EARLY WARNING
WORKING GROUP

User Needs Assessment for Forest Change Early Warning Systems

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GFOI Global Forest Observations Initiative

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Contents

List of Acronyms

ACA – Amazon Conservation Association

ACCA – Association for the Conservation of the Amazon Basin (Asociación para la Conservación de la Cuenca del Amazonas)

ACTO – Amazon Cooperation Treaty Organization

AWF – African Wildlife Foundation

BFAST – Break detection For Additive Season and Trend

CENSIPAM – Centro Gestor e Operacional do Sistema de proteção da Amazônia

CFT – Compagnie Forestiere et des Tranformations

CNMIA – Centro Nacional de Monitoramento e Informações Ambientais

CSO(s) – Civil Society Organization(s)

CIGN – Centre d'Information Géospatiale et Numérique

CURAT – Centre Universitaire de Recherche Appliquée en Télédétection

BNETD – Bureau National d'Etudes Techniques et de Développement

DETER – Brazil's Real Time Deforestation Detection System (Sistema de Detecção de Desmatamentos em Tempo Real)

EW – Early Warning

FAO – Food and Agriculture Organization of the United Nations

FEMA – Office of the Environmental Prosecutor in Peru (Fiscalia Especializada en Materia Ambiental)

FIPI - Forest Inventory and Planning Institute

GFC – Ghana Forestry Commission

GFW – Global Forest Watch

GIS – Geographic Information Systems

GFOI – Global Forest Observations Initiative (GFOI)

GFW – Global Forest Watch

GLAD – Global Land Analysis and Discovery lab of the University of Maryland

HaKA – Hutan Alam dan Lingkungan

IBAMA – Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - Centro Nacional de Monitoramento e Informações Ambientais (CNMIA)

IBC – Instituto del Bien Común

ICMBio – Instituto Chico Mendes de Conservaçao da Biodiversidade

JICA – Japan International Cooperation Agency

KPK – Natural Resources Corruption Eradication Unit for Natural Resources

LAPAN – Lembaga Penerbangan dan Antariksa Nasional

MINAM – Ministry of the Environment of Peru (Ministerio del Ambiente)

MRV – Monitoring, Reporting and Verification

NRT – Near-real time

OIPR – Office Ivoirien des Parcs et Réserves

OSINFOR – Agency for the Supervision of Forest Resources and Wildlife (Organismo de Supervisión de los Recursos Forestales y de Fauna Silvestre)

PNCBMCC – National Forest Conservation and Climate Change Mitigation Program (Programa Nacional de Conservación de Bosques y Mitigación de Cambio Climático)

REDD+ - Reducing Emissions from Deforestation and Degradation

SEPAL – System for Earth observations, data access, Processing & Analysis for Land monitoring

SERFOR – National Forest Service of Peru (Servicio Forestal del Perú)

SERNANP – National Protected Areas Service of Peru (Servicio Nacional de Areas Naturales Protegidas)

SNCV – National Monitoring and Control System (Sistema Nacional de Control y Vigiliancia)

SNIFFS – Sistema Nacional de Información Forestal y de Fauna Silvestre

SDG – Sustainable Development Goal

UMD – University of Maryland

UNCBD – United Nations Convention on Biological Diversity

UNFCCCC – United Nations Framework Convention on Climate Change

USAID – United States Agency for International Development

USGS – United States Geological Survey

WRI – World Resources Institute

WUR – Wageningen University and Research

Executive Summary

The Early Warning (EW) Working Group together with GFOI stakeholders performed a user needs assessment (UNA) on tropical deforestation EW systems. The UNA sought to determine how such technologies are being used and to identify opportunities for improvements that can meet country needs. The three objectives of this UNA were:

1) Assess current state of EW technologies for forest monitoring, including their technical specifications and other notable features related to operational systems,
2) Capture user experiences to date with EW technologies,
3) Consult providers of EW technologies to identify how they currently assess and seek to address user needs, and determine the best way to identify and communicate user needs to providers for consideration and possible action.

The UNA was performed from the beginning of February to the end of June 2018. Initially, the procedure was discussed with the FAO and WRI and then consolidated with other GFOI stakeholders during the GFOI Plenary held in Bogotá, Colombia, from 12th to 16th of March. The UNA collected responses from a series of institutions (18 respondents in eight countries) across the tropical countries which activities require early-stage forest cover change information. An online questionnaire available in English, French and Spanish was designed to capture their experience and needs. In Peru, a series of in-person interviews was also performed. In parallel, a second questionnaire was sent to some expert tool developers which scientific and technological contributions provide support to the advancement of EW systems. This report presents a synthesis of this assessment and a series of recommendations for consideration by GFOI stakeholders towards improved technical capability and usability of early warning technologies.

The UNA demonstrated that most surveyed entities develop and/or use EW systems to respond to the same objectives with national and international policy contexts ranging from climate change mitigation to biodiversity loss and Sustainable Development Goals (SDG). Five out of the eight surveyed countries indicated that EW system information is already recognised as a source of evidence by Legal authorities (court, law enforcement). All respondents reported commitment to raising public awareness. Local landholder empowerment was mentioned by five respondents. Most of respondents reported coordinating their work with a variety of stakeholders such as Universities, NGOs and governmental agencies including top levels (e.g., Presidency in Ivory Coast). Some respondents indicated that better coordination can help progress while others reported issues due to dysfunctional coordination (e.g., lack of governance, data sharing issues, or corruption). Overall, ten out of 18 respondents have developed Standard Operations Procedures to operate their EW system.

Although some respondents benefit from advanced and operational systems while others are some steps behind for the moment, all of them face a series of institutional barriers (e.g., coordination issues across stakeholders, corruption, lack of governance, budget limitations, personnel skills) and technological barriers (e.g., Earth Observation and ground data availability, cloud coverage in optical

data and difficulty to access and use SAR data, tool and system interconnections, internet access) to fully meet their specific monitoring needs. Beyond the expected needs for accurate change detection and follow up land use characterisation, the need for accurate identification of forest cover change date and accurate estimation of changed surface have been expressed in relation to prosecution matters. Need for monitoring techniques that work well outside rain forests was also reported (e.g., Andean forests, mangroves, peatland, savannas). The request for training was expressed in relation to the aforementioned technological barriers and to meet some country-specific needs.
Among the five surveyed tools (GLAD Alert system, JJ-Fast, WUR and DLR change detection toolboxes, Open Datacube), two consist in operational change detection systems. The GLAD Alert and JJ-Fast systems are available for 22 and 77 countries, respectively. The survey showed that all tool developer experts take user needs into consideration to develop and update their technologies. Developers are notably working on improving their tools to make them more flexible regarding data input. Therefore, technological progress towards some of the expressed user needs is likely to occur in a near future. Importance of using open source solutions and having a country-owned system were expressed by a majority of country respondents. Activities of the EW WG should be developed following this approach and aim.

