GFOI Module: Deforestation Alerts

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1. Introduction

Recent advances in satellite monitoring have led to near-real-time monitoring of forest and tree cover loss on local to global scales. Near-real-time alert systems using optical and radar satellite imagery can detect forest and tree cover loss at daily, weekly or monthly time intervals. The frequency and low latency can enable rapid response to illegal and unsustainable human activities in forests by on-the-ground law enforcement for example. This can potentially halt further clearing of forest. Early warning systems can identify areas at risk for near-future deforestation and enable preventive actions (e.g., focused patrolling).

This document provides information about deforestation alerts (hereafter 'alerts') identified through the interpretation of satellite imagery so that forest policy experts, decision-makers and forest-management and conservation practitioners gain access to alerts and make the most out of this valuable resource in the fight against deforestation. While alerts are used by different actors for different purposes, this document focuses on the use of alerts as a tool to support law enforcement actions. The field is rich in terms and definitions, and **Box 1** explains key forest/tree monitoring definitions used here.

Box 1: Key terminology related to deforestation alerts

(Deforestation) alert: A detection of tree cover or forest loss, delivered in a spatial format such as a pixel or polygon on a map or as geographic coordinates. The alerts detect loss from different types of disturbances. Such disturbances may or may not be legal or planned and although they are termed 'deforestation' alerts, they generally capture forest or tree cover loss resulting from different disturbance types and therefore may or may not lead to an immediate or future change in long-term land use.

Near-real-time (deforestation) system: A set of procedures whose main purpose is to identify forest or tree cover loss on a regular high-frequency basis and as quickly as possible (ideally days to weeks). Data are often made available very shortly after the satellite image is available (e.g. in near-real-time).

(Deforestation) early warning system: A set of procedures whose main purpose is to identify *preliminary indications of potential* forest or tree cover loss. This may also be run in near-real-time, or at specified intervals, e.g. monthly. As of December 2023, none of the few existing early warning system data is publicly available.

Both near-real-time and early warning systems are a set of procedures to analyse and interpret satellite-imagery (e.g. satellite data processing, detection algorithms and post processing), but their purpose and timing are slightly different. They vary in geographic scope, frequency and resolution depending on the availability, periodicity and resolution of the satellite imagery they run on, and the detection algorithms used.

Integrated alerts: A complimentary approach to merging data allowing utilization of alerts from more than one near-real-time (deforestation) system in a single layer allowing the user to compare and/or combine them.

It should be noted that this is an evolving field, and these terms are not recognized or adopted consistently by all stakeholders, and we use official terms to refer to other named systems, which may contradict the terms laid out here.

2. Use of deforestation alerts

Deforestation alerts have many uses including to raise awareness of deforestation, to support design and implementation of deforestation-free commitments, and as a law enforcement support tool for a broad range of stakeholders assessing and responding to deforestation. Primarily, the alerts help stakeholders to implement a quick response action to illegal/unplanned deforestation or degradation. This contrasts to other forest monitoring objectives, which are largely designed for reporting obligations (**Box 2**).

Box 2: How alert use differs from other forest monitoring

Forest monitoring is carried out for many purposes, including forest management and planning, but frequently governments use monitoring to produce information using internationally agreed principles which is relevant for reporting progress on international commitments such as REDD+, UNFCCC or the FAO’s State of the World’s Forests Report. Forest monitoring is typically carried out using national forest monitoring systems and national forest inventories on an annual or longer frequency. Generally, the aim is to detect forest changes over a specified period but not in near-real-time, and the results are often used for estimating area of forest change and other related variables such as biomass estimates to inform the design and implementation of forest policies at the country level. Results are primarily generated for national agencies rather than a wider public audience.

In contrast, deforestation alerts are increasingly becoming a key law enforcement supporting tool enabling authorities or other concerned stakeholders to take actions to stop illegal and unsustainable human activities in forests. For this use case, the focus is to detect forest disturbance rapidly to allow quick actions and not on very accurate calculations of disturbance area. Often ‘confidence’ information is provided on the alerts, allowing the user to select alerts based on their accuracy.

For alerts to be effective, they must reach relevant stakeholders, who then must gather the information required to decide whether or not to act on the alerts (Figure 1).

Figure 1: How Satellite-Based Deforestation Alerts Work: typical workflow from satellite imagery to action on the ground.

Further information is required to assess if an alert represents a real loss event, and is anthropogenic, illegal, unplanned or is not desired according to the land use and/or natural resource management priorities for the territory. In addition, users also need to identify the actors legally liable and responsible for the loss, and to assess if further action is required. Fine resolution, high-frequency satellite imagery (e.g., Planet data) may help to verify that alerts represent a real loss and provide additional context on their drivers, including whether the alert is anthropogenic or not. Some commercial systems provide screening/prioritisation of alerts based on various criteria, and several users have developed their own methods to prioritise follow-up action. Auxiliary data (e.g., protected area, concession boundaries and forest management plans) can often help identify if the loss is illegal or unplanned. Available data on drivers of alerts could also support these decisions. On-the-ground information is often required, and GPS units, mobile phones and drones can guide users to alert locations and gather evidence required by the investigators, courts of law or other authorities, including photos of the location, descriptions of activities, equipment used for the clearing and vegetation status. A number of different apps are available for this purpose including ODK, which allows users to create customizable forms, and Locus map which allows route planning. The Forest Watcher mobile app helps users to navigate to the alert sites, as well as gather information required to decide on follow-up actions (**Box 3**).

Box 3: Forest Watcher

The Forest Watcher mobile app brings the online forest monitoring and alert systems hosted on Global Forest Watch (GFW) into the field. Users can monitor areas of interest, view deforestation and fire alerts, navigate to points for investigation, and collect information about these points, regardless of connectivity using offline functionality. After installing the app and caching data to a mobile device, the app directs users to nearby forest clearings – even without a cell signal. It also enables users to capture photos and fill out forms about the deforestation they encounter, which they can upload when back online. It incorporates the latest 'integrated deforestation alerts' available through GFW, and allows users to customize its online forms and sampling approaches. The app is currently being used operationally by several local and national organizations to combat deforestation. More information including guidance on how to use the app can be accessed through GFW: https://forestwatcher.globalforestwatch.org/

For enforcement-related activities, alert systems are typically used by stakeholders who have the capacity to investigate and follow up on alerts, such as law enforcement agencies, protected area managers, private landowners, companies and on-the-ground civil society organizations and communities. Ideally, governments using the alerts must have proper institutional arrangements to allow for data sharing between the agencies generating deforestation alerts and those acting on them.

3. Characteristics of deforestation alert systems

While alert systems rely on different optical and/or cloud-penetrating radar satellite sensors, many have similar processing steps and trade-offs:

- No differentiation between human-caused and other (natural) disturbance types.
- Alerts available quickly, in some cases before a follow-up land use (if any) is established.
- Alerts produced only within the boundaries of a forest baseline map.
- Broadly similar data processing steps: characterizing historical forest conditions using satellite image metrics, preprocessing newly acquired images, applying a disturbance algorithm, and establishing confidence through successive observations.
- Alerts are initially triggered by a single observation, and subsequent observations are utilized to enhance confidence, leading to a transition from a low confidence alert (initial detection) to either a high confidence alert or the dismissal of detected changes. The alert's date corresponds to the image date that initially triggered it.
- Designed to be conservative to minimize false alarms, a trade-off exists between alert confidence and detection timeliness. In general, single-image detections are immediate but carry lower confidence levels, while multiple subsequent observations increase confidence at the expense of a waiting period.

