledge of geospatial applications such as Google Earth, Maps, among others. The platform includes videos or user manuals, as support material for users.

This research paper reviews:

- The global non-profit services (Global Forest Watch and MapX),
- The private sector providers (Planet)
- The tool for monitoring land cover change (Openforis)
- The national systems of global suppliers of palm oil (Indonesia), soy (Paraguay), beef (Brazil) and pineapple (Costa Rica)
- The existing forest land cover system for Peru (Geobosques).

The LUCM solutions reviewed complement formal forest carbon inventories by including features that help verify if production of unit is free from tree forest cover loss from one year to the next.

This research paper contains two sections. The first reviews global services and tools, the second reviews the existing national systems monitoring land cover dynamics. Each featured solution is presented using a standard table to facilitate comparison of technical features such as resolution, periodicity of available data, and remote sensors used and useful hyperlinks. The conclusion summarizes findings and makes recommendations for monitoring land cover and commodities depending on objectives and targets of study. A matrix comparing the reviewed systems is included as an annex for practitioners to help decide what LUCM solution to use, depending on objectives and needs.

This paper has been developed by **UNDP** in partnership with **GIZ** and the **Good Growth Partnership**, and with funding from **BMZ** and the **GEF**. It is a joint endeavor of the UNDP Green Commodities Programme and the GEF/UNDP/MINAE Production Landscape Project in Costa Rica. It includes the results of a series of virtual workshops convened by the Green Commodities Community about existing land use change monitoring tools in support of deforestation-free commodities. A workshop held in Tarapoto, Peru, in May 2019 at the **Good Growth Conference** also served to discuss and compare the features of the services presented in the paper. This review was validated by interviewing experts.

What Can Effective LUCM Solutions Achieve?

The LUCM solutions offer different features that are useful depending on the objective of monitoring. There are five possible objectives that may be pursued using the reviewed LUCM solutions to determine if a production unit is free from tree forest cover loss due to agricultural activity on a given year:

The objective of monitoring may be to:

- a. **Identify the extent (hectares) of loss and gain of forest or tree land cover at a global or national level.** This can be done using the information generated by the University of Maryland data layer on loss or gain of tree land cover. These layers may be viewed and downloaded for free from the GFW and MapX platforms. This information allows users to know the change data with medium resolution (900 m² per pixel) annually. The technical requirements necessary to process this information are access to a computer with enough Ram and storage to process imagery quickly and a high-speed internet connection.
- b. **Identify the extent (hectares) of loss and gain of forest land cover at a global or national level,** but require a tailored approach. For example in terms of the display of final information, need for wider dissemination of the results in social media, or to improve periodicity and resolution from Global Land Analysis and Discovery (GLAD) data sets. In this case, it is advisable to generate additional features through contracting commercial platforms, such as Planet or MapHubs.



- c. **Generate early warnings for risk of deforestation at a global or national level, without identifying the area or shape of the polygon of the land cover being lost.** Users may consult the GFW platform and the alerts this system offers for free. The GFW solution uses algorithms to identify changes in forest land cover through the identification of the exact places where the change occurs, at different scales and temporality, as detailed in the GFW analysis chart. Similarly, this may also be achieved by hiring commercial companies such as Planet and MapHubs.
- d. **Determine tree forest cover loss within specific production units and the land cover that replaced tree cover in those units.** This may be done once the vector format of a production unit to be studied is known. Users may compare the University of Maryland GLAD annual data layers for “forest cover gain”, and of “forest cover loss” (with a resolution of 30m x 30m) to identify tree cover that was eliminated within that specific production unit. These data layers are found in GFW, MapX, MapHubs, Planet. In order to identify what class of land cover replaced tree cover due to agricultural expansion within a specific production unit, it is better to create locally new data sets of specific commodity land cover, than to rely on wider classifications. For example, the GFW layer related to dominant drivers generates classification pixels of 100km² (10km x 10 km) an area much larger than any production unit for palm oil, soy, pasture or pineapple. As such, it is not possible to determine if the tree forest cover loss identified within the studied production unit, took place specifically due to a change of an agricultural land use. In this case it will be necessary to develop data layers for the commodity land cover that is potentially replacing tree cover within a production landscape (see the example from Costa Rica).
- e. **Determine tree forest cover loss within specific production units identifying the agricultural land cover that replaced trees on an annual basis, without having the production unit as point of departure.** This implies the ability to determine the presence of changes in tree land cover and agricultural commodity land cover in any property in a given production landscape per year. From the reviewed LUCM solutions only the Brazilian and Costa Rican examples allow users to monitor on a property per property basis. The main difference being that in the Brazilian CAR systems, land tenants are required to enter only the baseline tree forest cover of the rural property when registered. There is no data layer identifying annual change of loss or gain of tree forest cover for any user to access. Only the Costa Rican MOCUPP system provides features allowing users to identify on an annual basis where tree forest cover loss or gain is taking place in general within a landscape and with relation to the ownership of the property.





I: Global Land Use Change Monitoring Services

GLOBAL FOREST WATCH

Global Forest Watch (GFW) is an online platform providing data and tools for monitoring forests at a global scale. It gives commodity supply chain and government stakeholders an option to monitor the dynamics of tree forest cover change within production landscapes worldwide. The data layers provided are annualized tree cover change at a global scale at 30-meter resolution, with some country specific features included in more detail. The solution offers different periodicities of available data layers, allowing for monitoring loss and gain of tree forest land cover globally. The platform includes applications to generate alerts of potential deforestation. It offers an online viewer and includes tutorials to help users navigate the website and access related sites. The data sets are compatible with many platforms and programs, facilitating efficient information management and map generation online. This solution has been developed for over 22 years by the Global Land Analysis and Discovery (GLAD) laboratory from the Department of Geographical Sciences at the University of Maryland and the World Resources Institute, with collaboration from other partners, generating a large stock of accurate and reliable information. GFW uses low-cost inputs including free satellite images from Landsat and Sentinel, allowing for long-term cost management.

Classification	Definition
Name	Global Forest Watch (GFW).
Hyperlink	GFW main page https://www.globalforestwatch.org/ GFW mapping platform https://www.globalforestwatch.org/map
Lead Agency	World Resources Institute.
Governance*	World Resources Institute coordinates GFW, but the main partners are: GLAD Maryland University, NASA, Center for Tropical Agriculture and other collaborators provide technical information through inter-institutional agreements.
Funding	World Resources Institute, Bobolink Foundation, Blue Raster, Carto Company, Center for Global Development, Ministry of Foreign Affairs of Denmark, Esri, GEF, Global Forest Watch Canada, Google, Amazon, Ministry of Foreign Affairs of the Netherlands, Norwegian Ministry of Climate and Environment, OSFAC, ScanEx, Swedish International Development Cooperation Agency, the Jane Goodall Institute, The Tilia Fund, United Nations Environment Programme (UNEP), University of Maryland, UKaid, USAID, Visuality, Inter-American Development Bank (IDB), Cargill, Generation Foundation, MacArthur Foundation, and others.
Study area	Global.
Objective	<ol style="list-style-type: none"> 1. Monitor tree forest cover loss at a global scale 2. Determine areas with risk of tree forest cover loss 3. Generate warnings of tree forest cover loss to interested parties
Data processing characteristics	A specific algorithm is created for the object of study.
Remote Sensors Used	<ul style="list-style-type: none"> • Landsat 7 y 8 • Sentinel • MODIS
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	Display of relevant features <ul style="list-style-type: none"> • Alerts for deforestation • Forest cover gain • Forest cover loss • Forest cover • Intact forest landscapes • Palm oil factories
Resolution of imagery	<p>Resolution varies from one layer to another. Layers are elaborated from different sources. The most important layers to help verify commodities disassociated from tree forest cover loss:</p> <ul style="list-style-type: none"> • Forest cover loss: It was created by University of Maryland, Google, USGS, and NASA, using Landsat images scale 30x30 meters. • Forest cover gain: It was created by the University of Maryland, Google, USGS, and NASA, uses Landsat images scale 30x30 meters.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Classification	Definition
Resolution of imagery	<p>Forest cover loss alert:</p> <ul style="list-style-type: none"> • Global Land Analysis & Discovery (GLAD) Alert: Prepared by University of Maryland, using Landsat images 7 and 8 at 30x30 meters. It identifies areas of probable loss of tree cover in near real time. The information is collected from regressions of red, infrared and shortwave bands, and ranks of NDVI, NBR, and NDW. • Tropical Forest Alert (Terra-i Alerts) Prepared by International Center for Tropical Agriculture and other collaboration (CIAT). Scale 250 x 250 meters. It uses satellite data from MODIS vegetation indices and products related to presence of water bodies, as well as Tropical Rainfall Measuring Mission, precipitation data to detect anthropogenic changes in vegetation cover. • Fire Alerts (VIIRS): Source is NASA, with scale 375 x 375 meters: Displays fire alert data for the past 24 hours, 48 hours, 72 hours, or 7 days. Information is collected from the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor, and processed with a fire detection algorithm to flag active fires • Tree Cover Loss by Dominant Driver (Global): It has several data sources, with scale 10 km x 10 km: Shows the dominant driver of tree cover loss within each 10 km grid cell and the intensity of that loss for the time period 2001-2015. Land Covers (Global Land Uses) use MERIS images 300x300 meters.
Area calculations	The application allows for area calculations for most layers of information.
Periodicity	<ul style="list-style-type: none"> • Forest cover loss layer: Annual • Loss / gain forest cover: Every 3 years (last 5: 2019, 2022) • GLAD alerts (30 degrees north to 30 degrees south, plus the far east of Russia): Weekly • WAY alerts (tropical forests): No data • A Terra-i Alerts (Latin America): Monthly • VIIR Alerts: twice a day • Terrestrial Covers (Global land uses) uses MERIS images: Annual
Online viewer	Global Forest Watch has one only viewer: GFW mapping platform https://www.globalforestwatch.org/map
Vector format geospatial data may be downloaded	Geospatial data can be downloaded using KML and WMS formats.
Compatibility with other software	Compatible with: Arc Gis Online, Arc Map, Google Earth, Google Earth Engine , Qgis , and others
Specialized equipment required	Basic computer equipment with internet access is the only requirement. To download layers, it is necessary that you use Geographic System Information (GIS) software.
Approximate costs to use the tool	No cost associated with the use of the tool.

Can GFW be used to monitor if a selected production area gains or loses tree forest cover from year-to-year as a result of a specific agricultural activity?

Yes. GFW may be used provided the vector format of the production unit to be analyzed is available beforehand. Once the vector format of a production unit (farm, plantation, concession, etc) to be studied is determined, users may compare GFW annual data layers for "forest cover gain", and of "forest cover loss"(with a resolution of 30m x 30m) to identify tree cover that was eliminated within that specific production unit.

However, in order to identify what type of land cover replaced any tree cover that was lost, the existing layers available in GFW are less useful. GFW does provide a data layer on "Tree Cover loss by dominant driver" which enables users to determine if tree forest cover loss changed due to different drivers, such as "commodity production". However, the precision of such a layer is not comparable with the precision of the "Tree Forest Cover Loss" layers. The layer related to dominant drivers generates classification pixels of 100km² (10km x 10 km) an area much larger than any production unit for palm oil, soy, pasture or pineapple. As such, it is not possible to determine if the tree forest cover loss identified within the studied production unit, took place specifically due to a change to agricultural land use.

- In order to determine what land cover replaced the tree forest that was lost in a production unit, the authors recommend the use of GFW for tree forest cover loss monitoring, but combined with a tailored monitoring of the commodity surface that may be causing the identified tree forest cover loss.
- The information on tree forest cover gain or loss is available from 2001 to 2019. However, each data layer is developed through different methodologies. It is therefore to be used as non-comparable query data.
- According to Hansen, et al, (2015), the loss of forest tree cover reported by the GFW platform includes vegetation greater than 5 meters in height. So, if the purpose of study is to monitor vegetation of less than this height a new methodology must be employed.
- The loss of tree forest cover that is recorded includes all possible causes of loss such as forest fires, diseases, floods, land use changes. It is therefore essential to corroborate that the loss data is linked to agricultural productive units and not to another causes.

**GLOBAL
FOREST
WATCH**

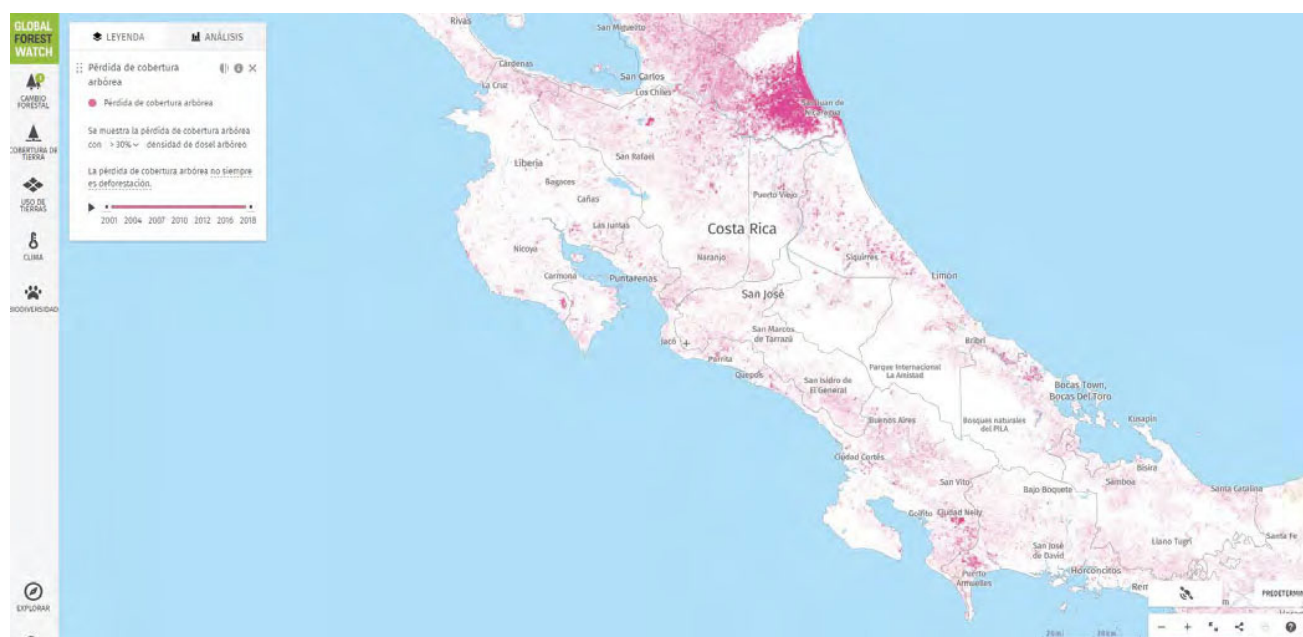
How practitioner-friendly is the GFW?