Based on the outcomes of this survey, this report provides a series of recommendations for consideration by GFOI stakeholders. Recommendations include guidance for further development by workshops, joint publications, and development of training materials. Suggestions for targeted research and development (R&D) activities that could be catalysed by the EW WG were provided. Such recommendations are the results of the UNA. R&D topics such as development of SAR-based and optical-SAR-based change detection techniques, development of methods allowing early discrimination of anthropic and natural drivers of change, and development of tools facilitating field work were the most relevant. The use of the newly developed Criteria for consistently Assessing Levels of Maturity (CALM) framework by GFOI would provide strong support to such R&D activities. Overall, reference to CALM framework is advised and should be fostered across all components of GFOI mainly to scale tool readiness and assess progress and to provide guidance to countries.

In conclusion, the fact that countries demonstrate several common core needs facilitates prioritization of R&D and capacity development efforts. Some surveyed countries demonstrated more advanced technologies and practical knowledge than others. This suggests that a South-South cooperation approach, complementary to the current GFOI activities, could be incentivised. Some past GFOI workshops have already set the stage for such an approach. The International Forum on Forest Early Warning Systems to be held in Lima, Peru, 9-10 July 2018 can be another opportunity to develop potential country cooperation.

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1. Background and Objectives

In 2017, a working group of international partners was established to consider Early Warning (EW) systems for forest cover change and options for improving the availability and uptake of these technologies to support improve forest management in developing countries. To guide its efforts, the Early Warning Working Group (EW WG) has undertaken a user needs assessment (UNA) on tropical deforestation EW to determine how such technologies are being used and to identify opportunities for further improvements that can meet specific country needs.

The objectives of the UNA are:

1. Assess the current state of EW technologies for forest monitoring, including their technical specifications and other notable features of operational systems,

2. Capture user experiences to date with EW technologies. Target users include national and sub-national government officials, law enforcement agencies, policy makers, and land managers, and, where appropriate, civil society organizations. Specific objectives were to:

   a. Produce a typology of existing or desired features and applications by user (e.g., law enforcement, fires, reporting),
   b. Confirm the technical requirements for operational EW systems,
   c. Build an understanding of compatible policy settings and institutional arrangements to facilitate the uptake and sustained use of EW technologies,
   d. Assess barriers to the implementation of EW technologies and identify possible solutions,
   e. Determine what kind of assistance may be needed from the international community to improve EW capacities in country,

3. Consult providers of EW technologies to identify how providers currently assess and seek to address user needs, and determine the best way to identify and communicate user needs to providers for consideration and possible action.

This report presents a synthesis of the results from this assessment and a series of recommendations for how GFOI stakeholders could support improved technical capability and usability of EW technologies.

The Global Forest Observations Initiative (GFOI) is an international partnership for coordinating the delivery of forest monitoring and greenhouse gas accounting support to developing countries. The group is led by representatives from Australia, the Committee on Earth Observation Satellites (CEOS), the European Space Agency (ESA), the Food and Agriculture Organization (FAO) of the United Nations, Norway, the UK, the USA and the World Bank. GFOI is supported by a range of other contributing

partners, including the World Resources Institute (WRI) and others.

2. General Approach

The UNA was performed between the beginning of February and the end of June 2018. The approach was primarily discussed with the GFOI Office hosted by FAO and WRI, and consolidated in consultation with the other EW WG members and other stakeholders during the GFOI Plenary in Bogota, Colombia, 12-16 March, 2018. The UNA targeted a series of institutions across tropical countries where activities require early-stage forest cover change information. An online questionnaire available in English, French and Spanish was designed to capture their experience and needs. In Peru, a series of in-person interviews was also performed. Concurrently, a second questionnaire was sent to international experts and tool developers whose scientific and technological contributions support to the advancement of EW technologies.
The next two sections of this report present the approach, the results and a synthesis for each the two surveys. The final section provides recommendations to GFOI stakeholders for possible follow-up actions.

3. Country Expert Survey

3.1. Presentation

The Country Expert questionnaire was designed to capture: the policy and institutional context for EW technologies either as they are currently used or are needed, potential institutional and technical barriers, available resources (platforms, datasets and tools), and the type of training that may be needed.
Targeted countries and respective institutions were selected based on connections from GFOI stakeholders among people already using EW systems, or that have an interest in such systems. Table 1 lists the contributors to the survey.

Table 1. Country Expert contributors to the survey.

Country	Institution	Respondent
Peru	SERFOR - Servicio Forestal del Perú	Ms. Lucy Rocío del Carmen Malleux Hernani - General Director
	PNCBMCC - Programa Nacional	Mr. Daniel Castillo Soto -

	de Conservación de Bosques y Mitigación de Cambio Climático	Technical Assistance Coordinator
	SERNANP – National Protected Areas Service of Peru (Servicio Nacional de Areas Naturales Protegidas)	Mr. Edgar E. Vicuña Miñano, Mr. Benjamin Lau - Director of Strategic Development
	OSINFOR - Organismo de Supervisión de los Recursos Forestales y de Fauna Silvestre	Mr. Carlos Rafael Candia Dipaz - Coordinador, GIS Specialist
Argentina	Forest Agency (Environmental and Sustainable Development Ministry) - Dirección de Bosques - Ministerio de Ambiente y Desarrollo Sustentable de la Nación	Ms. Yamila Barasch - FAO Consultant
Brazil	CENSIPAM - Centro Gestor e Operacional do Sistema de proteção da Amazônia	Ms. Tahisa Kuck - Analyst Dr. Miguel Archanjo Bacellar Goes Telles Junior - Assessor
	IBAMA - Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - Centro Nacional de Monitoramento e Informações Ambientais (CNMIA)	Mr. George Porto Ferreira - Coordenador-Geral
Democratic Republic of Congo	DIAF - Direction des Inventaires et Aménagements Forestiers - Ministère de l'Environnement et Développement Durable	Mr. André Mpongo - GIS Technician
	CFT - Compagnie Forestiere et des Tranformations - Concessionnaire forestier	Ms. Beverly Yanguile - Légalité & Administration Ms. Cécile Lubwilu Lolo - Responsable Cellule Aménagement et Cartographie
	AWF - African Wildlife Foundation	Mr. David Williams Director-Conservation Geography
Ghana	GFC - Ghana Forestry	Mr. Yakubu Mohammed

	Commission	
Ivory Coast	OIPR - Office Ivoirien des Parcs et Réserves	Mr. N'Dri Pascal Kouame
	CNTIG - Comité National de Télédétection et d'Informations Géographiques – Présidence de la République	Mr. Fernand Bale Directeur Ingénieurie et Projets
Indonesia	LAPAN - Lembaga Penerbangan dan Antariksa Nasional/ Indonesian National Institute of Aeronautics and Space	Dr. Ms. Orbita Roswintiarti - Deputy Chairman for Remote Sensing Affairs
	KPK - Natural Resources Corruption Eradication Unit for Natural Resources at the Corruption Eradication Commission	Mr. Dian Patria
	HaKA - Hutan Alam dan Lingkungan (NGO in Aceh)	Mr. Agung Dwinurcahya - GIS Manager
	NFRM - National Forest Resources Monitoring - Ministry of Environment and Forestry	Mr. Judin Purwanto
Vietnam	FIPI - Forest Inventory and Planning Institute	Mr. Nguyen Cao Tung - Head of FIPI's Remote Sensing Centre

3.2. Results

This section provides the most important findings captured during the interviews, summarised at country level. Annex 1 provides the detailed transcripts of the interviews, while section 3.3 provides an overall synthesis of the findings.