Unlike analysing historical changes, a near real-time monitoring system's timeliness (how quickly after an event an alert is registered) is a crucial characteristic for users. For instance, identifying illegal logging operations within a few days can be vital for a timely response. Thus, it's essential to consider both spatial accuracy and timeliness when evaluating a near real-time monitoring system. Delays in alert creation, which can take weeks to months due to environmental (e.g., clouds) and technical factors (e.g., sensor revisit times, or algorithm parameters), can impede alert timeliness, and also will impact the accuracy. While consolidated methods exist to evaluate historical forest monitoring systems (e.g., annual forest cover change maps), community accepted guidelines for assessing near real-time and early warning systems are under development.

4. Available systems

In addition to openly available alert systems that cover global geographies (e.g., GLAD-L/S2, JJ-FAST, RADD and Tropisco), several regional and national systems (e.g., DETER in Brazil, Geobosques in Peru, SMByC Colombia) have been created utilizing diverse optical and radar satellite data streams.

Integrated alerts are a complimentary way of utilizing more than one alert system. Integrating alerts results in faster detection, higher confidence, and more resilience (e.g., in the case of sensor failure). It also means that users don't have to make decisions about which data to select. Some alert systems also integrate multiple sensors in the process of creating alerts (e.g. DIST-ALERT).

Operational forest disturbance alert systems primarily utilize freely distributed medium-scale resolution (10 – 50 m) imagery from sources such as Landsat and Sentinel-2 multispectral satellites or Sentinel-1 radar satellites. Systems using radar satellite imagery can complement optical-based systems in cloudy regions. Examples of openly accessible operational deforestation alert systems and their key characteristics are listed in Table **1.**

Table 1: Examples of operational and openly available near-real-time alert systems. Status as of December 2023, so subsequent changes and updates are not included.

Alert system (Producer)	**Sensor (optical or radar)**	**Pixel spacing (minimum mapping unit)**	**Coverage**	**Periodicity**	**Scientific reference**	**Data access and information**
GLAD-L (University of Maryland)	Landsat (optical)	30 m (1 pixel = 0.09 ha)	30°N to 30°S	1- 8 days, depending on cloud cover	Hansen et al., 2016	GLAD website, Global Forest Watch
Glad-S2 (University of Maryland)	Sentinel-2 (optical)	10 m (1 pixel = 0.01ha)	Amazon basin	5 days at best, depending on cloud cover	-	GLAD-S2 app, Global Forest Watch
DIST-ALERTS (University of Maryland)	Harmonized Landsat Sentinel-2 (optical)	30 m (1 pixel = 0.09 ha)	Global	2-4 days	Product Specification Document and Algorithm Theoretical Basis Document	USGS
RADD (Wageningen University)	Sentinel-1 (C-band radar)	10 m (10 pixel = 0.1 ha)	Humid pan-tropics	6–12 days	Reiche et al., 2021	RADD website,

Alert system (Producer)	Sensor (optical or radar)	Pixel spacing (minimum mapping unit)	Coverage	Periodicity	Scientific reference	Data access and information
						Global Forest Watch
Tropisco alerts (CNES)	Sentinel-1 (C-band radar)	10 m (10 pixel = ~ 0.1 ha)	French Guiana, Suriname, Guyana, Vietnam, Laos, Cambodia, Gabon	6-12 days	Ballere et al., 2021	Tropisco website
LUCA (Ctrees)	Sentinel-1 (C-band radar)	10 m (10 pixel = 0.1 ha)	Global	14 days	Mullissa et al., 2024	LUCA website
JJ-FAST (JICA-JAXA)	ALOS-2 PALSAR-2 (L-band radar)	50 m (8 pixel = 1 ha)	Pan-tropical	42 days	Watanabe et al., 2021	JJ-FAST website
GFW integrated alerts (Global Forest Watch)	RADD + GLAD-S2 + GLAD-L	Varying (depending on individual systems), but presented at 10 m (1 10 m pixel = 0.09 ha)	30°N to 30°S	At least weekly (based on input systems)	Reiche et al. 2024	Global Forest Watch
MapBiomas (integrated) alert (MapBiomas)	GLAD-L + multiple national deforestation alerts	Varying (depending on coverage of individual systems)	Brazil	Weekly	-	MapBiomas website

Using alerts from openly available operational alert systems (e.g., GLAD, RADD) and producing alerts in a national system both have advantages. Advantages of using existing operational alert systems (e.g. GLAD, RADD), include:

- Up-to-date algorithms and easy implementation in workflows (via APIs, etc.). Importantly, no additional development time would be required to generate alerts
- Available and accessible to all user groups (NGOs, communities, private sector, etc.)
- Integration of multiple alert systems is possible (see GFW integrated alerts, MapBiomas alert)
- Alerts already exist so several can be tested to identify what best suits the user needs

Benefits of producing deforestation alerts in a national system include:

- Ownership and therefore reduced institutional / legal restrictions, and potentially easier uptake in courts
- Tailored to suit local/national context - local or customized forest baseline maps, optimized algorithm parameters, and own confidence thresholds

5. How to produce your own alerts

For technical users, producing their own alerts allows for finetuning of the alert system. For example, some stakeholders that respond to alerts over extensive areas may have a very low tolerance for commission errors (or false alerts), due to the high cost of field interventions (at the expense of higher omissions, or missed alerts). On the opposite end of the spectrum, those that conduct regular patrols of smaller areas, say a national park, may be able to tolerate a higher level of false positives in order to reduce omission.

In addition to operational alert systems, cloud computing and analysis systems can be used by stakeholders to access and process the satellite data, either by developing or adapting existing algorithms to produce their own alerts. Cloud processing and analysis platforms include Google Earth Engine, SEPAL (**Box 5**) and OpenEO.

Box 5: SEPAL

Developed by the Food and Agriculture Organization of the United Nations (FAO), the System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL) helps countries monitor and report on forests and land use. SEPAL is an easy-to-use interface powered by cloud-based super computers, and offers users access to satellite data. A number of change detection algorithms can be applied to available optical and radar satellite time-series data, including all Landsat, Sentinel-2, and Sentinel-1 data for the entire globe. Workflows allow users to run algorithms including CCDC, BAYts and CUSUM in near-real time, and parameters such as confidence can be set by users. Other datasets such as Planet are also available on SEPAL and can be useful for visual interpretation. Workflows are updated and improved continuously.

6. Examples of Deforestation Alert Use

Here we introduce several use cases demonstrating how deforestation alerts have been applied in practice.

We include both national systems and those implemented by civil society and NGOs, focusing mainly on those used primarily to take action on illegal deforestation. Countries are under no obligation to create their own near-real-time or early warning deforestation alert monitoring systems and can use existing global or private alert data if they like. The differences summarized in Table 1.