3

VERY USER FRIENDLY

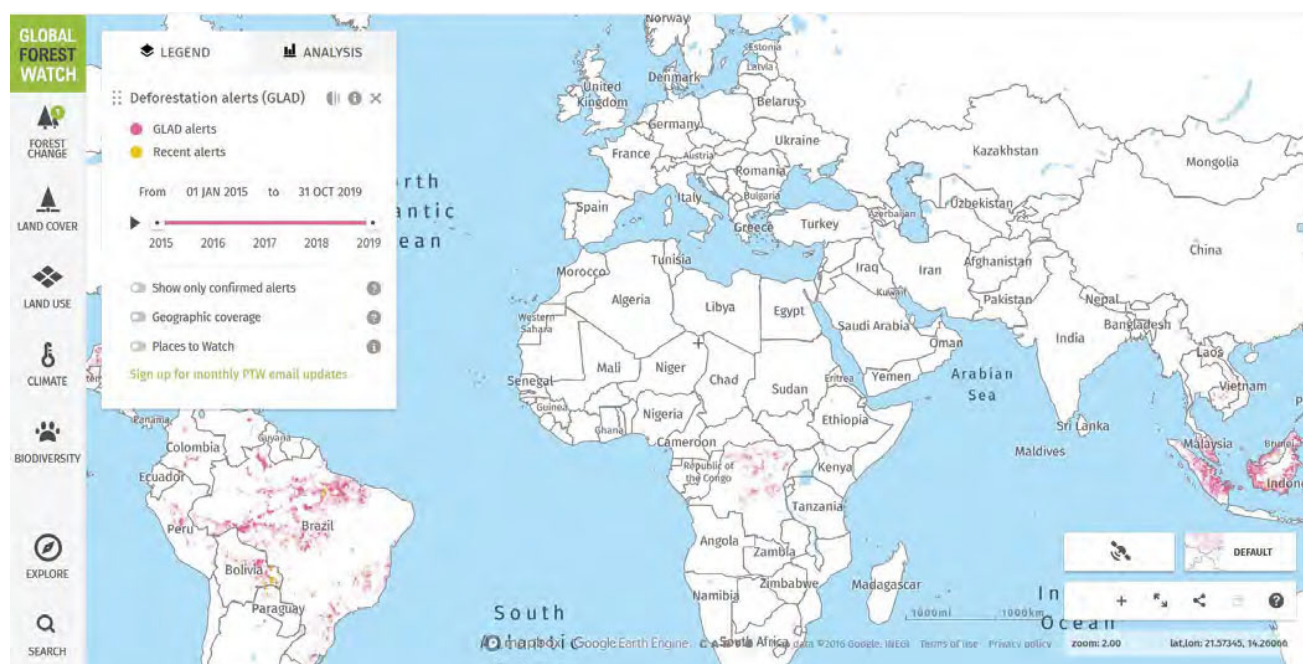
The screenshot shows the Global Forest Watch web application. The left sidebar contains navigation icons for Forest Change, Land Cover, Land Use, Climate, and Biodiversity. The main map area displays a world map with a color-coded overlay representing tree cover loss between 2001 and 2019. A legend on the left explains the color scale, ranging from green (low loss) to red (high loss). The map shows significant loss in tropical regions like the Amazon and Central Africa. The bottom of the screen features a search bar, a map scale bar, and a footer with copyright information and a privacy policy link.

FIG. 2. GLOBAL FOREST WATCH: TREE COVER LOSS IN COSTA RICA.



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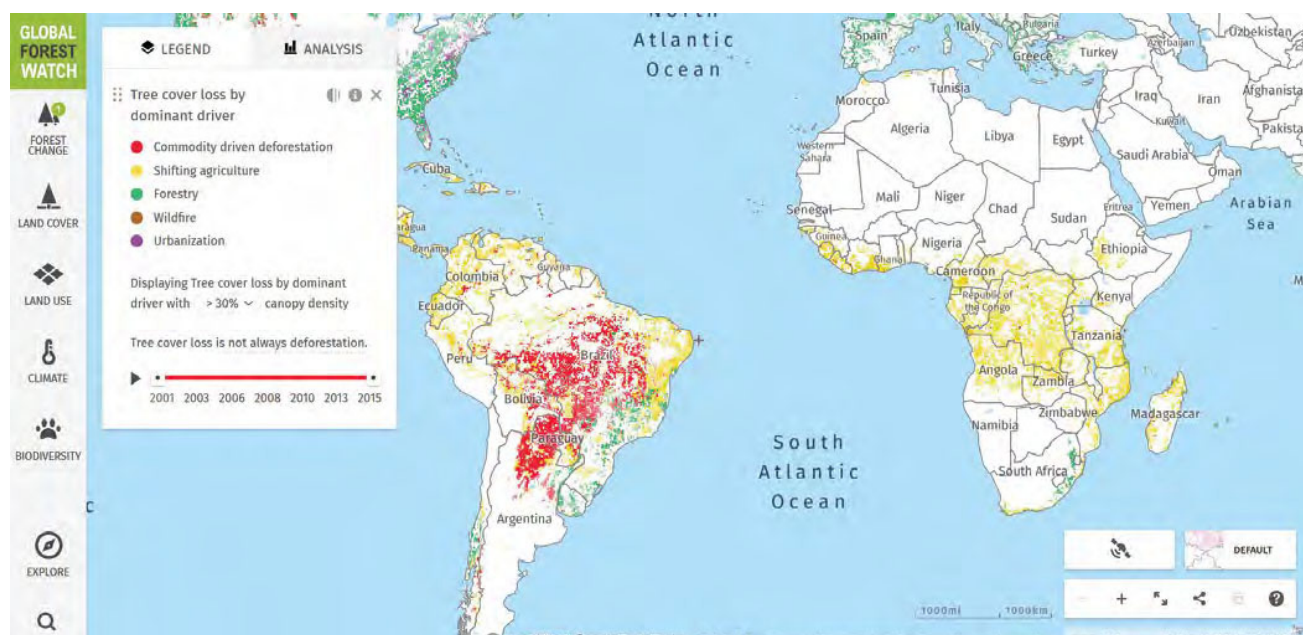
FIG. 3 GLOBAL FOREST WATCH: AREAS OF PROBABLE LOSS OF TREE COVER IN ALMOST REAL TIME.



Legend: Pink color depicts deforestation risk yellow color depicts most recent alert. Information only available for tropical countries.

Reference here: <https://www.globalforestwatch.org>

FIG 4. GLOBAL FOREST WATCH: DOMINANT DRIVER OF FOREST COVER LOSS.



Legend: Each pixel is 10 x 10 km y and the monitoring period is between 2001 and 2015.

Reference here: <https://www.globalforestwatch.org/>



MapX is an online platform for managing geospatial data on natural resources, providing the backend of the UN Biodiversity Lab web portal. MapX was developed by UN Environment, the World Bank and the Global Resources Information Database (GRID-Geneva) in 2014. Its aim is to provide countries with basic **GIS** functionalities and globally available spatial data to help make informed environmental decisions. The platform is designed to allow users to access global data layers, upload and manipulate their own datasets (stored within a secure private project space), and query multiple datasets to provide key information on nature-based goals and targets. The UN Biodiversity Lab expects the tool to grow to make available geospatial data layers for natural resources that can be mapped and to serve as an extensive information database. It also aims to be a platform for building partnerships among data providers and data users ensuring that governments have access and capacity to use cutting-edge spatial data to make key conservation and development decisions.

The platform runs as open access technology. Data layers included are generated by different institutions and organizations and is constantly updated. Existing data layers provide information on a global scale, but the platform may be viewed and disaggregated at a country level. MapX contains a broad database on different themes and users may access information for free. Forestry related datasets have been created using freely accessible satellite imagery, such as Landsat and applying **remote sensing** techniques and **algorithms** developed with global parameters. Data layers can be visualized and mapped through an online viewer, a map making interface, and section including short descriptions of the uses of data layers in "stories" formats. Most data layers can be downloaded for use with common GIS software.

Classification	Definition
Name	MapX.
Hyperlink	MapX main page https://www.mapx.org/ MapX mapping platform https://app.mapx.org/?project=MX-3ZK-82N-DY8-WU2-IGF&language=es
Lead Agency	UN Environment, World Bank and Global Resource Information Database (GRID-Geneva).
Governance*	UN Environment, World Bank and Global Resource Information Data base (GRID-Geneva) and other collaborators with Maryland University, United States Geological Survey and others.
Funding	United Nations Biodiversity Lab, United Nations Environment, World Bank and Global Resource Information Data base (GRID-Geneva), GEF, United Nations Development Programme, Convention on Biological Diversity, NASA, Maryland University, and others.
Study area	Global.
Objective	<ul style="list-style-type: none"> • Visualizing data on natural resources and the environment • Alerts and dashboards for monitoring impacts • Provide basic GIS analytics
Data processing characteristics	A specific algorithm is created for the object of study.
Remote Sensors Used	Landsat 7/8.
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	<ul style="list-style-type: none"> • Forest loss (2000-2018)-Generated by Maryland University. • Forest gain (2000-2012)-Generated by Maryland University • Both loss and gain Generated by Maryland University • Forest extend Generated by Maryland University • Global Land Cover (Creation date 2018/ Modification date 2019) • Forest Structural Integrity Index (NASA/ Univ. of Montana/UNDP) • Forest Structural Condition Index (NASA/ Univ. of Montana/UNDP)
Resolution of imagery	<ul style="list-style-type: none"> • Forest loss (2000-2018)-Generated by Maryland University: 30m x 30m (900 m2pixel) • Forest gain (2000-2012)-Generated by Maryland University: 30m x 30m (900 m2pixel) • Both loss and gain Generated by Maryland University: 30m x 30m (900 m2pixel) • Forest extend Generated by Maryland University: 30m x 30m (900 m2pixel)
Area calculations	It allows area calculation for polygon type vector layers .
Periodicity	No periodicity.
Online viewer	MapX has one only viewer: Online viewer: https://app.mapx.org/?project=MX-3ZK-82N-DY8-WU2-IGF&language=es
Vector format geospatial data may be downloaded	Geospatial data may be downloaded using shapefile , GeoJSON, Geopackage , DXF and SQLite formats.
Compatibility with other software	Compatible with: Arc Gis Online, Arc Map, Google Earth, Google Earth Engine, Qgis, and others
Specialized equipment required	Basic computer equipment with internet access is the only requirement. Anyone can download the layers. However, to make use of other data layers, it requires a GIS software or other non-GIS computer languages that enable working with geospatial data (in, Python , OGR/GDAL, R, etc.)
Approximate costs to use the tool	No cost associated with the use of the tool use.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can MapX be used to monitor if a selected production area gains or loses tree forest cover from year-to-year as a result of a specific agricultural activity?

Yes. This system may be used to monitor tree forest cover, since the platform includes the data layers for tree forest cover loss and gain generated by the University of Maryland. One aim of MapX is to become a global repository of geopositioned data layers about natural resources. When this happens and data layers for commodity surface areas are included for the production unit being analyzed, then it will be possible to use this platform as main instrument to verify if production units are free of tree forest cover loss.

The platform may also be used to monitor if specific production units gain or lose tree forest cover from year-to-year as a result of agricultural production activity, provided the vector format of the production unit to be analyzed is available beforehand, or can be drawn in the platform using tools to create polygons. Once the vector format of a production unit (farm, plantation, concession, etc) to be studied is determined, users may compare annual data layers for "forest cover loss" to identify tree cover that was eliminated within that specific production unit. Nevertheless, MapX does not provide information or data layers that enable users to study the interaction of tree cover loss with other land covers. By 2020 this platform had not included data layers related to commodity land cover.

- As a tool created by UN Agencies, MapX provides countries with an invaluable service or; an independent repository of geospatial information. As it grows in storage capacity, it may host data layers that may not be published through national geospatial viewers because they may be too controversial, or have not finalized going official sanctioning processes, and as such support the periodicity of monitoring systems. MapX should therefore be promoted as an impartial repository of information which can be accessed by everyone.
- MapX includes the same data layer of tree forest cover gain and loss being used in Global Forest Watch, as such the same recommendations apply.

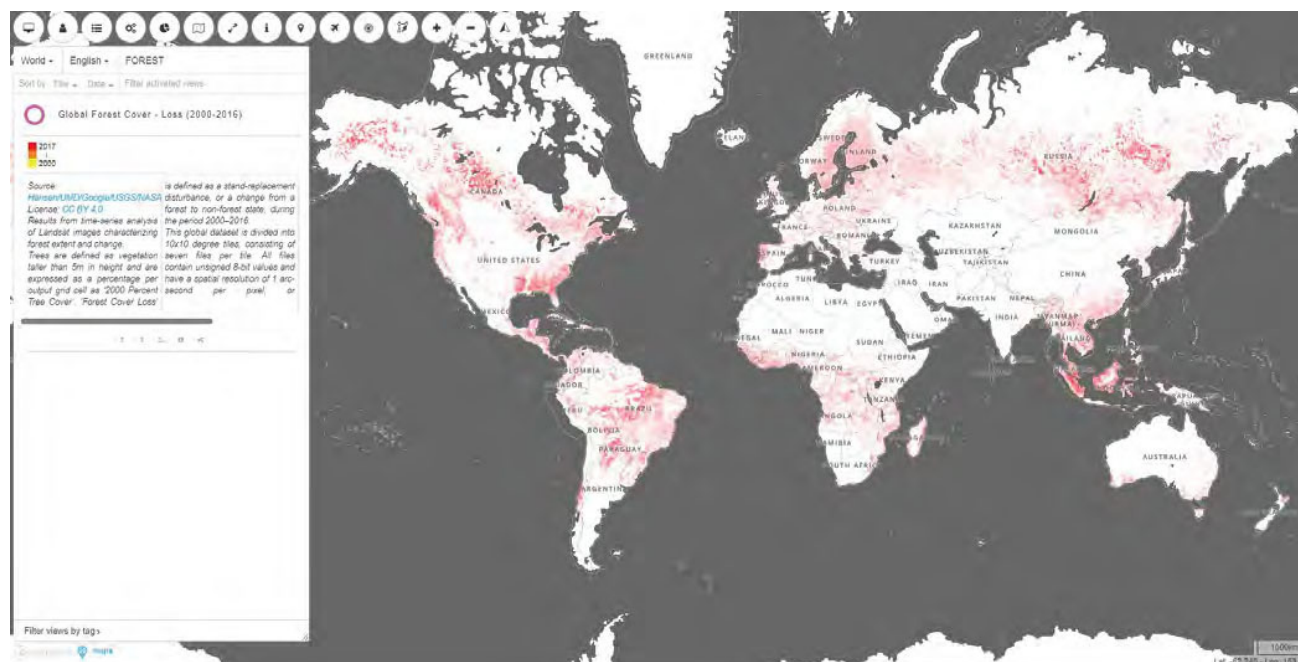


How practitioner-friendly is the MapX?