AFRICA

In the **Democratic Republic of the Congo** (DRC), DIAF which belongs to the Ministry of Sustainable Development, uses the GLAD Alert system in the context of REDD+ monitoring and reporting activities, with illegal logging and concession monitoring as main applications. Information from the EW system is recognised by the legal system. Forest cover change and follow up land use is the most

important information needed by DIAF. Support is provided on the use of the GLAD Alert system (WRI) and the use of GIS systems in general (FAO Forestry). AWF, an NGO interviewed during the survey, supports also the government in improving management effectiveness and facilitating data provision. DIAF is not an EW system developer, however the use of a country-owned solution is considered as important.
CFT, a forestry company, uses also the GLAD Alert system with illegal logging within their concessions as main application. Very high spatial resolution imagery is needed, and Google Earth imagery is used in the absence of airborne sensors. Support was requested on development of precise digital elevation models.

In **Ivory Coast**, two governmental entities interviewed have been identified as EW system developers. Use of a country-owned EW system was seen as important by both respondents.
The CNTIG which is the National Committee on Remote Sensing and Geographic Information, is directly linked with the Presidency. Strong coordination is made with Ministries, Universities and NGOs to develop an EW system that has been operational for a year. The institutional and legal frameworks are still under development to recognize officially the EW system information. Main applications are illegal logging and protected area monitoring in the context of REDD+. Forest cover change and follow up land use constitute the most important information needed. Very high spatial resolution data is used to characterise follow up land use after change has been detected. The System for Earth observations, data access, processing & analysis for land monitoring (SEPAL) is used for improved data storage and computation power. Training is followed on remote sensing in general and mobile applications.
The OIPR, which is the Parks and Reserves Office of Ivory Coast, develops its own EW system to support management of protected areas with illegal logging monitoring as main application. The system is not operational yet. No coordination with another entity is declared, however the SEPAL system from FAO is used for higher computational capacity. The EW system is not recognised by the Legal system (*Parquet*) yet. The *Parquet* requests more tangible evidences such as material/ physical evidences. The EW system is seen as a tool to guide persons towards such material/ physical evidences. Data and resource sharing issues are reported as main institutional barriers. Forest cover change and follow up land use is the most important information needed by CNTIG. Current optical data used is not considered as satisfying to meet objectives due to cloud cover and spatial resolution (>=10m spatial resolution).

In **Ghana**, the Forestry Commission uses a non-yet fully operational EW system for activities related to REDD+. Main activities are investigation of illegal logging and management of protected areas. Use of a country-owned EW system is seen as important. Work coordination is made with academic research, NGOs, and local authorities. The EW system is recognised as an official source of information by Law enforcement. MODIS fire products are notably used to detect hotspots. Early detection of fire and illegal mining is critical to mitigate their impact. Hence high temporal and spatial resolution data is needed for both phenomena that can spread quickly. Training is needed on remote sensing and GIS applications, and forest inventory systems.

SOUTH AMERICA

In **Argentina**, the *Dirección de Bosques - Ministerio de Ambiente y Desarrollo Sustentable* is developing an EW system for activities related to REDD+ and national Law on native forests. The system is not operational yet. Main information needs relate to illegal logging, concessions' monitoring and compensation programs. Work is coordinated with investigation institutions and the National Commission on Spatial Activities (*Comisión Nacional de Actividades Espaciales*). The EW system is not recognised by the Legal system yet. Argentina as a Federal State, has a decentralised environmental (incl. forest) monitoring scheme which makes difficult the implementation of monitoring systems. Additional institutional barriers are related to limited human and economic resources. Human resources, internet bandwidth, and technical knowledge are cited as additional barriers to achieve the completion of the EW system. Remarkably, minimum mapping area varies from five hectares to 50ha, depending on the forest type, and local deforestation type. Both optical and SAR data are used. The use of a country-owned system is seen as important.

In **Peru**, four governmental entities were surveyed. Two are affiliated with the Ministry of Environment (MINAM): the *Programa Nacional de Conservación de Bosques para la Mitigación del Cambio Climático* (PNCBMCC) and the *Servicio Nacional de Áreas Naturales Protegidas* (SERNANP). The *Servicio Nacional Forestal* (SERFOR) is affiliated with the Ministry of Agriculture and Irrigation (MINAGRI), and the *Organismo de Supervisión de los Recursos Forestales y de Fauna Silvestre* (OSINFOR) belongs to the *Presidencia del Concejo de Ministros* (Presidency of the Council of Ministers).

SERFOR and PNCBMCC use EW system information notably for activities related to REDD+ and the SDGs. SERNANP and OSINFOR use EW system information for activities related to biodiversity conservation in protected areas (linked to United Nations Convention on Biological Diversity (UNCBD)), and legal and sustainable use of forest and wildlife resources, respectively.

The MINAM's PNCBMCC GeoBosques platform disseminates PNCBMCC's EW alerts previously disseminated by the University of Maryland's GLAD Alert system. PNCBMCC mentioned uncertainty about the availability of GLAD Alert system over time as an incentive to develop the PNCBMCC EW alert system available through GeoBosques.

SERFOR has developed a Satellite Monitoring Unit (UMS) focused on the use of EW for rapid action against deforestation. The UMS initiated actions in 2017 focusing on using EW information to analyse and identify the activity that has caused the forest use change, in addition to the affected area and forest heritage, among other analyses. The main objective is, as a forestry governing body, to provide detailed and timely information to generate adequate control actions for decision makers at the local, regional and national levels. Main reason expressed by SERFOR to develop an enhanced EW system is the timeliness of information provision across institutions.

The work done by the UMS is framed within the *Sistema Nacional de Información Forestal y de Fauna Silvestre* (SNIFFS[1]). SNIFFS will produce its own EW information incorporating Sentinel-2 data in a near

[1] https://www.serfor.gob.pe/sniffs/reportes-de-alertas/reporte-de-alerta-de-deforestacion

future. Likewise, the EW information analysed by the UMS feeds the Forest and Wildlife Control and Surveillance National System (SNCVFFS), which aims to bring together all government stakeholders to coordinate the application of the law and control actions. Both systems are conducted by SERFOR, and are legally recognized within the forestry law.

The SNIFFS is responsible for managing information related to forest heritage, and is composed of modules. One of them is the Forest Coverage Monitoring Module (MMCB), which includes the EW sub-module, which is located in the EW System of the PNCB and GLAD alerts. The MMCB is coordinated by PNCBMCC and SERFOR.