Table 1. Overview of the case studies

	Use case	Type of Deforestation alert system	Ownership	Purpose-built, or existing alert use
1	Mapbiomas, Brazil	Near-real-time	Civil society	Existing alerts
2	INPE, Brazil	Near-real-time	National	Existing alerts
3	Ethiopia	Near-real-time	NGO	Existing alerts
4	Guatemala	Near-real-time	National	Existing alerts
5	Indonesia	Near-real-time	NGO	Existing alerts
6	Lao	Near-real-time	National	Purpose built
7	Peru	Near-real-time	National	Purpose built
8	Forest foresight, Gabon	Early warning	NGO	Existing alerts

6.1 Mapbiomas, Brazil

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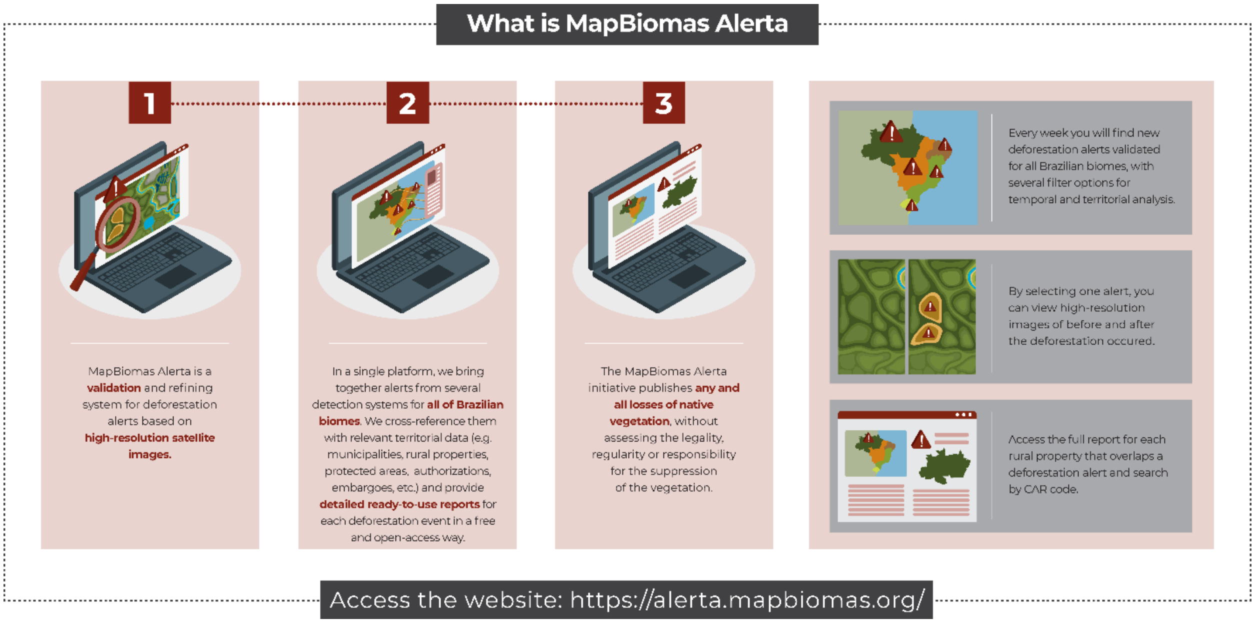
Background

Mapbiomas is a collaborative network that manages the Mapbiomas Alerta open access platform showing deforestation events in the Brazilian biomes from January 2019 onwards.



MapBiomas Alerta is a **validation** and refining system for deforestation alerts based on **high-resolution satellite images.**

In a single platform, we bring together alerts from several detection systems for **all of Brazilian biomes**. We cross-reference them with relevant territorial data (e.g. municipalities, rural properties, protected areas, authorizations, embargoes, etc.) and provide **detailed ready-to-use reports** for each deforestation event in a free and open-access way.

The MapBiomas Alerta initiative publishes **any and all losses of native vegetation**, without assessing the legality, regularity or responsibility for the suppression of the vegetation.

Every week you will find new deforestation alerts validated for all Brazilian biomes, with several filter options for temporal and territorial analysis.

By selecting one alert, you can view high-resolution images of before and after the deforestation occured.

Access the full report for each rural property that overlaps a deforestation alert and search by CAR code.

Access the website: https://alerta.mapbiomas.org/

Figure 1.1. Overview of the MapBiomas alert system.

Partners

- The Mapbiomas partners span 70 local organizations, including NGOs, universities, and technology start-ups in 14 countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, French Guiana, Guyana, Indonesia, Paraguay, Peru, Uruguay, Venezuela and Suriname).

Alert/sensor data

- The Mapbiomas integrated alerts for Brazil include alerts from: Deter/INPE; SAD/Imazon; GLAD/University of Maryland; SAD Caatinga/Geodatin; SIRAD-X/ISA; SAD Mata Atlântica/SOS Mata Atlântica and ArcPlan; SAD Pantanal/SOS Pantanal and ArcPlan; SAD Pampa/GeoKarten and UFRGS; SAD Cerrado/IPAM.
- High resolution imagery (Planet 4-meter monthly mosaics) is provided as background imagery (Figure 1.1)