3

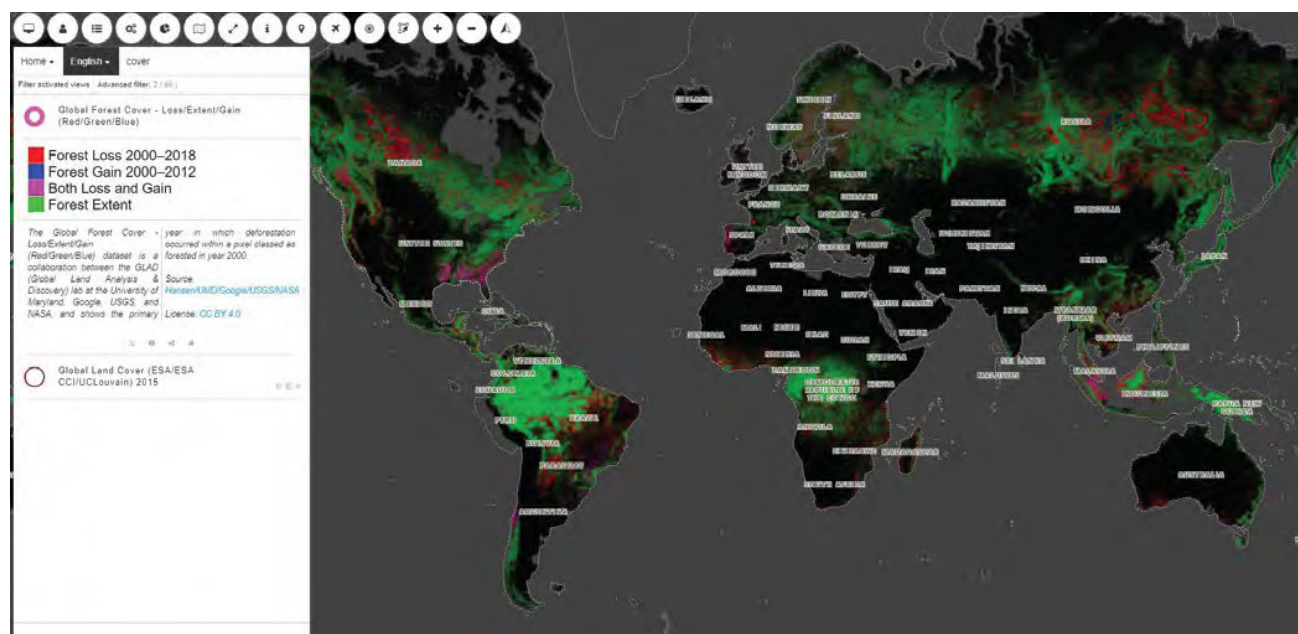
VERY USER FRIENDLY

FIG 5. MAPX: LAYER OF TREE FOREST COVER LOSS AND GAIN FROM THE UNIVERSITY OF MARYLAND.



Reference here: <https://app.mapx.org/?project=MX-YBJ-YYF-08R-UUR-QW6&language=en>

FIG 6. MAPX: GLOBAL FOREST COVER LOSS AND GAIN.



Reference here: <https://app.mapx.org/?project=MX-YBJ-YYF-08R-UUR-QW6&language=en>



Planet, a private sector provider incorporated in 2010, holds one of the world's largest constellations of earth-imaging satellites. It offers customers a diverse selection of 3-meter, 5-meter, and 80-centimeter data layers. Planet designs, builds, and launches satellites using lean, low-cost electronics and design iteration. The company's ownership of nanosatellites allows for a "line scan" of the planet to image the entire Earth daily. Currently, the Planet company generates inputs of satellite images from different satellites Planet Scope, RapidEye and Skydat. Planet Scope has about 150 satellites in orbit sending daily information.

These satellite images included in planet can be used for an immense array of studies, as their high level of resolution allows them to register land cover changes in much more detail than Landsat or Sentinel remote sensors, and with much more frequency. Planet allows for more frequent land use monitoring and tree forest cover loss and gain monitoring. It can also provide data layers for daily monitoring.

Classification	Definition
Name	Planet.
Hyperlink	Planet main page https://www.planet.com/ Planet mapping platform https://www.planet.com/login/
Lead Agency	Planet Labs Company.
Governance*	Planet is a private entity owned by Planet Company in association with Black Bridge Company (Rapideye) and Sky Sat Satellite.
Funding	Planet Labs Company.
Study area	Global.
Objective	Monitor the earth through satellite images.
Data processing characteristics	<ul style="list-style-type: none"> • A specific algorithm is created for the object of study. • Spectral classification (uses algorithms contained in common GIS software)
Remote Sensors Used	<ul style="list-style-type: none"> • Planet Scope: Daily • Sky Sat: 4 - 5 days • Rapid Eye: 5.5 Days
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	Planet is a service provider for tailored data layers, as such it does not publish information regularly.
Resolution of imagery	<ul style="list-style-type: none"> • Planet Scope 3 m • RapidEye 5 m • Sky Sat 0.8 m (multispectral and 1 m (analytic) Uses) use MERIS images 300x300 meters. • Sentinel: 30x30 m (900 m2) • Landsat: 10x10 m (100 m2) <p>Planet stores the imagery catalogue of both Sentinel and Landsat remote sensors. Planet main page https://www.planet.com/</p>
Area calculations	Area calculations are possible, once the service is hired for image processing.
Periodicity	<ul style="list-style-type: none"> • Planet Scope 3 m • RapidEye 5 m • Sky Sat 0.8 m
Online viewer	https://www.planet.com/login/
Compatibility with other software	Compatible with: Esri, Google Earth, Google Earth Engine, Qgis, and others.
Specialized equipment required	Basic computer equipment with internet access is the only requirement.
Approximate costs to use the tool	Not free.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can Planet be used to monitor if a selected production area gains or loses tree forest cover from year-to-year as a result of a specific agricultural activity?

Yes. Planet is a commercial company providing data layers, imagery and services at a cost. The platform offers a 14-day free trial that enables users to download data and interact with data layers, allowing the user to get familiarized with the products to determine if they are functional for the desired monitoring purpose. The satellite images contained by Planet may be used for any monitoring objective. From the national tree forest cover analysis, to monitoring tree forest cover loss or gain; to mapping commodity land cover. Prices vary depending on the satellites and extension of the study required. Each available satellite provides images of the same place at different times during the day.

This platform provides very high-resolution inputs required for monitoring, at a cost. It does not provide readily available data layers, such as GFW or some of the national systems reviewed in this paper. As such, the company may be contracted to develop specific monitoring services. The possibility of monitoring specific production units from one year to the next and to determine if tree cover is replaced by commodity surface area will depend on funding available and on the existence of the vector format of the production unit to be studied.

- This service is recommended for high resolution and high frequency monitoring programmes. As with any engagement with a private service provider, practitioners must ensure enough funding in order to establish long term periodicity and sustainability of the purchase of satellite images.
- Planet can be used to complement monitoring systems that rely on middle-resolution imagery. When practitioners identify a land cover change area that requires additional corroboration because the imagery is inconclusive, or when field verification is needed in an area of difficult access, Planet's higher resolution imagery can be used. In this way, land use change monitoring systems may use middle-resolution remote sensors for the majority of the land reviewed and high resolution for areas that need additional corroboration, reducing the costs of overall monitoring.



How practitioner-friendly is Planet?

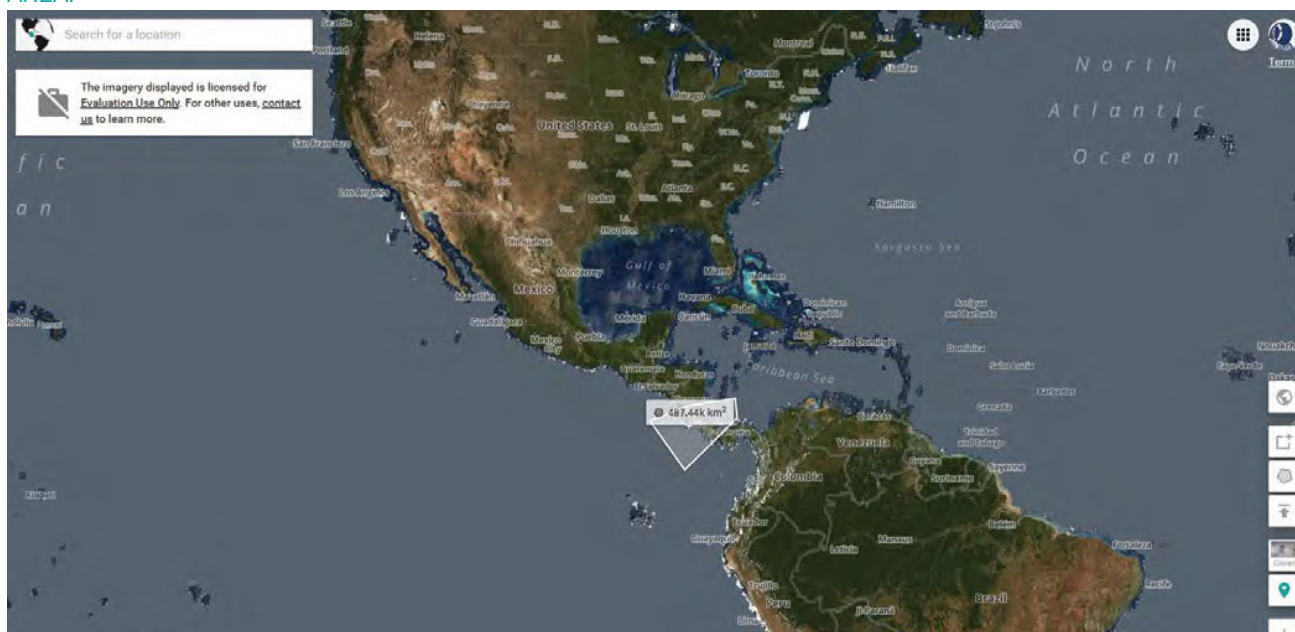


FIG 7. PLANET: IMAGE FROM THE FREE TRIAL VISOR.



Reference here: <https://www.planet.com/products/planet-imagery/>

FIG 8. PLANET: EXAMPLE OF HOW TO DOWNLOAD PLANET SATELLITE IMAGERY IMAGES BY DELIMITING THE WORK AREA.



Reference here: <https://www.planet.com/products/planet-imagery/>

FIG 9. PLANET: EXAMPLES OF IMAGERY FROM PLANET SCOPE, RAPIDEYE AND SKYSAT.



Reference here: <https://www.planet.com/products/planet-imagery/>



MapHubs is a commercial online platform and service that features data management, interactive map publishing, map stories, and microsites called "hubs". It can be deployed as a website or as a private repository and published maps can be embedded into websites and social media accounts. The platform is developed using open source technology.

MapHubs provides services for forest tree cover loss and gain monitoring. It generates automatized reports and statistics of areas with identified tree cover changes. Depending on the contract of each service, the MapHubs platform may identify specific drivers of deforestation, including agricultural commodity land cover expansion as well as due to forest fires or urbanization. The platform also offers the possibility of using their own geospatial web viewers for third-party consultation of the data layers produced, or for third-party download and monitoring purposes and the creation of interactive maps.

Classification	Definition
Name	MapHubs.
Hyperlink	MapHubs main page: https://www.maphubs.com/ MapHubs mapping platform: https://maphub.net/map
Lead Agency	MapHub Company.
Governance*	Commercial Company.
Funding	Commercial Company. Funding through service provision.
Study area	Global
Objective	Provide clients with geospatial monitoring services and online repository of microsites.
Data processing characteristics	<ul style="list-style-type: none"> • A specific algorithm is created for the object of study. • Spectral classification (uses algorithms contained in common GIS software). • Photointerpretation (manual digitization).
Remote Sensors Used	Landsat, ESRI.
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	Does not publish free access data layers. Company can tailor monitoring and repository for specific needs of clients.
Resolution of imagery	Users may access various remote sensors with varying resolutions.
Area calculations	It allows users for area calculation.
Periodicity	MapHubs viewer may be tested online for free Online viewer: https://maphub.net/map
Online viewer	https://www.planet.com/login/
Vector format geospatial data may be downloaded	Import or export (download) data in KML, GPX or GeoJSON formats.
Compatibility with other software	Compatible with: ESRI, Google Earth, Google Earth Engine, Qgis, and others
Specialized equipment required	Basic computer equipment with internet access is the only requirement.
Approximate costs to use the tool	Not free.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can MapHubs be used to monitor if a selected production area gains or loses tree forest cover from year-to-year as a result of a specific agricultural activity?

Yes. MapHubs platform provides a commercial service to create maps interactively. The platform offers free trials for users to interact with the tool. The data generated may be socialized using one shared link and enables users to download files in different formats compatible with common GIS software. The tool has a high applicability to monitor land use change within production units. Currently users are mapping and monitoring surface areas of palm oil, cocoa crops, other land uses, and are generating interactive maps of loss and gain of forest cover in several parts of the world.

When selecting this tool for long-term monitoring, practitioners are advised to secure enough funding for several annual iterations of monitoring events. Land use change monitoring for deforestation-free commodities should maintain the same methods, use the same remote sensors and employ the same strategy year after year so that data layers are comparable over time for effective monitoring.