SERFOR is currently working with JICA on how complementary optical and SAR (with JJ-FAST) satellite data sources can be in order to improve further EW information. SERFOR coordinates activities also with WRI (GLAD Alert system), the *Associación para la Conservación de la Cuenca Amazónica* (ACCA), Japan International Cooperation Agency (JICA), United States Agency for International Development (USAID), and local authorities. Additionally, SERFOR will soon deliver drones to regional authorities to support validation, surveillance, control actions, and inventory activities.

To date SERNANP considers that commission errors of GeoBosques platform are too numerous. SERNANP plans to train a team dedicated to the use of GeoBosques and considers inclusion of high spatial resolution data in its forest monitoring activities. SERNANP is developing also an online system to produce information and generate reports on forest change in natural protected areas. The system is expected to become operational in 2021. The need for a route planning tool to optimize ranger activities on the ground based on detected changes is expressed by SERNANP.

Regarding PNCBMCC's alert system, once a change has been detected by the EW system, Sentinel-2 data is used to estimate precisely the area of change, and also for detection of forest degradation, however usability of Sentinel-2 data for this purpose is ongoing. Planet data is also considered as useful for validation purposes. PeruSat-1 data can be useful but access remains difficult. Overall in Peru, pending issues relate to cloud coverage and shadows in optical imagery hamper capability to detect changes. Early distinction between anthropic and natural causes of change remains a challenge. Precise date of change is important notably when landownership changes. The correct person responsible for an illegal change must be identified. There is also a need to extend the EW system to other forest types such as dry forests and Andean forests. Other barriers are reported such as a lack of information/ communication among stakeholders, corruption, and training notably for local partners.

In March 2018, the GeoSERFOR platform was launched with the aim to meet increasing demand for information on forest cadastre, qualifying titles, among other information that is generated and administered by SERFOR.

OSINFOR uses information from the GLAD Alert system and GeoBosques. Test is ongoing to integrate information from GLAD Alert system and GeoBosques with OSINFOR's SISFOR system that allows visualization of OSINFOR's spatial information (e.g. forest management and/or concessions supervised by OSINFOR) on forest state.

Overall in Peru, PNCBMCC and GLAD Alert system generate and distribute EW information based on Landsat data. SERFOR is in the process of building a new EW system based on Sentinel-2 data. To date SERFOR, OSINFOR and SERNANP remain user of EW information. Note the four respondents find that having a country-owned system is important.

SOUTHEAST ASIA

In **Vietnam**, the Forest Inventory and Planning Institute (FIPI) uses an EW system for activities related to REDD+, UNCBD, and monitor some SDGs. The system is not operational yet. Main applications of the EW system are management of protected areas, empowering local landholders, enforcing conservation compensation programs, and raising people awareness. Coordination is performed with SilvaCarbon of the United States Geological Survey (USGS), University of Maryland (UMD), and JAC through training activities. The EW system is recognised by Law enforcement as a source of evidence. Vietnam Forest rangers use the EW system as a source of information. Most critical information includes forest cover change, follow up land use with particular interest in distinguishing anthropic and natural causes. Programming and image processing capacities are needed to develop/ maintain, and adjust the EW system for the specific case of Vietnam. Limitations reported relate to the lack of equipment, and capacity to use satellite imagery, and other forest monitoring technologies in general. Use of a country-owned EW system is seen as important.

In **Indonesia**, the Indonesian National Institute of Aeronautics and Space (LAPAN) is developing an EW system for activities related to REDD+. LAPAN together with UMD and WRI develop the EW system based on the requirements of the National Forest Resources Monitoring (NFRM) of the Ministry of Environment and Forestry (MoEF). The Natural Resources Corruption Eradication Unit for Natural Resources at the Corruption Eradication Commission (KPK) is a user of the EW system that is expected to become fully operational in 2019. The process towards recognition of the EW system by authorities is in progress. MoEF has the mandate to report on forest state on an annual basis. Several institutional barriers are reported by the three interviewed entities (LAPAN, NFRM, KPK): agreement on which monitoring system will be used (LAPAN) (Editor's note: this indicates that at least another systems exists however no information was obtained), communication with higher levels in the MoEF, political issues (NFRM), and lack of capacity, coordination, system and information interconnection, and lack of leadership (KPK). Most critical information to obtain relates to land use change and follow up land use. Spaceborne optical (>=10m and <10m spatial resolutions) and SAR data are used and considered satisfactory. LAPAN considers SAR data as a potential solution to overcome issues related to cloud coverage. A self-developed change detection method is used but no detail reported. Field data is collected by NFRM and partners such as NGOs, Universities, and civil society. Use of a country-owned system is considered as important.
The NGO *Hutan Alam dan Lingkungan* (HaKA) uses the GLAD Alert system as EW system to monitor activities in the region of Aceh. Coordination is performed with MoEF, Conservation Agency, National Park Agency, Police, other partner NGO, and Research Institutes. The EW system is recognised by the Law Enforcement unit in MoEF as preliminary evidence. Institutional barriers reported come sometimes from main stakeholder, management body for forestry sector at provincial level, and the Law enforcement unit.

3.3. Synthesis

A total of **eighteen institutions coming from eight countries contributed** to the Country Expert survey (four in Peru, two in Brazil, one in Argentina, three in DRC, one in Ghana, two in Ivory Coast, four in Indonesia, and one in Vietnam). **Most participants to this survey are governmental entities (15)**. Two NGOs (HaKA in Indonesia, and AWF in DRC) and one private company (CFT) in DRC complete the list. A total of **ten entities** out of the eighteen that were interviewed **declared themselves as EW system developers**. Most respondents declaring using an operational EW system (eight) reported year 2017 as in-service date, OSINFOR (Peru) reported year 2012 as in-service date, the oldest EW system being in Brazil (CNMIA - IBAMA) with year 2007. The in-service date for the non-yet-operational EW system (seven) is comprised between one and five years. The GLAD Alert system is used as a source of information by DIAF and CFT from DRC, SERFOR, OSINFOR, and PNCBMCC from Peru, and CNMIA – IBAMA from Brazil, and HaKA in Indonesia. In most countries multiple feedbacks helped drawing the institutional landscape and understanding the work coordination around forest cover change EW system.