Methods

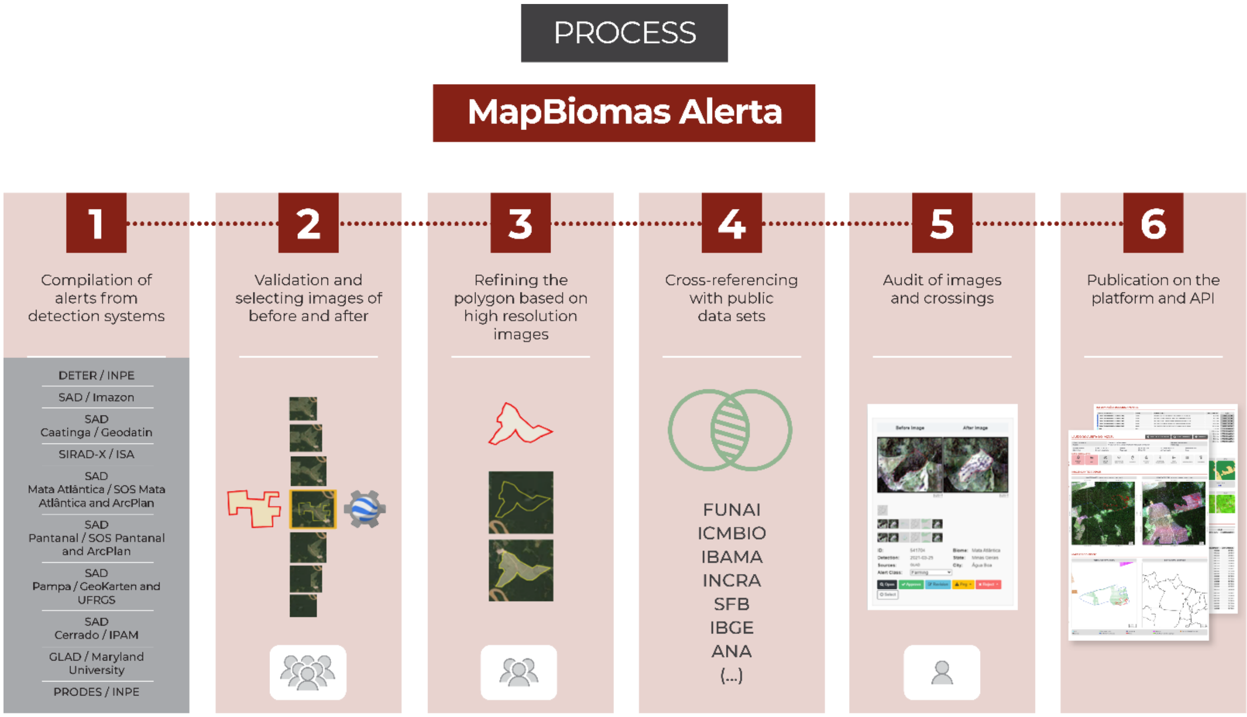


Figure 1.2. Overview of the MapBiomas alert workflow.

A summary of the MapBiomas steps to generate alerts is provided below:

- Alerts from contributing systems are combined monthly.
- Alerts containing land use conversions are identified by selecting overlaps with agricultural areas, and through visual interpretation of the remaining alerts. Images of suspected conversion locations are then purchased to validate that native vegetation originated at that location (Figure 1.2).
- Supervised classification is used to map natural vegetation.
- Drivers are noted by the interpreter.
- Areas of interest are then intersected with land tenure information including boundaries of protected areas, rural settlements, areas registered in the Rural Environmental Registry (CAR), including declared Permanent Preservation Areas (APPs) and Legal Reserves (RL), areas embargoed by the environmental agency, authorizations for suppression and forest management plans by Sinaflor and IBAMA.
- Final polygons are then audited and published on the platform.

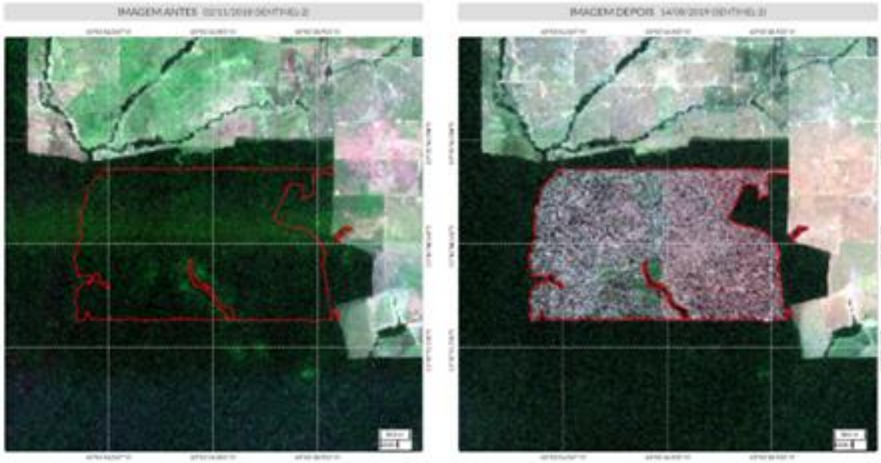


Figure 1.3. Example of Planet images before and after deforestation and the refined polygon of the Cód.93831 of 2019.

Outputs

Three outputs exist: (1) weekly updates of validated alerts along with high-resolution before and after imagery. (2) monthly reports for each deforestation alert detected in Brazil, and (3) an annual report summarizing the year. (e.g. https://storage.googleapis.com/alerta-public/dashboard/rad/2022/RAD_2022.pdf).

Challenges and next steps

- Time-lag of 30 to 90 days, from the date of detection by the source system until publication on the platform in MapBiomas Alerta.
- Limitations related to contributing alert systems, for example, omissions. A system's MMU leads to omission of smaller changes — e.g., 6.25 km in the case of DETER.
- Cloud cover makes visual interpretation challenging.
- The system covers non-forested ecosystems, but further work is required to overcome underestimations of change in biomes such as grassland.

6.2 INPE, Brazil: DETER Amazonia

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Background

Given the challenge to reduce deforestation in the Amazon, since 1988 Brazil has been developed technological innovations in deforestation monitoring. Initially, this was done by releasing annual rates and increments of deforestation by clear-cutting in the Amazon through the PRODES project, carried out by the National Institute for Space Research (INPE). Considering the rapid increase in deforestation rates, especially between 1997 and 2004, the need for a monitoring system able to cope with the rapid changes in forest coverage, and at the request of the Federal Government, led to the implementation of the near-real-time Deforestation alert system (DETER) in 2004 run by INPE. The creation of DETER system was possible due to financial resources provided by the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAM).

Since 2016, DETER Amazônia became a fundamental part of the Satellite Monitoring Program of the Amazon to support governmental agencies in charge of law enforcement and deforestation control in the Brazilian Legal Amazon. Federal, state and/or municipal control agencies have been using DETER alerts, which directly confront environmental crimes related to forest suppression. The high quality, reliability, agility and availability of DETER data enable rapid detection of newly deforested areas, as well as those undergoing forest degradation.

Since 2004, DETER has methodologically evolved (Figure 2.1), expanding and adapting its techniques from Amazonia to Cerrado and Pantanal biomes. The adoption of orbital sensors with higher temporal and spatial resolutions allowed for the detection of smaller deforestation events from 2016 onwards, thus providing more detailed reports. Spatial data, previously available in a less flexible internet environment, has been published since 2019 on the TerraBrasilis portal, developed in partnership with INPE and FUNCATE. It follows an open access policy to facilitate the dissemination of information to civil society, while temporarily being restricted from critical areas with ongoing inspection and enforcement operations.

Partners

- National Institute for Space Research (INPE)

Alert/sensor data

- WFI sensors onboard of the Amazônia-1, CBERS-4 and CBERS 04A satellites, with spatial resolutions of 64m for the first two and 55m for the latter, all of them with a revisit time of 5 days.