MapHubs

How practitioner-friendly is MapHubs?

2

FRIENDLY BUT CAN IMPROVE

FIG 10. MAP HUBS: MAIN VISOR, INCLUDED IN THE FREE TRIAL.

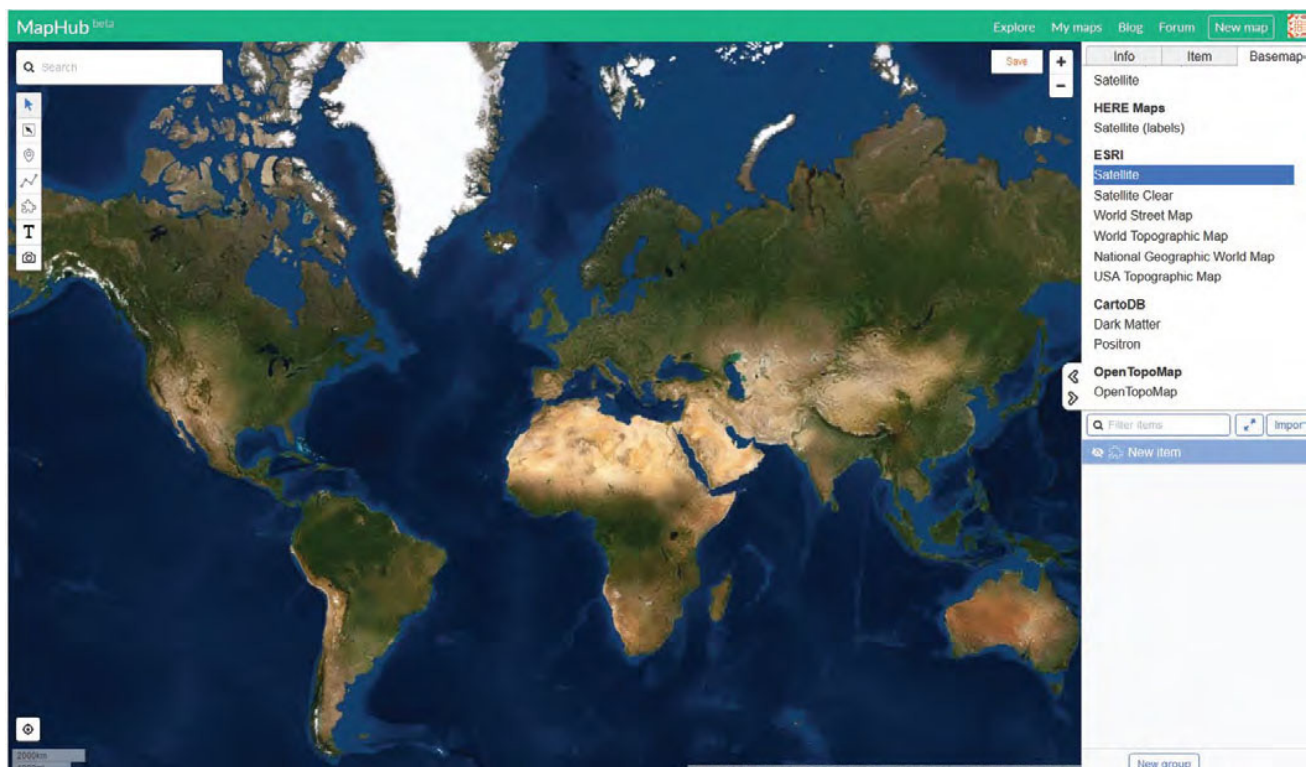
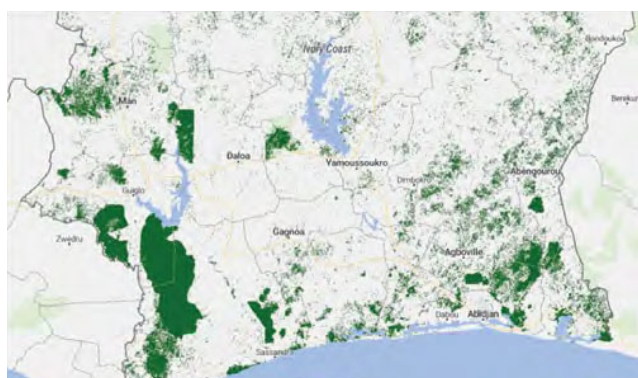
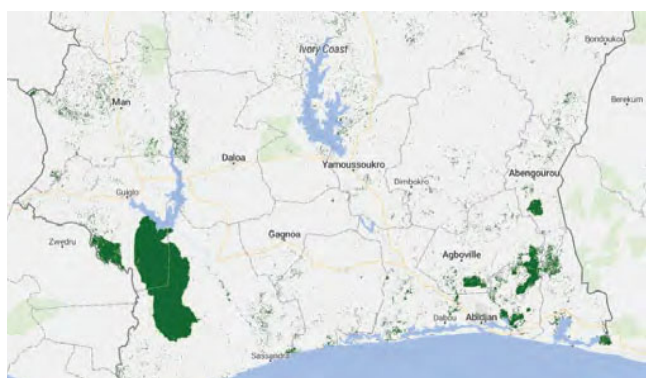


FIG 11. MAP HUBS: EXAMPLE OF LAND COVER CHANGE MONITORING.





Open Foris is a platform that provides users a set of free and open source software tools that facilitate data collection, analysis and reporting about forests and forest cover globally and nationally. The system was developed by the Food and Agriculture Organization of the United Nations (FAO).

Six tools are currently available in the platform:

- 1) **Collect:** A tool to support data collection of field-based forest inventories. It helps users handle multiple data types and complex validation rules. All in a multilanguage environment.
- 2) **Collect Mobile:** an Android app that allows the completion of surveys on biophysical, socio-economic or biodiversity data. It helps users with data quality validation, handling of large lists of species and other attributes, Geo-location through embedded GPS, integration with Collect for data management, analysis and export to commonly used formats and processes inputs and calculates attributes for quality control in the field.
- 3) **Open Foris Calcis:** a tool that allows expert users to perform calculations working with a variety of sampling designs. It offers a flexible way to produce aggregated results which may be analyzed and visualized through the open source software Saiku.
- 4) **Collect Earth:** Is a Java-based tool that draws upon a selection of other software to facilitate data collection through Google Earth. Users can analyze high-resolution satellite imagery, or many uses. Forms can be customized to suit country-specific classification schemes in a manner consistent with guidelines of the Intergovernmental Panel on Climate Change (IPCC), the European Commission (EC), the Food and Agriculture Organization of the UN and other international entities.

The default Collect Earth form contains IPCC consistent land use categories and sub-categories with land use sub-divisions from the European Commission's Land Use/Cover Area frame Survey (LUCAS).

- 5) **SEPAL:** a system for earth observation, data access, processing and analysis for land. It allows users to query and process satellite data, tailor their products, and produce geospatial analyses. It also enables users to access and process historical satellite data as well as newer data from Landsat and the Copernicus programme.
- 6) **Collect Earth Online (CEO):** a web-based, crowd-sourcing technology for land cover analyses. It allows users to collect reference data using high-resolution satellite images and big-data analysis through Google Earth Engine. It runs online and users can tailor applications, add a variety of imagery resources and process data layers allowing for landscape change, land cover monitoring, and deforestation studies.

One outstanding feature of the Open Foris platform is Collect Earth Online, a tool that allows users to study the change in land cover and land use with specific detail. It works by establishing a series of points within an area of study, that make it possible to monitor point-to-point changes that occur in temporal intervals. This methodology is designed to be used only with high-resolution imagery otherwise it would not show enough detail of the studied land changes. The point-to-point method is a novel and highly replicable way of monitoring land cover change in production landscapes and it is likely to be adopted in many countries for this purpose.

The table below describes Collect Earth Online

Classification	Definition
Name	Open Foris: Collect Earth Online
Hyperlink	Open Foris main page: http://www.openforis.org/ Online Collect Earth Online https://collect.earth/
Lead Agency	Food and Agriculture Organization of the United Nations (FAO) and SEPAL
Governance*	Food and Agriculture Organization of the United Nations (FAO), SEPAL, Ministry for Foreign Affairs of Finland, German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Norwegian Space Centre, Norway's International Climate, Forest Initiative, NASA and others.
Funding	Developed by SERVIR, a programme set by NASA and USAID in association of organizations as FAO and SEPAL.
Study area	Global.
Objective	Forest study and monitoring.
Data processing characteristics	Technical applications for grid monitoring, followed by statistical analysis of changes.
Remote Sensors Used	<ul style="list-style-type: none"> • LandSat • Sentinel • Digital Globe
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	This system does not publish data layers on a regular basis. It is a tool to help process information.
Resolution of imagery	Openforis uses images from Digital Globe (Maxar). Users may export into the tool any imagery or aerial photographs on any required resolution.
Area calculations	The method is grid monitoring. Postprocessing may include area calculation.
Periodicity	As required.
Online viewer	Online Collect Earth Online https://collect.earth/
Compatibility with other software	Compatible with R software, Google Earth Engine, Qgis, Google Earth, and others.
Specialized equipment required	Basic computer equipment with internet access is the only requirement.
Approximate costs to use the tool	No cost.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can Open Foris be used to monitor if a selected production area gains or loses forest cover from year-to-year as a result of a specific agricultural activity?

Yes, if used as part of field work in predetermined jurisdictions or production units. This platform offers basic data layers from Digital Globe imagery. It also allows users to upload satellite images of their choice. The tools included in the platform are for fixed-point monitoring, this permits systematic statistical data analysis about land cover change by users. This technique can be replicated in other land covers such as crops, urban areas, among others, with high applicability for monitoring land use change within production units.

- This platform uses point-to-point monitoring methodology, which allows detailed temporal analysis of specific areas. For it to be used, users need access to high-resolution imagery, otherwise the study may not yield the positive results of comparison.
- As a novel method of analysis, it is advisable to hire staff trained in point-to-point monitoring and interpretation.

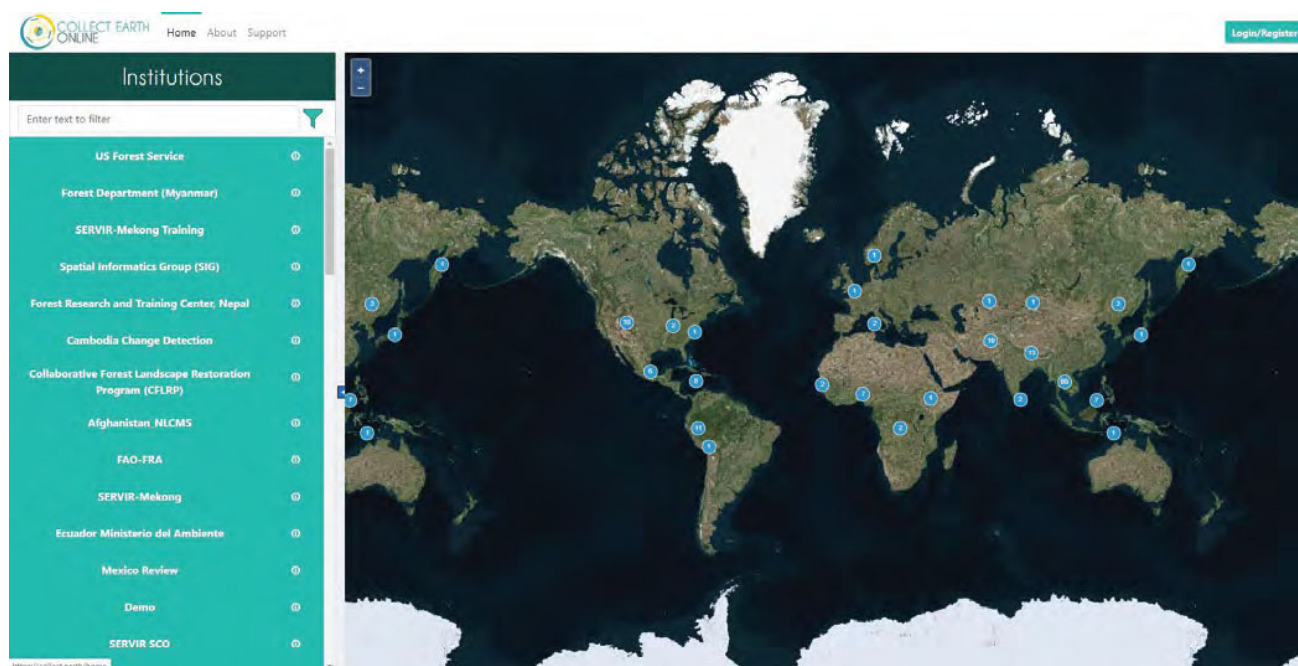


How practitioner-friendly is the Open Foris?

1

NOT SUFFICIENTLY FRIENDLY

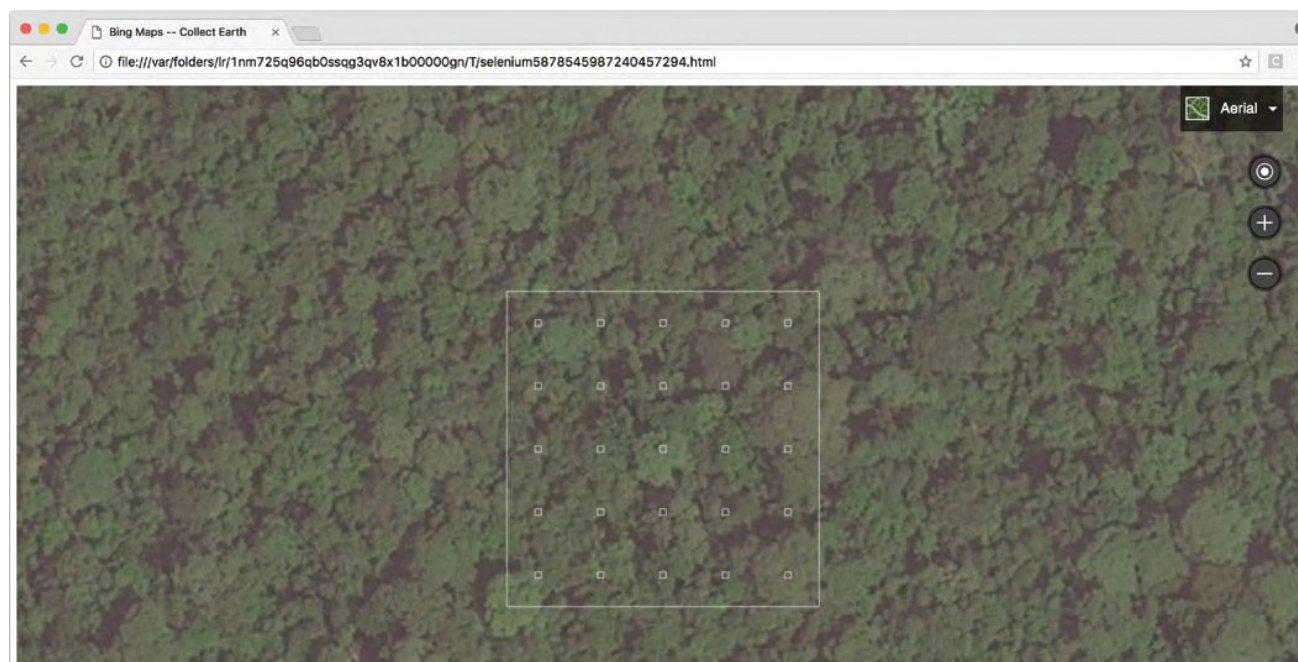
FIG 12. OPEN FORIS: MAIN VISOR OF OPEN FORIS.