International Conventions such as the **UNFCCC,** the **UNCBD,** but also the **UN SDGs were the most frequently reported policy frameworks** EW systems have been/ are being developed for. Policies at national level were also reported by some countries, such as Argentina (Law on native forests), DRC (CFT company for forest concession management), or Peru (PNCBMCC's NFI, SERFOR for wildlife Law, and SERNANP on biodiversity activities). This indicates that some of these policies are not necessarily linked to an international framework and/ or have been put in place before ratification of international agreements. **Five countries (out of eight) recognise information from EW systems as a source of evidence** (Peru, Brazil, DRC, Ghana, Vietnam). Typically, alerts trigger follow up actions on the ground for verification. Specifically, Law enforcement authorities of Ghana and Vietnam (rangers) use the EW system information. In Peru Prosecutors consider EW system information as one source of evidence. In Brazil, EW system information is recognised in court, and by Law enforcement. In Ivory Coast the legal framework is still under development while Indonesia and Argentina are performing an evaluation process. **All interviewees reported commitment to raise public awareness.** Among them, **nine indicated they were bound by Law,** while five indicated their commitment was an internal initiative, and two indicated both motives. **Local landholder empowerment is also specifically mentioned by five respondents.** Standard operation procedures (SOP) that regulate forest cover change EW activities have been defined in Argentina, Peru, Brazil, Ivory Coast (OIPR), Ghana, and in Indonesia by HaKA (NGO). No SOP was reported by DRC, Vietnam, Ivory Coast (CNTIG), and governmental entities from Indonesia. **Overall ten out of eighteen interview participants reported use of SOPs.**

Work coordination is performed with a variety of stakeholders. Governmental entities often coordinate their work with other governmental entities, from the same **Ministry** or not, **NGOs** (ACCA in Peru, AWF in DRC, HaKA in Indonesia), **research Academia** (e.g., UMD), and **Space Agencies** (JAXA/JICA supports SERFOR and PNCBMCC in Peru, but also CNMIA – IBAMA in Brazil). Depending on country circumstances, coordination with **local authorities** can occur (e.g., Peru, Ghana, Indonesia). CFT (DRC), a forest company, coordinates activities with an NGO (WRI), Academia, and Ministries.

Coordination with foreign entities, mostly for support, is performed by DIAF (DRC) with WRI, OIPR (Ivory Coast) with FAO, SERFOR/ PNCBMCC/ SERNANP/ OSINFOR (Peru) with WRI, ACCA, JICA, JAXA, ACTO, CNMIA (Brazil) with WRI, JAXA, JICA, FIPI (Vietnam) with USGS, UMD, LAPAN (Indonesia) with WRI, UMD.
Recurring **institutional barriers** reported were the **lack of governance and/ or leadership** (GFC in Ghana, LAPAN, NFRM, KPK and HaKA in Indonesia), the **limited availability of human resources** (Forest Agency in Argentina, KPK in Indonesia, PNCBMCC in Peru, CNMIA – IBAMA in Brazil) and **personnel skills** (CNMIA – IBAMA in Brazil, local stakeholders in Peru, KPK in Indonesia). In addition, **coordination issues** expressed notably in terms of data and resource sharing between stakeholders (OIPR in Ivory Coast, PNCBMCC and OSINFOR in Peru), and lack of monitoring system interconnections were also reported (SERFOR in Peru, KPK in Indonesia). Finally, **corruption** was mentioned by one interviewee only (PNCBMCC in Peru).

Most **recurring forest types** present in the monitored regions are **rain and dry forests**. These forest types are followed by mangroves, savannas, Andean forests and peatland. Some countries notified the **need for development of systems that work well outside rain forests** (e.g., Peru). Countries focus also on specific areas such as protected forest land and concessions where for example illegal logging can occur, both inside and within their direct surroundings. Forest cover change **EW systems are primarily meant to detect changes (deforestation, forest degradation)**, however need for information on **follow up land use, and the driver of change** was expressed. **Distinction between anthropic and natural causes** of change was a recurring need from five countries (Ghana, Peru, Brazil, Vietnam, Indonesia). These levels of information are needed for law enforcement ground operations but also for reporting in the context of IPCC framework.

Different **minimum mapping areas** were reported varying from 0.09ha to 60ha, **most being comprised between one and five hectares**. **Time resolution varied also, from one to 16 days**, most respondents being in need for weekly or biweekly periods. Few respondents reported **accuracy targets** (seven) varying between 70% and 90% (**avg. 80%**). Peru (SERNANP) and Brazil (CNMIA – IBAMA) reported tolerance for a few omission errors but requested **lowest possible commission error rate**. Too many false locations hamper capacity to verify and take proper measures to mitigate change. Beyond pure detection rate accuracy, **precise characterisation of the date of change is needed**. For example, Ghana reported need for early detection for the case of fires that can spread quickly, Peru (OSINFOR) needs most precise date of change to prosecute correct the person in the particular case of a land being traded. Furthermore, **accurate estimation of the surface affected by change** is deemed important in Peru (OSINFOR) since fines are based on this figure.

Optical data (Landsat and Sentinel-2) **is the most commonly used data type**. MODIS Fire products are used also (OIPR in Ivory Coast, GFC in Ghana). **SAR is used also** (CENSIPAM and CNMIA – IBAMA in Brazil, Forest Agency in Argentina, LAPAN and NFRM in Indonesia), and regularly cited as a **solution to overcome lack of data due to cloud coverage**. Though, SAR technology becomes difficult to use in mountainous areas (shadowing effects), as pointed by PNCBMCC (Peru). A total of **six entities expressed openness to commercial data**, while four expressed opposition, the rest providing no

feedback. Notably, SERNANP (Peru) follows a policy that prohibits purchase of commercial data. There is no consensus at national level on this question among respondents from Ivory Coast, Indonesia, and Peru. **Airborne data** (planes or drones) are used by five of the respondents. These datasets are used for validation of detected changes but also for follow up land use characterization (CNTIG in Ivory Coast), species identification (SERFOR in Peru), anthropic versus natural causes of change (SERNANP in Peru). Very high spatial resolution imagery like Planet data was also cited a source for validation purposes (PNCBMCC, Peru).

Typical suite of software used is composed of ArcGIS, QGIS, ENVI, and Erdas. Programming languages such as R and Python are mentioned. Google Earth Engine used by some respondents (GFC in Ghana, PNCBMCC in Peru, CNMIA – IBAMA in Brazil). The GLAD Alert system is used as a source of information by DIAF and CFT from DRC, SERFOR, OSINFOR, and PNCBMCC from Peru, and CNMIA – IBAMA from Brazil. **Resources on the Cloud are used by six respondents**: CNTIG, Ivory Coast (SEPAL), the Forest Agency of Argentina, then SERFOR, PNCBMCC, and OSINFOR in Peru, and CNMIA – IBAMA from Brazil (Google Earth engine). Respondents indicate data storage and computing power as the main motives for using Cloud resources. **Datacube technology** is used by none of the respondents, and sometimes not known at all. However, CNTIG (Ivory Coast) and PNCBMCC (Peru) expressed their interest towards this technology.

The **use of open source solutions is considered as a priority by 14 of the respondents (out of 18)**, while 14 **respondents find that having a country-owned EW system is important.** Two entities (AWF, HaKA) found this parameter as rather important.