Methods

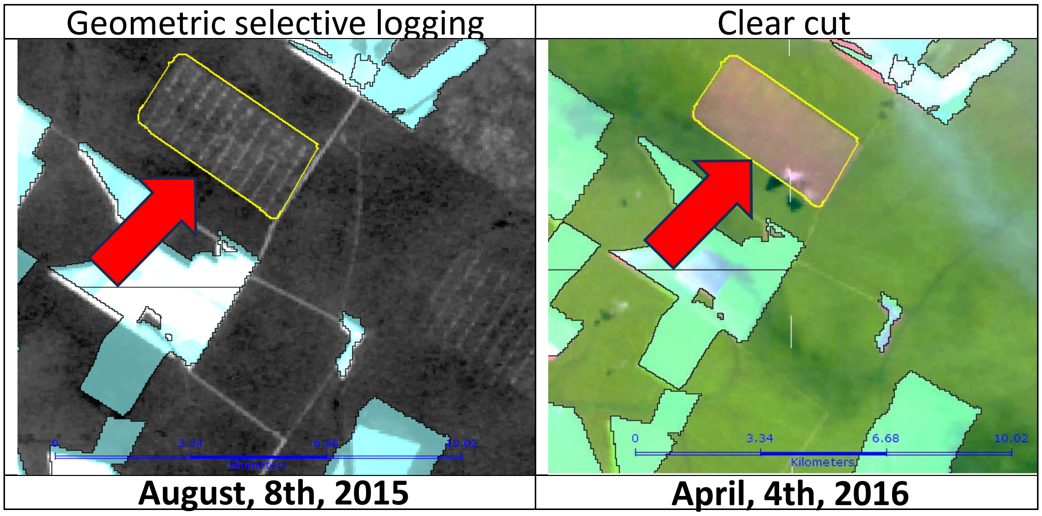
The methodological steps and techniques adopted by the operators of the DETER Amazônia system in their daily routine are presented below:

- **Download available images** from the INPE´s image catalog of WFI sensors onboard the Amazônia-1, CBERS-4 and CBERS 04A satellites.
- **Digital Image Processing:** Color compositions of WFI sensor images are generated using bands 15(R) 16(G) 14(B) and 16(R) 15(G) 14(B) for both CBERS-4 and CBERS 04A satellites. For WFI images from the Amazônia-1 satellite, the compositions used are 3(R) 4(G) 2(B) and 4(R) 3(G) 2(B). To assist interpreters in decision-making during mapping, the Spectral Linear Mixture Model (MLME) technique is employed. This technique involves extracting spectral fractions of soil, vegetation, and shadow from the analyzed area in the chosen bands, using sampled pixels considered to be pure spectral signatures of these fractions.
- **Mapping of deforestation classes:** Clear-Cut, Degradation, Burn Scar, Geometric Selective Logging, Disorderly Selective Logging, Deforestation with Vegetation, and Mining.
- **Visual interpretation of images** is conducted by a multidisciplinary team, based on color compositions, soil, shadow, vegetation fraction images, and a set of multi-temporal images from previous years of LANDSAT data. This stage is carried out based on the main elements of visual interpretation, namely tone, color, shape, texture, and context.
- **Polygon classification** is manually performed using the GIS (Geographic Information System) tool TerraAmazon, developed in partnership with INPE and FUNCATE (Foundation for Science, Applications, and Space Technology). At this stage, to avoid data repetition within already mapped areas or areas outside the limits of primary vegetation, an exclusion mask is generated, considering the vector base from the previous year, the annual deforestation rate of clear-cutting from the PRODES monitoring project, non-forest original vegetation areas and water bodies. This allows the detection of alerts in portions of images not covered by clouds, with areas greater than or equal to 3 hectares.
- **Data availability** is provided through the TerraBrasilis portal, an online platform with an interactive dashboard and GIS tools. This portal serves the rates, increments, and alerts from the deforestation monitoring projects PRODES and DETER, not only for the Amazon but for all other biomes developed by the National Institute for Space Research (INPE).

Figure 2.1. Timeline of DETER systems.

Outputs

The images analyzed on the same day from the three satellite platforms used are combined to eliminate overlap, and also to ensure one or more strips of the Amazon are covered every day. This procedure has made it possible to provide a significant amount of data from the same point in a short period of time. This means that alerts are issued in near-real-time as forest damage occurs, allowing enforcement agencies to obtain information before complete forest cover loss. This is exemplified in Figure 2.2, where an alert issued on 08/08/2015 and classified as geometric selective logging (indicating selective logging of trees) was then converted to clear-cutting on 04/04/2016, highlighting the complete deforestation of the area after approximately 8 months. In this case, enforcement agencies would have had enough time to prevent the complete suppression of the forest inside the indicated polygon in the figure.


Geometric selective logging

Clear cut

August, 8th, 2015

April, 4th, 2016

Figure 2.2. Example of the progression of alerts in the same geographical area over two consecutive years, highlighting the transition from geometric selective logging in 2015 to clear-cutting in 2016. This is a classic deforestation type that data from DETER help to avoid.

Challenges and next steps

- Continuous challenge of cloud cover: development of complementary methodologies based on radar images processing;
- Reduce data generation time and availability to surveillance Brazilian institutions;
- Increase data validation techniques online and/or automatically;
- Inclusion of artificial intelligence (AI) techniques to optimize class detection of the DETER Projects.

Additional information and data access: TerraBrasilis Portal

6.3 Ethiopia: Near-real-time alerts for protecting forests under participatory forest management

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Background

Currently in its third phase (2021-2025), the REDD+ PFM project in SW Ethiopia is producing a near-real-time forest monitoring system using Remote Sensing to detect forest changes in the project area. Having timely observations on changes and information on drivers of deforestation is expected to support local authorities to locate and identify hotspots, count annual and weekly detections, track main drivers, and design a mechanism to respond to changes as they happen.

Partners

- Alliance Bioversity & CIAT (The Alliance, or ABC)
- Ethio Wetlands and Natural Resources Association (EWNRA)
- Development Fund Norway (DF)
- NORAD

Alert/sensor data

- Terra-i NRT vegetation change monitoring system
- Integrated deforestation alerts from Global Forest Watch (GFW). Since GLAD-S2 alerts are not currently available for Ethiopia, this comprises GLAD-L and RADD.

Methods

Monthly alerts from Terra-i and integrated deforestation alerts from GFW are extracted using PFM boundaries and communicated to field officers as .kml files. Through Collect Earth Online, users validate alerts and extract information on drivers of forest change.

Outputs

Forest change alerts are mainly communicated through the Alliance Bioversity & CIAT office, and district-level officers and local staff members of the Ethio Wetlands and Natural Resources Association are provided with capacity building and equipment support to facilitate independent investigation of forest changes using different platforms. The officers also use Forest Watcher to locate areas of change in their territories. In accordance with the forest administrative laws, officers use the NRT information for protecting the PFM administered forests.

Challenges and any next steps

- The detection of small-scale deforestation events, especially during the rainy season, has proven to be challenging in montane moist forests.
- The validation of alerts and identification of drivers often face delays due to limited technological access and field travel restrictions.
- The promising results shown in producing NRT alerts at sub-national levels have attracted the attention of national stakeholders, leading to the development of a dedicated Terra-i system for Ethiopia.

Additional information: Blog

6.4 Guatemala: Near-real-time deforestation alerts

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Background

This system incorporates state-of-the-art technologies, and analyses satellite imagery in an automated process to provide accurate and timely deforestation detection within the country's forest cover. A notification system alerts authorities and stakeholders to deforestation events, allowing quick response. This specifically benefits forestry incentive programs of the National Institute of Forests (INAB).

Partners

- INAB – National Institute of Forests

Alert/sensor data

- Integrated alerts available on GFW. Since GLAD-S2 alerts are not currently available for Guatemala, this comprises GLAD-L and RADD.