Legend: blue dots correspond to project worksites.

Reference here: <https://collect.earth/>

FIG 13. OPEN FORIS: IMAGE SHOWS THE WORK METHODOLOGY BASED ON A GRID OF POINTS THAT IS MONITORED OVER TIME.



Reference here: <https://collect.earth/>





II: National Systems - Country Examples



Brazil

Brazil has a wide array of land use change monitoring services in place. The most comprehensive national system that enables periodic monitoring of forest cover gain and loss associated with specific production units is the Rural Environmental Cadastre (*Cadastro Ambiental Rural*, CAR). The CAR is a public mandatory registry for all rural properties in Brazil. The purpose is to integrate all environmental information of rural properties, in order to generate a data base for monitoring, planning and combating deforestation (Article 29 Federal Law 12.651 / 2012). This register contains georeferenced details of the total area of individual landholdings, the areas earmarked for alternative land use, Areas of Permanent Preservation (*Áreas de Preservação Permanente*, APPs) and Legal Reserves (*Reservas Legais*, RLs). The CAR also specifies APP and RL areas that should be restored. The system will help to distinguish between legal and illegal land clearing and facilitates land-use planning.

Enrollment in the CAR is the first step to obtain the environmental regularity of the property, and includes: data of the owner, rural owner or direct responsible for the rural property; data on documents proving ownership and / or possession; and georeferenced information on the perimeter of the property, areas of social interest and public utility areas, with information on the location of remnants of native vegetation, Permanent Preservation Areas, Restricted Use Areas, consolidated areas and Legal Reserves.

This system can be strengthened through several ways: for example the GEF-funded Good Growth Partnership contributed to consolidating the CAR validation process in Bahia and Tocantins, through support provided by Conservation International Brazil and technical experts supporting the CAR analysis, resulting in the acceleration of environmental regularisation of selected properties.

Classification	Definition
Name	Rural Environmental Cadastre (Cadastro Ambiental Rural, CAR).
Hyperlink	Rural Environmental Cadastre main page: http://www.car.gov.br/#/ Rural Environmental Cadastre mapping platform: http://www.car.gov.br/publico/imoveis/index
Lead Agency	National Environmental Information System.
Governance*	Managed by the Brazilian Forestry Service, Ministry of Agriculture.
Funding	National Environmental Information System.
Study area	Brazil national territory.
Objective	To consolidate a rural private property cadaster.
Data processing characteristics	<ul style="list-style-type: none"> • Spectral classification (uses algorithms contained in common GIS software). • Photointerpretation (manual digitization)
Remote Sensors Used	Different remote sensors of high resolution are used.
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	<ul style="list-style-type: none"> • Rural properties • Forest cover per property
Resolution of imagery	Different resolutions available depending on remote sensors used.
Area calculations	The application allows for area calculations.
Periodicity	No established periodicity of data layers per property.
Online viewer	Rural Environmental Cadastral mapping platform: http://www.car.gov.br/publico/imoveis/index
Vector format geospatial data may be downloaded	Vector format (shapefile) and Excel.
Compatibility with other software	Compatible with: ESRI, Google Earth, Google Earth Engine, Qgis, R, and others.
Specialized equipment required	Basic computer equipment with internet access is the only requirement.
Approximate costs to use the tool	Free.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can the Brazil approach be used to monitor if a selected production area gains or loses forest cover from year-to-year as a result of a specific agricultural activity?

Yes. The CAR system is designed first to register information of private properties in rural areas (cadastral map), and second, as a baseline of the areas with forest cover within each property. The registration of this information is online through a web viewer. The system publishes information by farm and its respective forest cover, which can also be downloaded in vector format to be displayed in GIS or through a calculation matrix (**CSV**).

This system can be used to monitor forest cover change by combining baseline information of forest cover included in the registry of a property into the CAR, with data layers included in other online platforms that provide inputs related to forest cover gain or loss, commodity surface area, total forest cover and deforestation risks. Brazil has over 30 different platforms providing geo-environmental information that may interact with the CAR system.

This is a comprehensive platform to understand forest tree cover changes in Brazilian rural areas. It could be significantly improved if generated data layers of the potential drivers of the tree forest cover loss such as pasture or soy. Brazil has many additional land use change monitoring services that generate regular data layers of these land covers but that may be used to complement this analysis, but these are not all yet included in the CAR system. If they did it would make this the most comprehensive land use change monitoring system in the world.



How practitioner-friendly is the CAR?



FIG 14. COUNTRY CASE STUDIES: BRAZIL; MAIN VISOR OF THE RURAL ENVIRONMENTAL CADASTER.



Legend: in yellow the area currently registered.

Reference here: <http://www.car.gov.br/publico/imoveis/index>

FIG 15. COUNTRY CASE STUDIES: BRAZIL; MAP OF PROPERTIES.



Reference here: <http://www.car.gov.br/publico/imoveis/index>

FIG 16. COUNTRY CASE STUDIES: BRAZIL; MAP OF PROPERTIES AND CORRESPONDING FOREST TREE COVER.

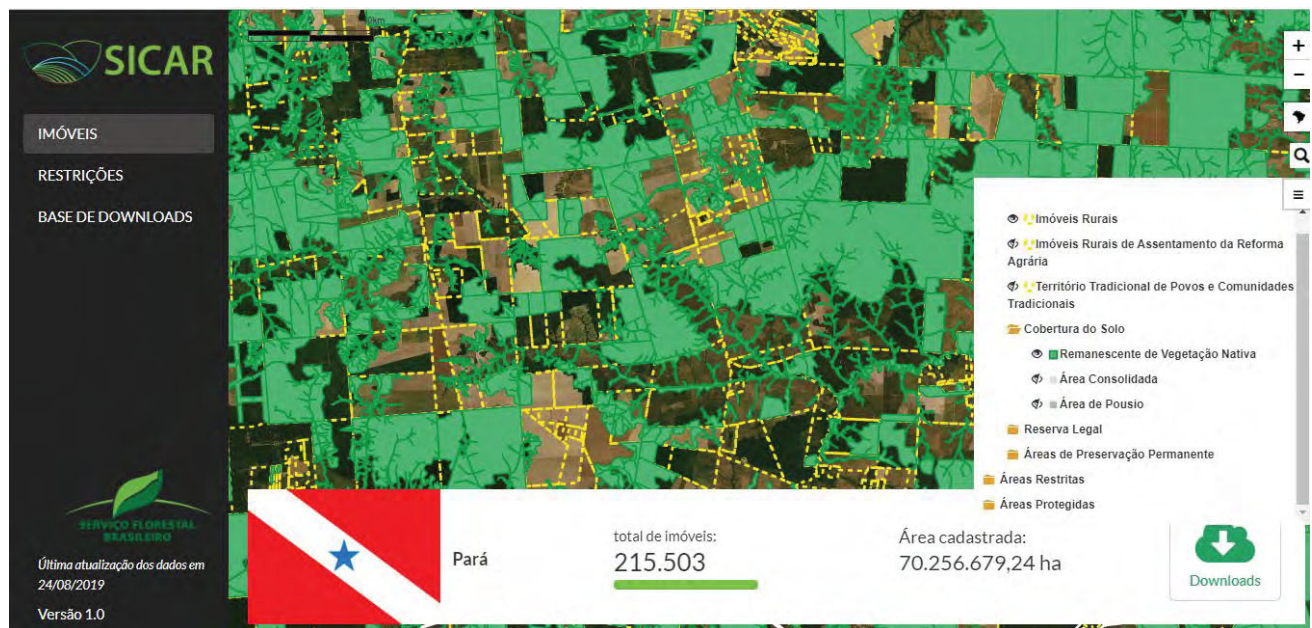


FIG 17. COUNTRY CASE STUDIES: BRAZIL; EXAMPLE OF PROPERTY RECORDS AND CORRESPONDING FOREST TREE COVER.



Reference here: <http://www.car.gov.br/publico/imoveis/index>



Indonesia

The Ministry of Environment and Forestry (MoEF) has the mandate to generate maps of land cover in Indonesia. The National Forest Monitoring System (NFMS) was established in the year 2000, but the ministry had started using and publishing data layers from Landsat 5 (Landsat Thematic Mapper/TM) and Landsat 7 (Landsat Enhanced Thematic Mapper Plus/ETM+) since 1990. The system has been updated to include Landsat 8 (Landsat Data Continuity Mission/LDCM) imagery. The National Aeronautics and Space Agency (LAPAN) in Indonesia is responsible for collecting and pre-processing satellite imageries before these are used by other agencies. The main layer generated by the MoEF is a land cover map with 23 land cover classes, consisting of 7 forest classes, 15 non-forest classes, and one class of clouds/no data. This platform was established to generate data layers once every six years since 1990. After the year 2000 once every three years, and since 2009 the NFMS generates land cover data layers annually.

Indonesia has increased efforts to generate data on land use and cover at a national scale. Many initiatives by multilateral and bilateral cooperation entities have joined nationally led efforts to improve land monitoring. The Good Growth Partnership project is mapping extensive crop areas currently used for palm oil, cocoa, coffee, rubber and rice. The data obtained to date is being used as a pilot to inform more precise mapping techniques per crop, through the development and application of **algorithms** for future monitoring. In 2018 a 1.0 version was launched which includes land cover data for palm oil, cocoa, coffee, rubber and rice.

Classification	Definition
Name	Ecosystem Platform.
Hyperlink	Ecosystem Platform mapping platform http://lulcc.ipb.ac.id/map/
Lead Agency	IPB University, Indonesia National Institute of Space and Aeronautics (LAPAN), Ministry of Environment and Forestry (MoEF).
Governance*	Ministry of Agriculture, Geospatial and Information Agency (BIG), United Nations Development Programme (UNDP), Ecometrica, University of Leicester, The University of Edinburgh, UK Space Agency, United PT. Hatfield Indonesia, Daemeter Consulting.
Funding	GEF.
Study area	National.
Objective	The data processing is: 1. Pre-processing data used cloud removal and topographic correction and composite image dataset. 2. The Landsat classification used automatic digitation used algorithm for each class. Algorithm for forest or no forest using vegetation index differences with Landsat and MODIS temporal dataset and for strategic commodities, the algorithm developed by machine learning (google earth engine).
Data processing characteristics	<ul style="list-style-type: none"> • Spectral classification (uses algorithms contained in common GIS software). • Photointerpretation (manual digitization)
Remote Sensors Used	Landsat 8 OLI and MODIS.
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	<ul style="list-style-type: none"> • Forest cover by type of forest • Forest Change: Tree Cover Gain and Tree Cover Los • Vegetation Gain Alert (IPB) 2019 -Early Warning • Vegetation Loss Alert (IPB) 2018 -Early Warning • Commodities: Palm Oil, Cacao, Rubber, Coffee, Rice
Resolution of imagery	<ul style="list-style-type: none"> • Ladsat-8 :30 x 30 m (900 m2 pixel) • The SPOT 6/7 (1.5 x 1.5 m) imagery will be used as a reference on validation only (The validation of the algorithm (automatic classification) has been planned on 2020
Area calculations	The application allows for area calculations.
Periodicity	<ul style="list-style-type: none"> • Forest cover by type of forest: Annual • Vegetation Loss Alert = once per 8 days (4 times per month) • Oil Palm Cover: Annual
Online viewer	Forests Indonesia has Ecosystem Online viewer http://lulcc.ipb.ac.id/map/frontend/Forest_Gain
Vector format geospatial data may be downloaded	Online use only. Version 2.0 will be downloadable.
Compatibility with other software	Compatible with: ESRI, Google Earth, Google Earth Engine, Qgis, R, and others.
Specialized equipment required	Basic computer equipment with internet access is the only requirement.
Approximate costs to use the tool	Free.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can the Indonesian approach be used to monitor if a selected production area gains or loses forest cover from year-to-year as a result of a specific agricultural activity?

Yes. The platform shows information on the extension of palm oil, coffee, cocoa, rubber and rice plantations. For each of these crops it includes data layers of two consecutive periods 2018 and 2019. The platform also provides users with a geospatial data layer called "expansion in forest cover" for each crop. This shows land areas with crop expansions. Additionally, it includes data layers of forest areas and their respective loss and gain of tree forest cover. These layers can interact and analyze deforestation events per crop and so identify if the driver associated with tree forest cover loss as well as an increase in hectares of specific agricultural crops. The data on loss and gain of tree forest cover is provided by GFW.

Both the Ecosystem Platform and the Forest Indonesia platforms are highly applicable to monitor forest cover loss within Indonesia's production landscapes, as they both offer a periodic monitoring of forest cover change and allow for interaction with surface areas of palm oil as well as cocoa, rubber, coffee and rice. The Ecosystem Platform, includes data layers for palm oil, and cocoa, rubber, coffee and rice.

The geospatial web viewer associates GFW deforestation alert data to the crop data layers in order to identify the risks associated with each crop. Information on agroclimatic suitability has been included for each of crop land cover data. In this way, users can identify which crop area falls outside the appropriate climatic condition for higher productivity. These features make the Indonesian platform a robust tool with high-quality studies for monitoring deforestation-free commodities and crop suitability.