Interest to participate in training activities has been expressed by the majority of respondents. These training activities **relate directly to the technological barriers** captured across the questionnaires and interviews. Interest in courses on use of **GIS and image processing software** were the most common expressed needs. **Additional needs were reported** such as the development of accurate digital elevation models (CFT in DRC), change detection techniques (DIAF in DRC), use of Google Earth Engine (CNMIA – IBAMA in Brazil), web and offline-mode mobile applications (CNTIG in Ivory Coast), route planner for ground validation activities (SERNANP in Peru), database management (OIPR in Ivory Coast), use of SAR data (PNCBMCC, OSINFOR, ACCA in Peru), satellite ground stations (CENSIPAN in Brazil), use of Global Forest Watch tools (HaKA in Indonesia), accuracy assessment (NFRM in Indonesia), blockchains and big data analytics (KPK in Indonesia). **Specific technological barriers were also reported** even though no request for training was expressed: use of geolocation tools such as tablets, and GPS receivers (OIPR in Ivory Coast), interconnection between systems, e.g., impossibility to import and export data from/ to GLAD Alert system (CFT in DRC), or field data upload and integration to EW system (CNMIA – IBAMA in Brazil), good internet bandwidth (Forest Agency in Argentina, SERNANP and PNCBMCC in Peru), non-adequate EW system set-up like JJ-FAST with a reporting period of 45 days (SERFOR in Peru). **Needs for training on following applications were reported**: land management (CFT in DRC), forest inventory (GFC in Ghana), monitoring of Andean forests and mountainous areas in general (PNCBMCC in Peru), anthropic versus natural disturbances and species identification (OSINFOR in Peru), drivers of deforestation, including mining (CENSIPAM in Brazil, LAPAN in Indonesia).

4. Tool Developer Expert Survey

4.1. Presentation

The Tool Expert Developer questionnaire was designed in such a way as to understand the development context of some of the state-of-the-art technologies that can contribute to the advancement of forest change EW system. The questionnaire aimed to capture potential evolutions of the tools in the context of forest change EW system, the motivations underpinning such evolutions, the type of EO data that can be handled, and the accessibility of these tools.
Targeted institutions were identified across the GFOI stakeholders. Table 2 lists the contributors to the survey.

Table 2. Tool Developer Expert contributors to the survey.

Tool	Institution	Respondent
EW GLAD Alert system	World Resources Institute	Ms. Mikaela Weisse
SAR change detection toolbox	DLR - Deutsches Zentrum für Luft- und Raumfahrt, Germany	Ms. Paola Rizzoli
SAR-optical change detection method	Wageningen University & Research, The Netherlands	Dr. Johannes Reiche
JJ-FAST	JICA - JAXA	Mr. Hiroaki Okonogi
Open DataCube	CEOS/ NASA	Dr. Brian Killough

4.2. Results

EW GLAD Alert system
The Global Land Analysis & Discovery (GLAD) lab. of the University of Maryland (UMD) developed the GLAD Alert system[2] in partnership with the World Resource Institute, as part of the Global Forest Watch initiative. The GLAD Alert system is the first Landsat-based system for tree cover loss monitoring. GLAD alerts are used across a variety of countries and institutions. They are currently available for 22 countries. WRI does not monitor all uses of the data, however some concrete examples are provided:
- Before developing their own system, the Peruvian government used GLAD alerts as their national EW system. They were made available through the GeoBosques webportal, and used by government and civil society actors (law enforcement, protected areas managers, working with indigenous communities etc.).
As presented in previous sections, the GLAD Alert system is used as a source of information by DIAF

[2] http://data.globalforestwatch.org/datasets/194662b1470e4c5f81aa370395c75485_8

and CFT from DRC, SERFOR, OSINFOR, and PNCBMCC from Peru, CNMIA – IBAMA from Brazil, and HaKA in Indonesia. Note that the GLAD Alert system is used beyond the reported cases contained in this report.

User feedback is captured via emails, and in-person meetings like workshops. From a study in Peru and conversations with other users within the GFW community, most important needs captured are:

1. Incorporation of radar data, as cloud cover causes long delays between deforestation and its detection,
2. Guidance on how to prioritize/use the data: while some governments know how to use the data technically, going from the raw data to actual action on the ground is a bigger leap,
3. Expansion to more countries (demands in particular for Panama, Madagascar, Liberia, Bolivia, Paraguay).

To date Landsat-7 and -8 data are used by the EW system. Actions are ongoing with UMD to incorporate Sentinel-2 data by 2020. The tool is freely available to the public via an online portal. The code is not open source, and no change in this policy is foreseen.

SAR-optical Data Integration Tool for Forest Cover Change Detection by WUR

The forest cover change detection method is developed by J. Reiche *et al.*[3] (Wageningen U.R.). The method allows for the combination of SAR and optical data time series, but can also be applied to single sensor time series[4]. Possible sensor configurations so far are:

1. Sentinel-1
2. Sentinel-1 / / Landsat
3. ALOS-2 / Sentinel-1 / Landsat

The tool is publicly available, open source and free. The tool is still considered to be at an R&D stage. To date no country has implemented the method. User feedback is captured through in-person meetings like workshops. Users expressed interest in having a free-data-based method that can also provide alerts at higher frequency (from monthly to weekly periods).

Evolutions of the method are planned based on this feedback. Robust Sentinel-based near-real-time deforestation monitoring tool that can be upscaled easily is foreseen. A robust Sentinel-based near-real-time deforestation monitoring tool that can be upscaled easily is foreseen. Work will be scaled to Malaysia and Indonesia, in coordination with WRI.

SAR-based EW system tools by DLR

[3] Reiche, J., Hamunyela, E., Verbesselt, J., Hoekman, D., Herold, M. (2018) Improving near-real time deforestation monitoring in tropical dry forests by combining dense Sentinel-1 time series with Landsat and ALOS-2 PALSAR-2. Remote Sensing of Environment, 204, pp. 147-161. https://doi.org/10.1016/j.rse.2017.10.034.

[4] Reiche, J., Verhoeven, R., Verbesselt, J., Hamunyela, E., Wielaard, N., Herold, M. (2018) Characterizing Tropical Forest Cover Loss Using Dense Sentinel-1 Data and Active Fire Alerts. Remote Sensing, 10: 5, 777, doi:10.3390/RS10050777.

A suite of SAR-based EW tools is developed by the German Deutsches Zentrum für Luft- und Raumfahrt (DLR – Microwaves & Radar Institute). The tool handles TanDEM-X and Sentinel-1 data. User feedback is captured by means of emailing and in-person meetings like workshops. Needs yet to be met are:

1. Capacity for large coverage and short revisit time,
2. Improve detection reliability of newly deforested areas.

Evolutions of the tools are planned based on this feedback. In particular a proof of concept on multi-sensor data fusion is planned by the end of 2018. Tools are still in development. They are not meant to become publicly available and the code will not be open source. However, algorithms may become available through peer-reviewed scientific publications. The suite of tools is still considered to be at an R&D stage.

JICA-JAXA Forest Early Warning System in the Tropics (JJ-FAST)

JJ-FAST[5] is a web-based system using JAXA's ALOS-2 to monitor tropical forests. JICA and JAXA launched the JJ-FAST in November 2016 as their commitment under the Forest Governance Initiative, which was announced at UNFCCC COP 21 in Paris in 2015.