In addition, the following layers of interest are used:

- Guatemala Forest Coverage 2020
- Territorial division of Guatemala; Departments and Municipalities
- Administrative Regions and Subregions of the National Institute of Forests (INAB)
- Guatemalan System of Protected Areas
- Forest Incentives 1998-2023
- Mangroves Forest Cover 2022

Methods

The following process is used to generate alerts:

- Alerts are downloaded automatically at 2:00 am every day using the MAKE web service for automating workflows.
- Alerts are stored in a Google Drive.
- Alerts, imagery and layers of interest are processed on ArcGIS Pro at 3:00 am every day. An automated model converts alerts to vector format and are assigned values based on layers of interest. The same model verifies the existence of new alerts by comparing the current layer with the previous day's layer.
- ArcGIS Enterprise stores the alerts web layer and is updated daily.

Outputs

New alerts are published in the web portal. An excel file is updated and shared with the Coordinators of the Forestry Incentive programs, so that they can keep track of alerts. At 10:00 am every day, the model groups alerts by subregion, region, incentive file, and affected ecosystem, and then sends SMS messages and Emails with the alerts shape file to the thematic managers:

1. Subregional Directors
2. Forest Incentive Regional Delegates
3. Forest Incentive Program Coordinators
4. National Technical Coordinator
5. Manager of the institution

After receiving the alerts, the thematic managers must monitor the affected projects, and if deforestation is confirmed, the established administrative process for these cases begins.

Challenges and next steps

- Coordination between government entities responsible for forest conservation and management.
- Lack of resources to follow up on all alerts.
- In future, efforts will be made to reduce response times by the authorities to reduce illegal logging further.
- Request support for incorporating additional types of alerts into 'GFW Integrated Alerts'.

6.5 Indonesia: Places to Watch for Illegal Logging

Author: Benita Nathania, WRI Indonesia (benita.nathania@wri.org)

Background

WRI Indonesia uses GLAD-L alerts to monitor three activities: illegal logging, landscape change, and peatland clearing. This example focuses on illegal logging. First, existing satellite data alerts are combined with contextual data from the Government of Indonesia in order to identify areas with indications of illegal logging. Clusters of alerts are investigated further using high-resolution satellite imagery to determine the causes of illegal logging. The top results are shared every three months in a publicly available blog known as Places to Watch for Illegal Forest Logging, so that local governments, forest management units (KPH), civil society organizations, forest guards and other stakeholders in forest protection initiatives can follow up on these areas of potential illegal logging.

Partners

- Government of Indonesia Ministry of Environment and Forestry (KLHK)
- Leuser Conservation Forum (Forum Konservasi Leuser or FKL)
- Independent Forestry Monitoring Network (Jaringan Pemantau Independen Kehutanan or JPIK).

Alert/sensor data

- GLAD-L alerts from the University of Maryland.

Methods

Identifying areas of illegal logging is done by filtering alerts using spatial data from the Ministry of Environment and Forestry, including forest area, land cover (primary forests) and forest utilization permits. Clusters are then identified within 5x5 km grid cells, using a Z-score analysis. Clusters in proximity to one another but in separate grids are merged, and then the largest clusters by alert area are identified for follow up. The top 10 regions are investigated further. Satellite images (Planet, Landsat, Sentinel – accessed on the GFW website) are used for visual assessments, with the aim of verifying that a disturbance has occurred (locations without identified disturbances are removed) and then subsequently identifying the cause of disturbance. Signs of plantations, agriculture, mining, aquaculture or selective logging are noted, and where no clear follow up land use is identified, it is assumed to be ‘land banking’ or speculation whereby land is cleared to claim land tenure before it is used for other activities. Areas where natural disturbances are identified, are also removed from the analysis (Figure 5.1).

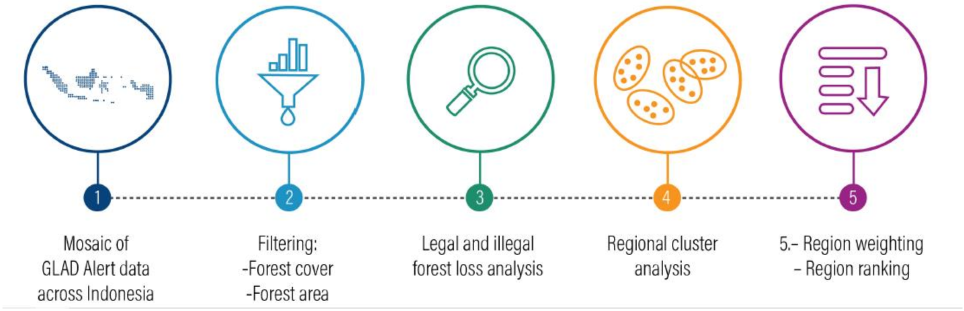

Figure 5.1. Methods to identify illegal logging under the Places to Watch method.

Outputs

The analysis is carried out every 3 months, identifying the 5 locations with the greatest concern for illegal logging. A blog post is released detailing the location and potential causes of deforestation. This information is used by GFW partners such as the Leuser Conservation Forum and the Independent Forestry Monitoring Network who carry out field verification of the locations.

Challenges and next steps

- GLAD-L alerts are optical, so clouds limit the effectiveness of the system.
- Errors (false positives) are also common in tidal areas and areas with high seasonality.
- Field visits and interviews with local communities to identify whether clearing is indeed illegal are often necessary, costly and time-consuming.
- A lack of up-to-date official documentation also makes identification of illegal activities challenging.

More information: [Places to Watch 12th Edition: Five Indicated Illegal Logging Area in Indonesia | WRI Indonesia (wri-indonesia.org)]

6.6 Lao PDR: Near-real-time Provincial Deforestation Monitoring System (PDMS) Implementation

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Background

Since 2018, Lao PDR has been piloting and implementing satellite-based forest monitoring, with the support of development partners, to assess and tackle deforestation driven by the agricultural expansion, shifting cultivation, infrastructure development and uncontrolled logging.

The Provincial Deforestation Monitoring System (PDMS), developed by the Japan International Cooperation Agency (JICA), provides near real-time remote sensing-based deforestation alerts, enables the local governmental institutions to conduct field verification for forest law enforcement on the ground, and provides a framework for reporting at various institutional levels. PDMS is considered an important tool for the implementation of the PMO 11 (Prime Minister Order – July 2023), which focuses on Strengthening Strictness on Managing, Protecting, Developing and Utilizing Forest and Forestland.

The PDMS, initially designed for the province level, has been endorsed by the Department of Forestry as a tool of national importance to strengthen forest monitoring.

Partners

- Department of Forestry (DOF), Department of Forest Inspection (DOFI) and their local offices, under the Ministry of Agriculture and Forestry, Lao PDR
- Japan International Cooperation Agency (JICA)

Alert/sensor data

- Sentinel-2 MSI Level-2A data

Methods

A Deforestation Detection Script on Google Earth Engine (GEE), using Sentinel-2 MSI Level-2A data, derives a forest loss image in a selected province by performing direct change classification using predictor variables generated from two images from different observation periods. Planet Basemaps for Tropical Forest Monitoring help to verify the result of the deforestation analysis.

Outputs

PDMS Web Application designed for a total of 18 provinces, facilitating deforestation analysis, verification, field-check requests, data storage and reporting.