The platform complies high quality data for analysis of productivity and deforestation-free production regarding their tree cover loss and gain data layers, as well as deforestation alerts. However, it is advisable that the platform includes data layers about land tenure, property record or concessions, so that data layers can be related to specific owner or tenants.



How practitioner-friendly is the Indonesian Platform?

2

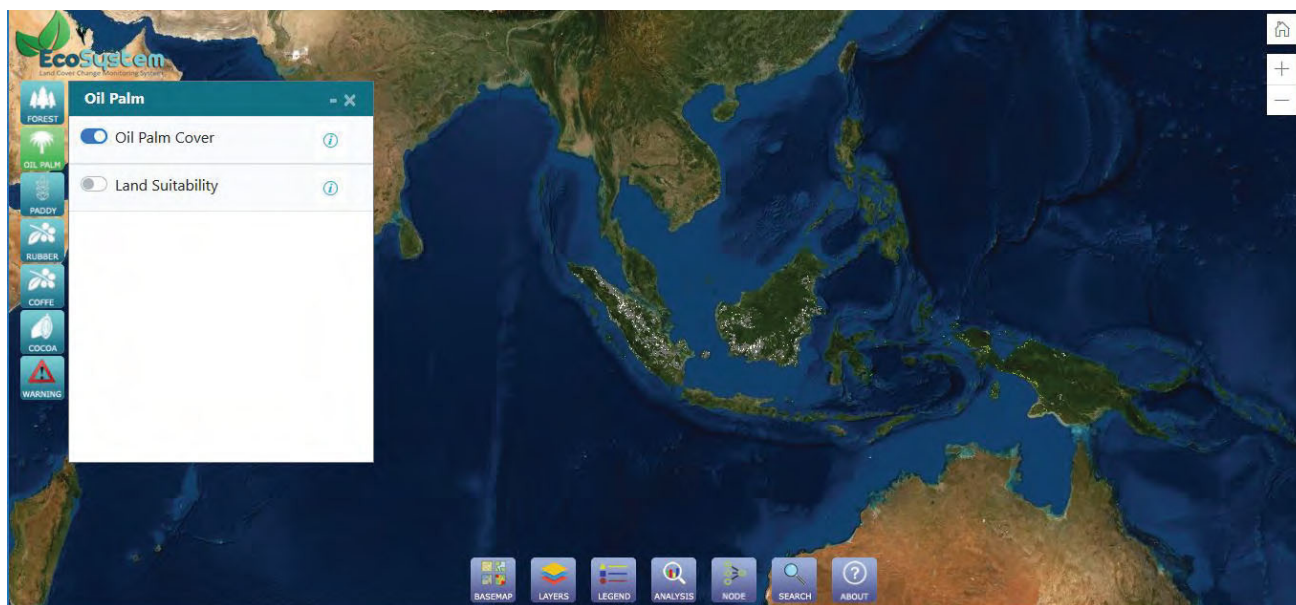
FRIENDLY BUT CAN IMPROVE

FIG 18. COUNTRY CASE STUDIES: INDONESIA; MAIN VISOR OF THE ECOSYSTEM PLATFORM.



Reference here: <http://lulcc.ipb.ac.id/map/>

FIG 19. COUNTRY CASE STUDIES: INDONESIA; PALM OIL LAND COVER.



Reference here: <http://lulcc.ipb.ac.id/map/>

FIG 20. COUNTRY CASE STUDIES: INDONESIA; FOREST COVER LOSS.



Reference here: <http://lulcc.ipb.ac.id/map/>

FIG 21. COUNTRY CASE STUDIES. INDONESIA, OVERLAPPING OF LAYERS OF PALM OIL OVER FOREST TREE COVER. CORRELATION BETWEEN TREE COVER LOSS AND PRODUCTION.



Reference here: <http://lulcc.ipb.ac.id/map/>



Costa Rica

In 2015 the Costa Rica National Environmental Information System (SINIA), with support from UNDP established MOCUPP, the System for Monitoring of Land Use Change within Production Landscapes. This system publishes yearly data sets on total land cover of pineapple, palm oil and pasture lands used for livestock activities. The system also publishes yearly land cover data of forest cover gain or loss associated to the above-mentioned crops' land cover. Data sets are generated through medium resolution satellite images, sent by the Landsat-8 satellites of the NASA and Sentinel-2A of the German Space Agency.

Data layers are generated by PRIAS Lab, an independent tele-detection unit of the National Center of High Technology (belonging to five State Universities). Data layers are published through a geospatial web visor called **SNIT**, the National Land Information System (www.snitcr.go.cr). Processed images by PRIAS Lab are verified in the field every year. Field verification leads to an accuracy of 98% for pineapple and palm oil land covers and an accuracy of 90% for pastures land.

The publication of layers through this open access viewer enables any user to relate the commodity land cover layers, and layers of gain and loss of associated forest cover, with official layers of information such as protected areas; or property records of the National Cadaster. The interaction of commodity land cover, gain and loss of forest cover and property records, allows users to identify online if a property is maintaining, increasing or decreasing forest cover between each monitoring event (every year in the case of pineapple and palm oil, and every two years in the case of pasture land).

MOCUPP was designed as an early warning system to support decision-making processes of the different public institutions, as the information is periodic and highly reliable, allowing better management of productive landscapes. Because the information is openly available through the SNIT it can support the private sector show if a production unit is complying with deforestation-free production.

Classification	Definition
Name	Monitoreo de Cambio de Uso de la Tierra en Paisajes Productivos (MOCUPP).
Hyperlink	MOCUPP main page: http://www.mocupp.org/ Mocupp mapping platform: http://www.snitcr.go.cr/
Lead Agency	United Nations Development Programme (UNDP).
Governance*	United Nations Development Programme (UNDP), Environment and Energy Ministry, National Territorial Information System-, PRIAS Lab, National Registry of Costa Rica and National Center for Geo-Environmental Information of Costa Rica
Funding	GEF; UNREDD; Green Commodities Programme UNDP.
Study area	National Territory.
Objective	Monitor gain and loss of forest cover associated with the expansion of agricultural commodities (Pineapple, pasture, palm oil).
Data processing characteristics	<ul style="list-style-type: none"> • Spectral classification (uses algorithms contained in common GIS software) • Photointerpretation (manual digitization)
Remote Sensors Used	Landsat and Sentinel.
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	<ul style="list-style-type: none"> • Pineapple Land cover year 2000 • Pineapple Land cover year 2015 • Gain and los of forest cover in relation to pineapple forest cover years 2000-2015 • Pineapple Land cover year 2016 • Pineapple Land cover year 2017 • Gain and los of forest cover in relation to pineapple forest cover years 2015-2016 • Pineapple Land cover year 2017 • National Cadaster of Costa Rica (private property delimitations)
Resolution of imagery	<ul style="list-style-type: none"> • Ladsat-7/8 :30 x 30 m (900 m2 pixel) • Sentinel 10m x 10m (100 m2)
Area calculations	The application allows for area calculations.
Periodicity	<ul style="list-style-type: none"> • Pineapple Land cover: Annual • Gain and los of forest cover in relation to pineapple forest cover: Annual
Online viewer	MOCUPP has Online viewer Mapping platform: http://www.snitcr.go.cr/Visor/index?p=cHJveWVjdG86OnBhaXNhamVzchJvZHVjdGl2b3M=
Vector format geospatial data may be downloaded	Files may be downloaded using a WFS format and then saved in other formats such as KML, KMZ, or other.
Compatibility with other software	Compatible with: ESRI, Google Earth, Google Earth Engine, Qgis, and others.
Specialized equipment required	Basic computer equipment with internet access is the only requirement.
Approximate costs to use the tool	Free.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can the Costa Rican approach be used to monitor if a selected production area gains or loses forest cover from year-to-year as a result of a specific agricultural activity?

Yes. This platform was specifically designed to identify the land cover that replaces tree forest cover loss on an annual basis and to relate such loss with specific properties and production units.

Although the information generated by global systems about loss and gain of tree cover are inputs of important technical value to this system, Costa Rica has a small land area (51,100 km²), and small extension changes in forest land cover may not be identified through the forest cover alerts of global services such as the GFW.

MOCUPP aims for a national homologation of monitoring processes. It produces data layers of forest cover loss and gain and commodity land cover at the same scale, using comparable methodologies, and incorporating field data verification. This allows the results to be more accurate than other systems for the land cover dynamics in the country, despite using the same free sensor images (Landsat and Sentinel) also used by systems here reviewed.

MOCUPP does not generate any cost to landowners or producers; it is simply a public access tool that can be used to demonstrate, for example, that pineapple or beef comes from a farm comprised of several properties with forest that remains intact over time, or that meat or dairy production on a given farm is following government recommendations of using live fences and agroforestry methods. The system helps producers differentiate their product and obtain better prices.

MOCUPP was originally established as a system to monitor all the major export crop land covers of the country and associated gain and loss of tree forest cover. So far it has generated annual data of pineapple, palm oil, pastures. It is advisable that it continues to grow to cover other crops with very significant land cover in Costa Rica such as coffee, and bananas. Other commodities that generate significant tree forest cover loss include rice and sugar cane, that although not as significant for export, should be included as well for their potential impact on forest ecosystems.



How practitioner-friendly is MOCUPP?

2

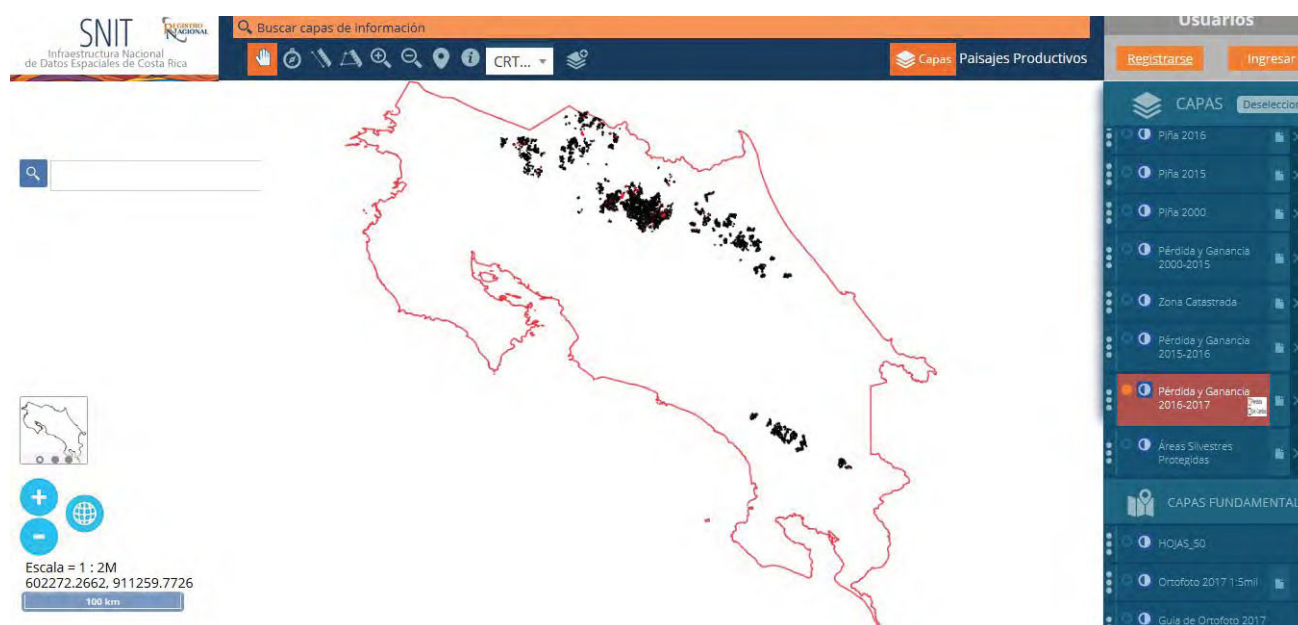
FRIENDLY BUT CAN IMPROVE

FIG 22. COUNTRY CASE STUDIES: COSTA RICA; MAIN WEB VISOR OF MOCUPP, SHOWING ALL AVAILABLE DATA LAYERS.



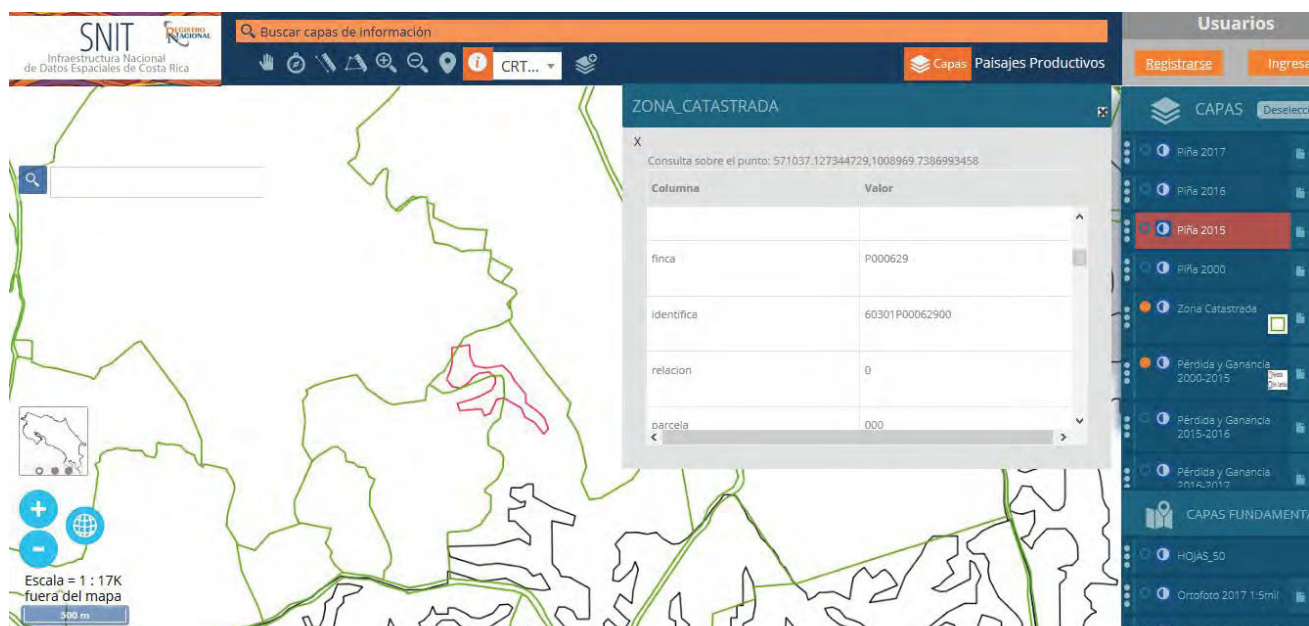
Reference here: <http://www.snitcr.go.cr/Visor/index?p=CHJveWJdG86OnBhaXNhamVzcHJvZHVjdGl2b3M=>

FIG 23. COUNTRY CASE STUDIES: COSTA RICA; MOCUPP SHOWING GAIN AND LOSS OF FOREST COVER ASSOCIATED WITH PINEAPPLE LAND COVER GROWTH.