ALOS-2 SAR data is the only source of EO imagery currently used, however evolutions are in discussion.

JJ-FAST covers 77 countries which have tropical forests and detects deforestation every forty-five days. User feedback is captured by means of emailing, website, and in-person meetings like workshops.

Until last year, JJ-FAST could detect minimum five hectares deforestation, users need to detect smaller size of deforestation. Evolutions of the tools are planned based on this feedback. Since April 2018, minimum detection size has been improved to three hectares. Efforts are ongoing to detect even smaller patches of deforestation using other algorithms or solutions.

The tool is publicly available and free of use. However, the code is not open source, and no change in this policy is foreseen.

Open Data Cube

The Open Data Cube (ODC) tool[6], is co-developed by the Committee on Earth Observation Satellites including USGS, Government of Australia (incl. CSIRO), Analytical Mechanics Associates, and CATAPULT Satellite Applications. ODC aims to meet the need to better manage satellite data and now supports interactive data science and scientific computing. Overall, ODC architecture and tools ''help removing the burden of data preparation, and fosters an active and engaged global community of contributors''. ODC can handle Landsat-7, Landsat-8, Sentinel-2, Sentinel-1, and ALOS datasets.

ODC is used by several countries for forest management (e.g., Colombia, Kenya, Taiwan). To date, ODC does not appear to be used for operational forest change early warning purposes. Many users

[5] http://www.eorc.jaxa.jp/jjfast/

[6] https://www.opendatacube.org/

are investigating some of the land change algorithms as an approach to support deforestation detection activities. Users need more training to understand how potential land change alerts are confirmed as forest change. This process should be supported by improved guidelines (e.g., in the Method and Guidance Document from the Global Forest Observation Initiative).

User feedback is captured by means of emailing, website, and in-person meetings like workshops. Based on this feedback, evolutions are planned and in progress. For example in Colombia, tests of several Landsat and Sentinel-1-based deforestation algorithms are ongoing. In addition, several new Landsat and Sentinel-1-based land change algorithms will be tested in 2018. The tool is publicly available and the code is open source.

4.3. Synthesis

Five Tool developer Experts responded to the invitation to contribute to this study (Table 2). Among them, Experts develop **two operational EW systems**: the **GLAD Alert system** (available in 22 countries) and **JJ-FAST** (available in 77 countries). The three other respondents develop forest cover change detection algorithms. ODC proposes also the **datacube** concept to store and prepare the data for analysis.

All five Tool developer Experts interact with their respective user communities by means of emails, workshops, but also with dedicated websites for JJ-Fast and ODC. Based on this interaction, user **needs are captured and taken into consideration**. **Recurring expressed need** relates to the capacity of the methods to handle heterogeneous data sources, notably **optical-SAR data combinations**. To date, the algorithm by WUR allows optical-SAR data combinations and ODC allows storage of various datasets (Landsat-7, Landsat-8, Sentinel-2, Sentinel-1, and ALOS). **All developers are working on making their solution more flexible in terms of data sources**. For example, tests are ongoing with the GLAD Alert system in Indonesia, to incorporate Sentinel-1 SAR data, DLR works on widening the list of input datasets (to date: TanDEM-X and Sentinel-1), and ODC works on making available change detection algorithms based on Landsat and Sentinel-1 datasets. Developers work on other improvements such as making their solutions available over a larger set of countries (GLAD Alert system), improving the code to allow upscaling of the method (WUR, DLR), and JJ-FAST works on improving detection of smaller *changed* patches (<3ha). **All tools are free to use, however only source codes of the WUR and ODC solutions are open source**. **Only GLAD Alert system and JJ-Fast are reported to be used in an operational context**.

5. Recommendations

The UNA demonstrated that most surveyed entities develop and/or use EW systems to respond to the same objectives with national and international policy contexts ranging from the mitigation of climate

change to biodiversity loss, and other adverse impacts of forest loss. However, the observed approaches cannot be straightforwardly assessed and compared due to different country circumstances (e.g., governance, environmental conditions, drivers of change, and readiness levels).
Although some respondents benefit from advanced and operational systems while others are some steps behind for the moment, all of them face a series of institutional and technological barriers to fully meet monitoring needs. The survey showed also that Tool developer Experts do take user needs into consideration to develop and update their technologies. As a result, foreseen tool updates are expected address some of the expressed user needs.
Based on the outcomes of this survey, this section lists a series of recommendations for consideration by GFOI stakeholders to support further tropical countries seeking to develop and strengthen their EW system.

I- Country institutional and policy matters

1. Organize forums dedicated to forest change mitigation policy frameworks requiring use of EW systems with the aim to facilitate identification of successful policy and governance implementations, and incentivise South-South collaboration (knowledge and experience sharing),
2. Produce a publication reporting lessons learnt from successful institutional arrangements put into practice, including standard operation procedures, that contribute to effective development and operation of an EW system, with tropical countries as target audience,
3. Produce a publication reporting lessons learnt from successful local landholder engagement in field activities, for both validation and public awareness purposes.

II- Capacity development

4. Engage with local academic institutions to foster in-country interactions with EW system users/ developers to produce and deliver training activities,
5. Develop further hands-on training exercises on change detection tools complementary to existing GFOI materials,
6. Develop materials to present operational and secured cloud computing solutions that can overcome issues such as processing power, data storage, data sharing,
7. Consider development of a guidance document dedicated to EW systems. Similarly to the MGD/ REDDCompass approach, a decision tree on development of EW systems could be inserted, along with reporting of relevant technological progress (cf. CALM framework) and developments,
8. Maintain non-prescriptive approach in EW WG activities, i.e., let choice of methods to countries.

III- Research and development

9. Reach out to local academic institutions to foster in-country interactions with EW system users/ developers to develop targeted R&D activities,
10. Support research Call formulations on multi-sensor approaches, SAR-optical notably,

11. Support research Call formulations to support progress of change detection methods towards higher levels of the GFOI's *Criteria for consistently Assessing Levels of Maturity* (CALM) framework (e.g., wrapper functions, code optimization for upscaled applications),
12. Incentivise R&D activity and reporting on monitoring methods dedicated to secondary forests types such as mangroves, and Andean forests,
13. Explore potential of IBAMA's technique on estimating deforestation speed, to support follow-up land use and anthropic vs. natural disturbance characterizations,
14. Consider inclusion of additional R&D priority topics based on technical barriers expressed by respondents (e.g., big data/ artificial intelligence, blockchain technology, mobile applications, and route planning tools for field activities),
15. Foster development of mobile applications supporting field work activities, and provide training on both use and development,
16. Foster development of open source tools.

IV- GFOI internal organization

17. Direct support towards country-owned EW system as an official activity of the EW WG,
18. Foster communication among EW system users within GFOI, for example by means of communication tools such as mailing lists, newsletters, and social media,
19. Widen further GFOI stakeholder community, notably for capacity development, R&D, and MGD/ REDDCompass activities.