PDMS applications are available in Lao language and tailored for local users such as provincial and district forest officers, requiring little specific GIS and remote sensing skills. The system has minimal operating costs due to freely available satellite imagery and open-source software.

With the PDMS Web Application (Figure 6.1), officers from the Provincial Agriculture and Forest Office (PAFO) can visualize deforestation areas provided by the Deforestation Detection Script on a weekly basis. Within the Application, they can scrutinize alerts and identify priority areas for field checking by referencing Planet data and other data layers such as national park and/or village land-use plans.

The areas selected for field checks are sent to officers from the District Agriculture and Forest Office (DAFO) who then collect information with a Mobile Device Application. Mobile Device Applications enabling field-checks by district forest offices using OruxMaps and ODK Collect for data collection and submission. The Web Application displays information from any visited plots, as well as a summary report, through a dashboard. All data are stored on a server under the responsibility of the Forest Inventory and Planning Division of the Department of Forestry.

Challenges and any next steps:

- Some challenges remain such as the implementation of law enforcement on the ground, insufficient numbers of local forest officers, and travel costs with limited operational budgets.

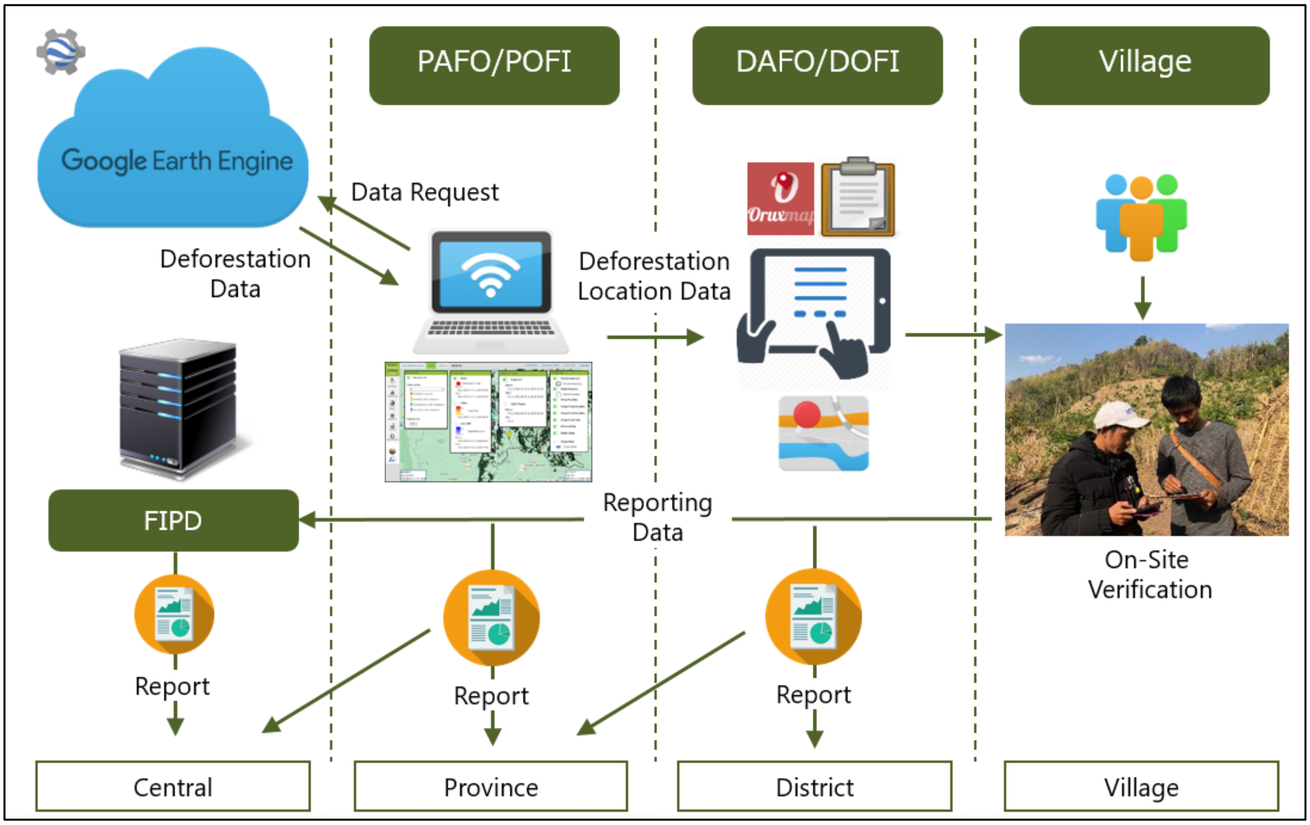

Figure 6.1. PDMS workflow in Laos.

6.7 Peru: National Program for the Conservation of Forests for Climate Change Mitigation (PNCBMCC)

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Background

PNCBMCC developed an MRV system in 2015 for reporting, but also wanted a deforestation alert system to assess deforestation within project sites of its Direct Conditional Transfer Program with indigenous communities. Since building the system, PNCBMCC has increased collaboration with the parks service and regional environmental prosecutors, who use the information to identify potential illegal deforestation on a regular basis and to apply legal remedies. The system covers the humid tropical forest in Peru.

Partners

Developers:

- Peru's Ministry of Environment

Users:

- PNCBMCC's Direct Conditional Transfers program
- Peru's Protected Areas Service and Environmental Prosecutor's Office
- Civil society organizations and communities
- The parks service and regional environmental prosecutors

Alert/sensor data

- Landsat data.

Previously the PNCBMCC used existing alerts, such as GLAD and JJ-FAST for near-real-time monitoring, as there were no requirements about country ownership. Then, after proving the utility of the system and determining what they wanted to improve, PNCBMCC developed its own system that is more attuned to the local context – for example, better detecting forest roads and smaller deforestation patches, and reducing false positives in flooded areas.

Methods

The alerting system uses a Direct Spectral Unmixing approach that is similar to Peru's annual forest cover loss monitoring (Vargas et al., 2019). However, the alerting system approach is less rigorous in the detection of cloud cover, post-processing removal of errors, etc. and alerts are updated semi-automatically on a weekly basis.

To detect deforestation alerts, we developed a new method called Direct Spectral Unmixing (DSU). DSU is based on the Linear Spectral Mixing Model (LSMM), which provides quantitative information about the materials that make up the pixel. LSMM assumes that the spectral response of a pixel is the linear combination of the materials inside the pixel (Endmembers).

DSU only uses endmembers for forest and forest loss, and assumes that when a pixel loses forest cover due to natural or anthropogenic causes, the result may be a pixel with bare soil, a mixed pixel with dry soil and vegetation, or deforestation debris such as tree logs that can also mix with standing forests. The endmembers used in this study were obtained from Landsat images. The advantage of extracting endmembers directly from the images is the ease with which they can be obtained and their similarity in scale to the data (Roberts et al. 1998).

Outputs

PNCBMCC has sought to make alerts readily available to the public through its Geobosques platform, which allows users to view and download the data, as well as sign up for notifications of new alerts in their area of interest. PNCBMCC also provides additional data layers on its Geobosques web platform, such as recent satellite imagery and boundaries of protected areas and concessions, to assist users in prioritizing alerts. In addition, it provides detailed reports, with before and after images, to partner agencies for areas of interest, such as protected areas. The Ministry provides regular training on the platform, with a focus on staff within Peru's Protected Area Service and Environmental Prosecutor's Office.