Reference here: <http://www.snitcr.go.cr/Visor/index?p=CHJveWJdG86OnBhaXNhamVzcHJvZHVjdGl2b3M=>

FIG 24. COUNTRY CASE STUDIES: COSTA RICA; MOCUPP, LOSS OF FOREST COVER DUE TO PINEAPPLE LAND COVER GROWTH PER PROPERTY.



Legend: in red the forest cover loss in black no forest cover change. the table includes registry information of properties.

Reference here: <http://www.snitcr.go.cr/Visor/index?p=cHlveWVjdG86OnBhaXNhamVzcHlvZHVjdGl2b3M=>

FIG 25. COUNTRY CASE STUDIES: COSTA RICA; MOCUPP, EXAMPLE OF AREAS OF FOREST COVER LOSS IDENTIFIED WITH THE SYSTEM.



Reference here: <http://www.snitcr.go.cr/Visor/index?p=cHlveWVjdG86OnBhaXNhamVzcHlvZHVjdGl2b3M=>



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Paraguay

The Ministry of Environment and Sustainable Development (MADES) of Paraguay, the National Forestry Institute of Paraguay (INFONA) and the UNDP through the GEF-funded Green Productive Landscapes and the Good Growth Partnership/ Green Chaco projects, are working together to generate regular data layers about changes in forest cover at a national scale, since 1986 as baseline, and monitoring from the year 2000 and 2018.

Classification	Definition
Name	National Forestry Institute of Paraguay (INFONA).
Hyperlink	INFONA main page http://www.infona.gov.py/
Lead Agency	National Forestry Institute of Paraguay.
Governance*	Ministry of Environment and Sustainable Development, National Forestry Institute of Paraguay and United Nations Development Programme (UNDP).
Funding	GEF.
Study area	National.
Objective	Monitor changes in forest cover.
Data processing characteristics	Spectral classification (uses algorithms contained in common GIS software).
Remote Sensors Used	<ul style="list-style-type: none"> • Landsat 5-8 • Sentinel images are used as support for parallel monitoring systems
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	<ul style="list-style-type: none"> • 1986 baseline of forest cover changes • 2000-2005-2011: Map of changes in forest cover • 2011-2013-2015: Map of changes in forest cover
Resolution of imagery	<ul style="list-style-type: none"> • Landsat-7/8 :30 x 30 m (900 m2 pixel) • Sentinel- 2A :10 x 10 m (100 m2 pixel)
Area calculations	The application allows for area calculations.
Periodicity	Map of changes in forest cover: time series mentioned above.
Online viewer	No online web viewer, users must contact INFONA to request information.
Vector format geospatial data may be downloaded	No online web viewer.
Compatibility with other software	Available layers are compatible with: Arc Gis Online, Arc Map, Google Earth, Google Earth Engine, Qgis, and others
Specialized equipment required	Basic computer equipment.
Approximate costs to use the tool	Free but entail an official request to INFONA.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can the Paraguayan approach be used to monitor if a selected production area gains or loses forest cover from year-to-year as a result of a specific agricultural activity?

Partially, as the system monitors forest cover loss but was not designed to specify what agricultural land cover replaced it. INFONA generates information on forest cover every year through the application of remote sensing techniques using free sensors. Currently, it has baseline data from the forest area and annual monitoring for the last 4 years. INFONA is currently developing the Forest Atlas of Paraguay, with support from Global Forest Watch, with this platform the system data will be freely available.

The applicability of this information is focused on forests and their respective changes. The causes are not currently identified in the areas of loss of forest cover, since it does not have data in relation to commodities land cover or urban areas, in relation to forest cover loss.

The MADES also contributes to land use change monitoring with the Environmental Information System (SIAM) through which all the land use plans are being uploaded.

The current platform and services may be strengthened if all data layers are published using an openly accessible geospatial web viewer. This will facilitate third party verification and user friendliness. Currently the system is in fact public, but not easily available. For effective forest resource management it is advisable for the system to include the incorporation pilot projects that generate data layers of specific crop land cover, such as soy and pastures, in order to identify drivers of deforestation as they occur.

INFONA and MADES are planning to work with the Gordon and Betty Moore Foundation to improve the information flow between the two institutions which would feed into a strengthened land use monitoring system. An upcoming project on results-based payments will further support MADES and INFONA to have a more efficient system.



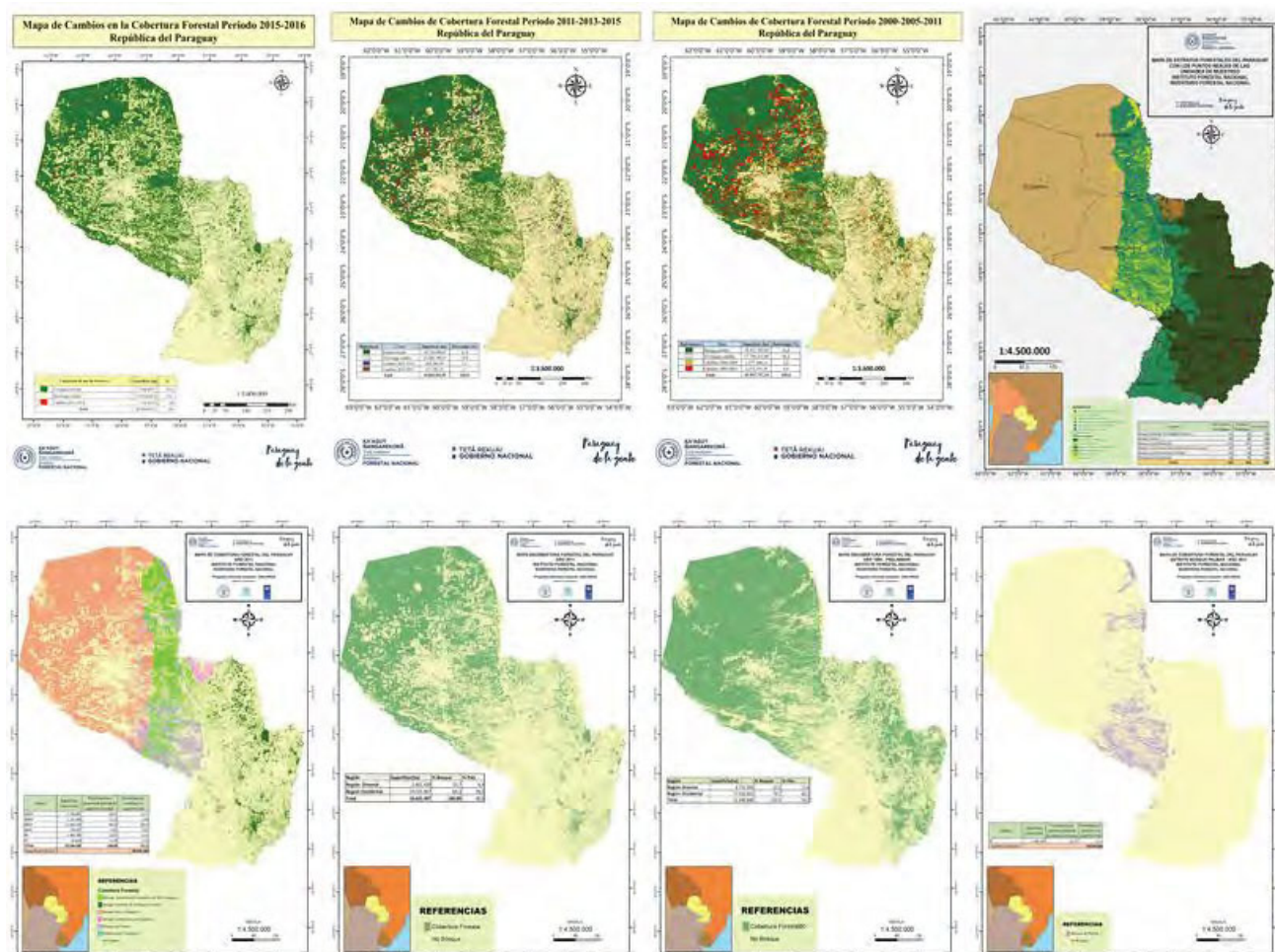
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How user friendly is the Paraguayan system:

1

NOT SUFFICIENTLY FRIENDLY

FIG. 26 COUNTRY CASE STUDIES: PARAGUAY; DOWNLOADABLE PDF MAPS, AVAILABLE FROM THE MAIN INFONA WEBSITE.



Reference here: <http://www.snitor.go.cr/Visor/index?p=cHJveWJdG86OnBhaXNhamVzcHJvZHVjdGl2b3M=>



Geobosques- Peru

GeoBosques is a government run platform coordinated by the Ministry of Environment of Peru. It publishes official layers of information from government institutions such as the National Forest and Wildlife Service (SERFOR), National Forest and Wildlife Information System (SNIFF) and the National Environmental Information System. It was created specifically to monitor changes in forest cover, with the aim of sharing the information generated to different users through reports, maps, web viewers and email alerts. The platform generates 5 modules of geospatial information: i) deforestation, ii) early warnings indicating disturbances in forested areas, iii) forest degradation focusing on deforestation processes, iv) land use and land cover, allowing users to determine potential land covers that generate deforestation; and v) the historical baseline of these five categories.

Classification	Definition
Name	GeoBosques.
Hyperlink	GeoBosques main page http://geobosques.minam.gob.pe/geobosque/view/index.php GeoBosques mapping platform http://geobosques.minam.gob.pe/geobosque/visor/
Lead Agency	National Forest Conservation Program Climate Change Mitigation and articulated to the Forest Coverage Monitoring Module (MMCB), under the coordination of the Ministry of Environment.
Governance*	Ministry of Environment of Peru, "Bosques en tus manos", GeoBosques, University of Maryland, Global Land Analysis and Discovery (GLAD), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Community Forest Conservation Project, WWF Peru, Norad, Japanese International Cooperation Agency, Global Forest Watch, United States Agency for International Development.
Funding	National Forest Conservation Program Mitigation Climate Change and articulated to the Forest Coverage Monitoring Module (MMCB). Peruvian Ministry of Environment
Study area	National.
Objective	<ul style="list-style-type: none"> • Forest Monitoring • Deforestation early warning • Identify different land uses replacing forest cover • Forest degradation
Data processing characteristics	Spectral classification (uses algorithms contained in common GIS software).
Remote Sensors Used	<ul style="list-style-type: none"> • Landsat-8 • Sentinel-2 A
Relevant layers of information for monitoring forest land cover gain or land cover loss associated with commodity surface area	<ul style="list-style-type: none"> • Concentration of Deforestation Alerts • Detected forest cover changes • Forest Early Warning System in the Tropics (JJ-FAST) • Forest Cover loss 2001-2017
Resolution of imagery	<ul style="list-style-type: none"> • Landsat-7/8 :30 x 30 m (900 m2 pixel) • Sentinel- 2A :10 x 10 m (100 m2 pixel)
Area calculations	The application allows for area calculations.
Periodicity	<ul style="list-style-type: none"> • Concentration of Deforestation Alerts: Monthly • Detected forest cover changes: Annual • Forest Early Warning System in the Tropics (JJ-FAST): 1.5 months • Forest Cover loss 2001-2017: Annual
Online viewer	http://geobosques.minam.gob.pe/geobosque/visor/
Vector format geospatial data may be downloaded	No download feature is available.
Compatibility with other software	Compatible with: Arc Gis Online, Arc Map, Google Earth, Google Earth Engine, Qgis, R, and others.
Specialized equipment required	Basic computer equipment with internet access is the only requirement.
Approximate costs to use the tool	Free.

* Governance includes the organizations that helped throughout the development and implementation of the tool.

Can the Peruvian approach be used to monitor if a selected production area gains or loses forest cover from year-to-year as a result of a specific agricultural activity?

Partially as the system monitors forest cover loss but was not designed to specify what agricultural land cover replaced it. The data layers included in the GeoBosques platform describe the state of the forest, so it is useful to identify areas with deforestation, or with high risk of deforestation according to its alerts and warnings, as well as to locate degraded areas. The platform makes this information available through an online viewer. However, no data layers on commodity surface area are included that enable users to determine what land cover replaced or is replacing tree forest cover. Users that start with a vector format of a specific production unit may tell if forest cover was lost but not identify if the source of this loss was agricultural activity.

- It is advisable for the geospatial viewer level to disaggregate the forest cover loss data. Currently there is a single layer and file covering the period 2001-2018. It would be convenient to divide it into annual data layers so users can consult the specific tree cover loss for specific annual periods, improving national capacities for tree forest resource management.
- It is also advisable to include the land cover data layer of specific crops that may be drivers of tree cover loss, or to relate these with the existing deforestation alerts that the platform currently includes.
- Finally, a cadaster layer, or a data layer of property records is an advisable inclusion for the future, as this would ease identification of tenants or entities responsible for tree forest cover gain or loss.