Communities use the information for their Direct Conditional Transfers program, since they must provide a field report for any alerts detected within their conservation area. If it is determined that the community violated their agreement, they may be dropped from the program. The Protected Area Service also regularly uses alerts to help plan patrols and identify areas of illegal activity. If they find evidence of illegality, they may destroy equipment and involve the Environmental Prosecutor's office. Many other civil society organizations in Peru use these alerts and those from global systems to prioritize patrol efforts, provide evidence of illegality in legal complaints, and expose illegal deforestation (Figure 7.1).

Figure 7.1. How Deforestation Alerts are used in Peru.

Challenges and next steps

With optical imagery only, cloud cover often delays deforestation detection in the Amazon. Improving detection during cloudy periods is a next step and experiments have begun with radar sensors such as ALOS-2 PALSAR-2.

More info:

- Vargas, C., Montalban, J. and Leon, A.A. (2019). Early warning tropical forest loss alerts in Peru using Landsat. Environmental Research Communications, Volume 1, Number 12
- Weisse, M., Nogueron, R., Vicencio, R.E.V. and Castillo Soto, D.A. (2019). Use of Near-Real-Time Deforestation Alerts. A Case Study from Peru. World Resources Institute.

6.8 Forest Foresight: Gabon (Early warning alerts)

Author: Jorn Dallinga, WWF Forest Foresight (jdallinga@wwf.nl)

Background

Forest Foresight is an innovative AI-driven technology developed by WWF and partners that uses satellite imagery and machine learning to predict with ~70% accuracy where deforestation is expected to occur within six months. Through the use of Forest Foresight and the power of prediction, developers aim to empower local stakeholders to act on the ground and intervene before forest damage occurs. It will empower law enforcement authorities, governments, civil society organizations, and the private sector in their efforts to prevent unwanted or illegal deforestation and meet their environmental commitments.

Partners

The institutions and NGO's in Gabon:

- Directorate General for the Environment and Nature Protection
- Directorate General of Aquatic Ecosystems
- Directorate General of Forests
- National Agency of National Parks
- Gabonese Agency for Studies and Space Observation (AGEOS)
- Agency for the Execution of Activities of the Forest Wood Sector
- BrainForest (NGO)
- The Nature Conservancy (NGO)

Other partners:

- WWF
- Wageningen University
- Deloitte.

Alert/sensor data:

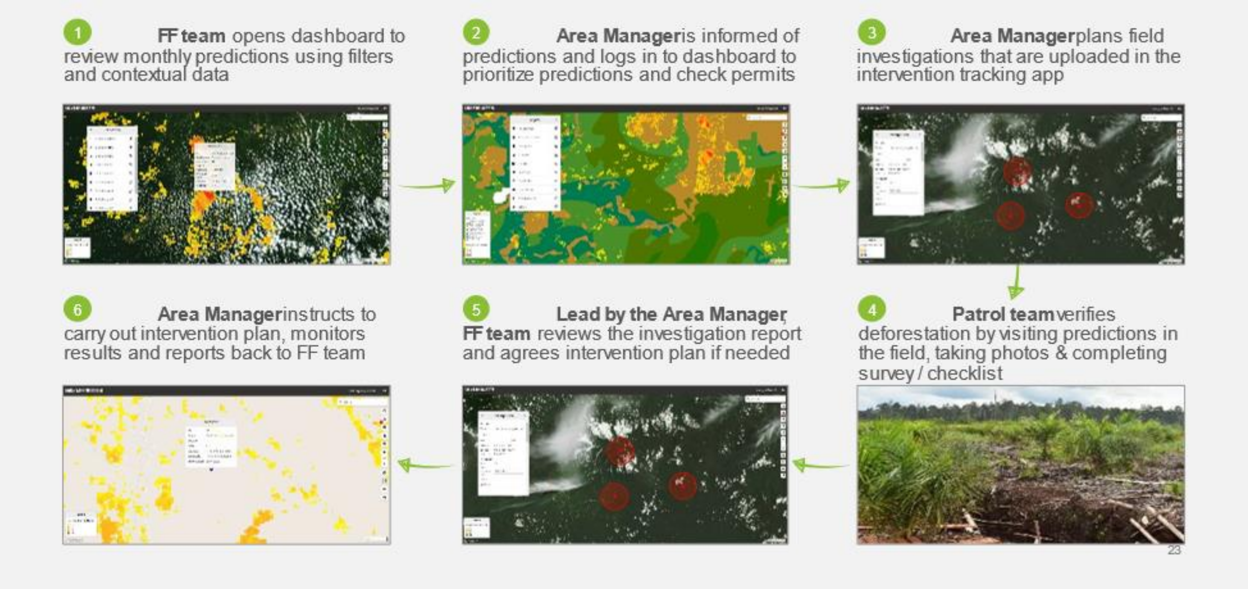
- RADD alerts from the past 6 months.
- NASA VIIRS fire alerts (*link*) from the past 6 months
- Other datasets such as road datasets, elevation and land use

Methods

Forest Foresight runs once per month across the landscape. Alerts from the previous 6 months are utilized in the XGBoost algorithm with ensemble trees and a pretrained model. The predictions are converted to a platform-readable datatype. RADD alerts are also used to verify the accuracy of predictions.

Outputs

The model is run within nationally owned landscapes that are provided by local stakeholders and government agencies. The deforestation prediction can be visualized either on the platform or as a service on the platform of stakeholders. Stakeholders may plan interventions to prevent deforestation based on this information (Figure 8.1).



1 **FF team** opens dashboard to review monthly predictions using filters and contextual data

2 **Area Manager** is informed of predictions and logs in to dashboard to prioritize predictions and check permits

3 **Area Manager** plans field investigations that are uploaded in the intervention tracking app

4 **Patrol team** verifies deforestation by visiting predictions in the field, taking photos & completing survey / checklist

5 **Lead by the Area Manager, FF team** reviews the investigation report and agrees intervention plan if needed

6 **Area Manager** instructs to carry out intervention plan, monitors results and reports back to FF team

Figure 8.1: A typical end-to-end Forest Foresight process.

Challenges and next steps

Forest Foresight's pilot in Gabon saw successful engagement from stakeholders. The technology was found to be cost-effective, with affordable maintenance. Based on strong political will and stakeholder engagement, including a commitment from the government for adoption, a scaling phase has begun. This includes improvements such as increasing prediction accuracy, incorporating driver information, developing cloud infrastructure and improving data visualization. Globally, Forest Foresight aspires to be adopted across 15 landscapes in 12 countries in WWF's deforestation fronts by 2027.

Some challenges, which are being addressed during the scaling phase, still exist:

- Poor quality roads make preventative actions in remote areas difficult and expensive.
- Monitoring the impact of short-term projects is beyond the scope of Forest Foresight since combatting deforestation entails a substantial long-term investment.
- Uptake is slow as institutions need time to evaluate and adopt new technologies.