How user friendly is GeoBosques:

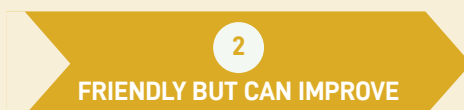


FIG 27. COUNTRY CASE STUDIES: PERU; PRINCIPAL WEB VIEWER GEOBOSQUE, EXAMPLE OF DEFORESTATION ALERT



Reference here: <http://geobosques.minam.gob.pe/geobosque/visor/#>

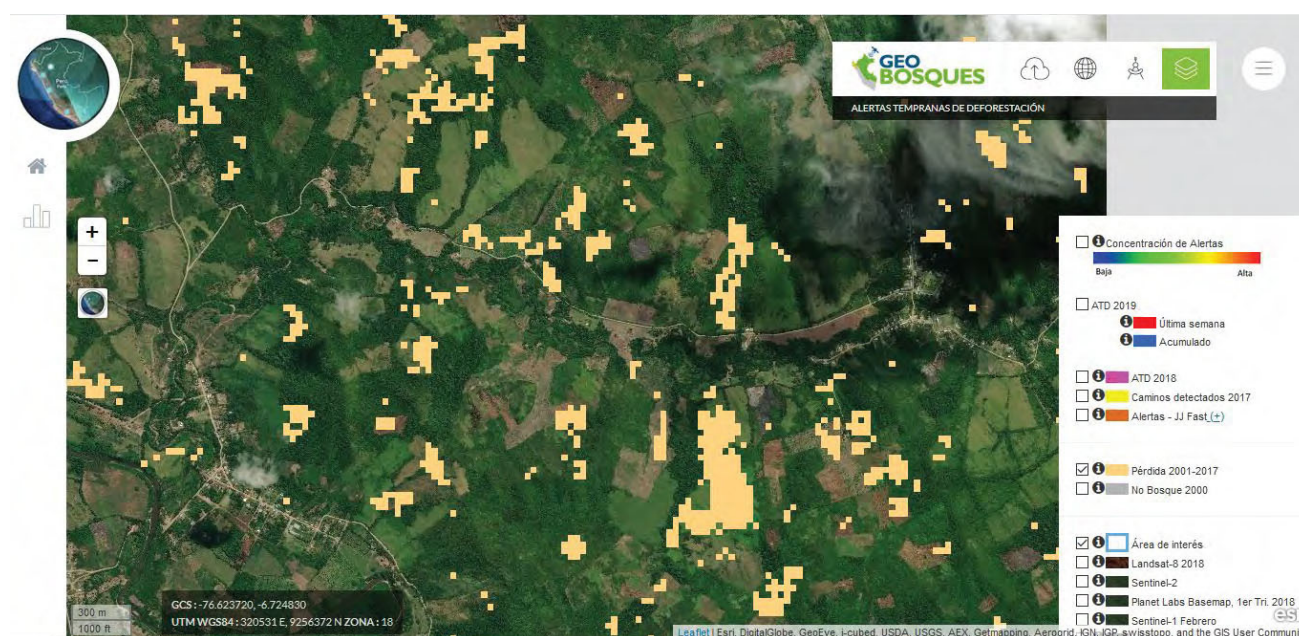
FIG 28. COUNTRY CASE STUDIES: PERU.



Legend: data layer on forest cover loss in yellow.

Reference here: <http://geobosques.minam.gob.pe/geobosque/visor/#>

FIG 29. COUNTRY CASE STUDIES: PERU.



Legend: data layer on forest cover loss in yellow.

Reference here: <http://geobosques.minam.gob.pe/geobosque/visor/#>





III: Conclusions

The majority of the reviewed LUCM tools provide geospatial data layers of forest and tree cover dynamics with high periodicity. Data layers for other land uses are less common and happen at lower frequency.

The LUCM tools that include periodic monitoring of land cover dynamics of the agricultural commodities present in target jurisdictions, published through openly accessible geospatial viewers that may be accessed by third parties, provide more useful information for decision-makers to determine if production units are deforestation-free.

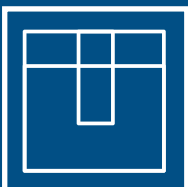
The reviewed LUCM solutions work at different scales, use different methods and have different objectives of study. However they share one important similarity, they all use Landsat and Sentinel remote sensors that are available to all users for free. This means the pixel size of the imagery processed by these platforms is the same for all. Nevertheless, the usefulness of each LUCM solution will depend on the objective for monitoring forest cover change due to the features of each solution.

When attempting to monitor land cover at a global scale, data layers of agricultural land cover are less detailed or disaggregated, and the algorithms used may not identify changes for all types of ecosystems and forest covers of the planet or may provide resolutions much wider than one production unit. As a result, the data derived from such platforms may serve as a useful reference and as warning system of what land use was replacing forest cover loss. However, the precision of these systems may be insufficient for national stakeholders to report at national level forest cover loss or gain accurately.

Both global and national systems and services provide useful and valid information. It is up to the user to determine what scope is required, and to choose the level of data accuracy required.

The LUCM solutions from Brazil and Costa Rica provide greater detail and accuracy than the available global data layers. The algorithms constructed by local experts are more familiar with the types of forests present, as they may have expert criteria from the reviewed regions and in many cases possess field information from primary sources. As a result, processed imagery shows greater detail and precision. Brazil has the most extensive land use change monitoring availability of services, with over 30 tools in place providing regular updates of data layers for different classes of land cover. The objective of the LUCM solutions reviewed for Peru and Paraguay is only to monitor forest land cover using nationally defined methods. Both systems use GFW warnings to complement their systems. The Costa Rica system (MOCUPP) helps users identify forest cover loss associated with specific commodity land covers and relate this information with property records at a national scale. Although the feature of relating land cover layers with property records for the entire national territory is incomplete, its availability is growing as the country expands the cadaster layers from the National Registry. The recent inclusion of national data layers of palm oil, and pasture to complement the existing layers of pineapple will further complete the system. This makes this LUCM solution one of the most openly accessible online to any user, making it highly transparent. Landowners may use it to prove or disprove that their production unit is free of forest cover change.

LandSat and Sentinel are the most common remote sensors used by all the reviewed LUCM solutions. The platforms to download free remote sensor images are easy to use (Annex 1). This can provide the basis for local monitoring through advanced classification methods through alliances with universities (Costa Rican & Indonesian models).



Glossary

Algorithm: Refers to a calculation procedure applied with information sets to solve problems in informatics (González Aguayo, 2013).

ArcGIS: Is a mapping and analytics software and platform that provides conceptual tools for mapping and spatial reasoning (ArcGIS, 2019a).

CSV (Comma-separated values) format: Refers to a table data representation, used for storage of alphanumeric information (Cuadrado, 2017).

Data Layer: Refers to a digital coverage that shows a geographic representation of different themes (González Aguayo, 2013).

Digital Globe: Is a global provider of satellite imagery, geospatial information, and location-based intelligence. (Digital Globe, 2019).

Digitize: Conversion of any document from analogical format to digital format (González Aguayo, 2013).

ENVI (Environment for Visualizing Images): A specialized software to process and analyze geospatial imagery for GIS users (ENVI, 2019).

ESRI: Acronym for Environmental Systems Research Institute Inc (Naciones Unidas, 2000).

Geographic Information Systems (GIS): A raster and vectoral application to prepare, present and interpret data over land surface (González Aguayo, 2013).

Geomatics: A systemic, multidisciplinary, integrated approach for selecting instruments and the appropriate techniques for collecting, storing, integrating, modeling, analyzing, retrieving at will, transforming, displaying, and distributing spatially georeferenced data from different sources with well-defined accuracy characteristics and continuity in a digital format. (Gomasca, 2010).

Geopackage: Refers to an open, standards-based, platform-independent, portable, self describing, compact format for transferring geospatial information (GeoPackage, 2019).

GFW (Global Forest Watch): Global Forest Watch, land use change monitoring system reviewed in this document.

Google Earth: Refers to an online application that shows a virtual globe developed with satellite imagery and georeferenced information (NASA, 2019).

Google Earth Engine: A planetary-scale platform for Earth science data & analysis (Google Earth Engine, 2019).

GPX format: Refers to a HTML scheme for GPS data transferring between applications (Cuadrado, 2017).

KML (Keyhole Markup Language) format: Refers to the language based on XML to represent three-dimensional geographic data (Cuadrado, 2017).

KMZ format: Refers to a KML compressed file (Cuadrado, 2017).

Land cover: The element that covers the earth's surface. It may be both natural or artificial coverage. These can be classified as forests, shrubs, bodies of water, snow, sand, rocky outcrops, among others (Amazon Institute SINCHI, 2006).

Landsat 7-8: Refers to the mission of the Landsat satellite for earth observation. The numbers 7 and 8 correspond to the seventh and eighth mission (González Aguayo, 2013).

Land use: It refers to the way in which and the purposes for which humans employ land and its resources (Turner et al., 2001).

MODIS (Moderate Resolution Imaging Spectroradiometer): Refers to the instrument operated on both the Terra and Aqua spacecraft. It has a viewing swath width of 2,330 km and views the entire surface of the Earth every two days. Its detectors measure 36 spectral bands between 0.405 and 14.385 μm and acquire data at three spatial resolutions -- 250m, 500m, and 1,000m.

National Territorial Information System (SNIT in Spanish): This is geospatial web viewer developed to provide public access to different data layers and geographic information from Costa Rica (SNIT, 2019).

Normalized Burn Ratio (NBR) Index: This ratio is used to identify areas affected by forest fires (burned areas). The formula uses near-infrared (NIR) and shortwave-infrared (SWIR) portions of the electromagnetic spectrum (Earth Lab, 2019).

Python: Refers to an interpreted, high-level, general-purpose programming language (Python, 2019).

Qgis: This is a free Geographic Information System software for GNU / Linux, Unix, Mac OS, Microsoft Windows and Android platforms (Qgis Platform, 2019).

Raster Format: A method for visualization and storage of individual information points for imagery process, and organized in grids (González Aguayo, 2013).

Remote Sensing: Information capture of areas, objects and phenomena through no direct contact by airborne platforms and satellites (González Aguayo, 2013).

Sentinel - 2: Is one of the satellites of the Copernicus Program of the European Union, which captures high-resolution images between 10 and 60 meters (ESA, 2019).

Shapefile: Refers to a non-topological format used for storage geometric information such points, lines and polygons. (ArcGIS, 2019b).

Software R: Refers to a free software environment for statistical computing and graphics. It compiles and runs on a wide variety of UNIX platforms, Windows and MacOS (R Project, 2019).

SQLite format: Refers to a data base for storage tile sets used for map construction with each set like units with SQLite format (Cuadrado, 2017).

TIFF (Tagged Image File Format): Refers to a standard file format that is largely used in the publishing and printing industry. The extensible feature of this format allows storage of multiple bitmap images having different pixel depths, which makes it advantageous for image storage needs (Techopedia, 2019).

Tree Forest cover: Natural or semi-natural areas, consisting of tree elements of native or exotic species (FAO, 2010). It may be classified as: dense, fragmented natural forest, riparian and forest plantations.

Tree Forest cover gain and loss: Refers to the spatiotemporal change in a forest cover area from a determined geographic zone.

Vector layer: Refers to the quantity, magnitude, direction and assigned significance of spatial data (González Aguayo, 2013).

WFS (Web Feature Service) format: Refers to a service that provides information about layer stored data (Cuadrado, 2017).

WMS (Web Map Service) Format: Refers to the service that provides picture format maps for browser or user visualization (Cuadrado, 2017).



Annex

Annex 1: Links to websites to download Landsat and Sentinel free imagery

Platform

Earth Explorer: United States Geological Survey (USG)

Hyperlink: <https://earthexplorer.usgs.gov/>

The screenshot shows the USGS Earth Explorer website. The top navigation bar includes the USGS logo and links for Home, Feedback, and Login. Below the navigation bar, there are tabs for Search Criteria, Data Sets, Additional Criteria, and Results. The main content area is titled "2. Select Your Data Set(s)" and includes a search bar, a list of data sets (Aerial Imagery, AVHRR, CEOS Legacy, Commercial Satellites, Declassified Data, Digital Elevation, Digital Line Graphs, Digital Maps, EO-1, Global Fiducials, HCMM, ISERV, Land Cover, Landsat, LCMAP, NASA LPDAAC Collections, Radar, Sentinel, UAS), and a "Clear All Selected" button. On the right, there is a "Search Criteria Summary (Show)" section with a map of the United States and a "Clear Search Criteria" button. The bottom of the page contains a footer with links for DOI Privacy Policy, Legal, Accessibility, Site Map, and Contact USGS, and a disclaimer: "The provided maps are not for purchase or for download; it is to be used as a guide for reference and search purposes only."

Platform

Global Visualization Viewer (GloVis): United States Geological Survey (USG)

Hyperlink: <https://glovis.usgs.gov/>

The screenshot shows the USGS GloVis website. The top navigation bar includes the USGS logo and links for Home, Take Tour, Release Notes, and FAQ. Below the navigation bar, there are tabs for Feedback, Login, and Help. The main content area is titled "GloVis" and includes a "Page Expires In 1:59:23" timer. On the left, there are "Interface Controls" for "Choose Your Data Set(s)" (with radio buttons for DOQ, EO-1 ALI, EO-1 Hyperion, Global Land Survey, IRS AWIFS, and IRS LISS-3) and "Metadata Filter" (with fields for Date Range, Cloud Cover, and Months). The main content area is titled "Selected Scenes (0)" and features a map of the United States with a green rectangular area highlighted. Below the map, there is a "Global Land Survey" timeline view showing years from 1999 to 2009. The bottom of the page contains a footer with links for DOI Privacy Policy, Legal, Accessibility, Site Map, and Contact USGS, and a disclaimer: "The provided maps are not for purchase or for download; it is to be used as a guide for reference and search purposes only."

Platform

Copernicus Sentinel data

Hyperlink: <https://scihub.copernicus.eu/dhus/#/home>

The screenshot displays the Copernicus Open Access Hub search interface. On the left, the 'Advanced Search' panel is open, featuring a search bar at the top. Below it, there are sections for 'Sort By' (Ingestion Date) and 'Order By' (Descending). The 'Sensing period' and 'Ingestion period' are set to empty date ranges. The 'Mission' section is set to 'Sentinel-1'. Under 'Sentinel-1', the 'Satellite Platform' is set to 'Sentinel-1A', 'Product Type' is 'SAR', 'Polarisation' is 'VH', 'Sensor Mode' is 'Stripmap', and 'Relative Orbit Number' is set to 'from 1 to 175'. The 'Mission: Sentinel-2' and 'Mission: Sentinel-3' sections are also visible but not selected. The main area on the right shows a map of Europe with a search bar and a 'DD' button at the bottom. The map displays various cities and geographical features across Europe and North Africa.



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