Annex 1. Country Expert Interviews

AFRICA

Democratic Republic of Congo (DRC)

The ***Direction des Inventaires et Aménagements Forestiers*** (DIAF) of the *Ministère de l'Environnement et Développement Durable* of DRC uses an EW system for REDD+ monitoring and reporting activities. Illegal logging and concession monitoring are the main applications. No Standard Operation procedure has been developed. Work is coordinated with an NGO: WRI thanks to meetings and workshops. The Legal system recognises the EW system. The EW system is also used to monitor land use in general. No institutional barrier is provided regarding the operational use of EW system. Main forest types and lands monitored are dry and rain forests, peatland, mangrove, plantation and concessions. Most critical information needed from the EW system relates to deforestation, forest degradation, and follow up land use. Main information to be obtained is related to follow up land use. Minimum mapping area is five hectares and revisit period is of eight days. No justification is provided.
DIAF is not an EW system developer and the system currently used is operational (GLAD Alert system). DIAF needs to further develop competencies in the use of GIS systems (ArcGIS, QGIS), which is ongoing with FAO Forestry support. No information is provided regarding the use of data and cloud computing infrastructure, however the GLAD Alert system is the EW system used by DIAF. We refer the reader to section 4 to learn about the GLAD Alert system, notably on used datasets.
DIAF personnel follows training activities on change detection and management of alerts coming GLAD Alert system.
Use of open source solutions is seen as a priority while a country-owned EW system is considered as important.
DIAF is legally bound to communicate information to the general public.

The ***African Wildlife Foundation*** (AWF) provides support to authorities of DRC in terms of data provision in the frame of REDD+ monitoring and reporting activities. AWF uses an EW system (not a developer) to investigate illegal activities, manage protected areas, empower local landholders and raise public awareness. No Standard Operation Procedure is defined, and coordination with performed with public authorities in charge of protected areas (ICCN), local NGOs, and conservancies. Work consists in helping improvement of management effectiveness through introduction of tools/approaches like SMART[7], a GIS/ database software, and facilitating data provision (e.g., data layers). SMART is used as an EW system in the sense that this tool helps predicting threats in unpatrolled areas via spatial modelling. EO data is used for fire monitoring and as a proxy for human activities. The EW system used is recognised by Legal authorities for Law enforcement. No institutional barrier is reported.

[7] Spatial Monitoring And Reporting Tool, GIS supporting law enforcement related to wildlife) smartconservationtools.org

Forest types and areas to monitor reported are dry and rain forests, savannas, and protected areas, with most critical information the obtain being deforestation, forest degradation, land use change, and associated time of occurrence. Best minimum mapping area is 0.09ha with a yearly time frequency (Editor's note: adequate time for REDD+ reporting, not for purpose of EW system). No specific target accuracy provided.
The EW system used by AWF is not fully operational and the expected time of completion is about three years. Training is needed on image processing, accuracy assessment and data dissemination/ reporting. AWF does not participate in any capacity development activity. Open source solutions are not considered as a priority while having a country-owned system is seen as rather important.

The ***Compagnie Forestiere et des Transformations*** (CFT) (Forest company) uses an EW system for concession monitoring purposes. No Standard Operational Procedure has been defined. Coordination of activities are performed with Universities and Ministries, and NGO. The Legal system recognises the EW system. Deforestation (notably illegal logging within managed land) is the most important information to be obtained from the EW system. Real time monitoring of activities within concessions is sought.
CFT is not an EW system developer and the GLAD Alert EW system being used is considered as not fully operational yet. Main reasons reported were the impossibility to import data (vector data to delineate areas of interest, and GPS points) and export data (areas labelled as changed by the System). Though results provided by the System are considered very satisfying. Datasets used comprise Landsat imagery (through the GLAD Alert system notably), but also elevation data from the Shuttle Radar Topography Mission (SRTM) digital elevation model. We refer the reader to section 4 where the GLAD Alert system is discussed for further information. No airborne data is collected or used, and Google Earth is the source of high spatial resolution imagery. Ground data is collected to geolocate changes with a GPS device. Beside the EW system, software suite comprises ArcGIS, QGIS, and GoogleEarth.
CFT personnel follows training courses on forestry, GIS, land management, GLAD Alert system. Trainers are AGEDUFOR, WRI among others. Access to general training on GIS/ remote sensing is sought. Training on how to build precise digital elevation models for hilly/ mountainous areas was also expressed.
Use of open source solutions is considered as a priority and having a country-owned system is seen as a priority. CFT is legally bound to publish openly information on its activities.

<u>Ivory Coast</u>
The ***Comité National de Télédétection et d'Informations Géographiques*** (CNTIG) of Ivory Coast, which is linked directly with the Presidency, uses an EW system for monitoring and reporting activities linked to REDD+. The EW system is designed in order to monitor illegal logging, protected areas (incl. for conservation purposes), local landholder empowerment, and public information. Activities related to the EW system are coordinated with the *Ministère des Eaux et Forêts, Ministère en charge de l'Environnement, Centre Universitaire de Recherche Appliquée en Télédétection (CURAT)*, and *Bureau National d'Etudes Techniques et de Développement (BNETD),* among others. Coordination is

performed thanks to meetings and workshops. Though, no standard operation procedure has been defined for the operation of the EW system and the Legal system does not recognise the EW system yet. The institutional and legal frameworks are still under development. No institutional barrier was reported.
The EW system targets rain forests, plantations and protected areas which face both deforestation and forest degradation. Main thematic classes to be mapped are cut forest, degraded, and follow up land use. No further detail is provided regarding the expected accuracy and minimum mapping unit. The CNITG is an EW system developer and the system has been operational for less than a year at the time of the interview.
Satellite and airborne (drone) optical data at spatial resolutions smaller than 10m meet the needs of the EW system developers. Drones are used to characterise follow up land use after change has been detected. Ground data is collected with the aim to document toponymy, vegetation type, species, and infrastructures. The EW system developers are opened to the use of commercial satellite data for land cover mapping activities.
The developers use Cloud computing solutions (i.e., SEPAL) for improved data storage and computation power. No datacube is currently used however developers consider the use of such a tool in the future. ArcGis and Erdas software are currently being used. This suite of software covers their needs and no diversification or addition of software is considered for now.
Developers participate in training activities on web and mobile application development, but also on low and high spatial resolution imagery analysis.
Use of open source solutions is not a priority for CNTIG and using an EW system entirely developed by CNTIG was qualified as important by the interviewee. Reporting information is released to the public as an internal initiative.

The ***Office Ivoirien des Parcs et Réserves*** (OIPR) develops an EW system for monitoring activities linked to a protected area management framework. The EW system is designed in order to monitor mainly illegal logging, and protected areas (incl. direct surroundings). Standard operational procedure has been defined to operate the EW system. These include:

1. Satellite monitoring of land use in protected areas and their peripheral zones through diachronic analyses based on optical image processing (annual),
2. Exploitation of data provided by fire warning systems (MODIS),
3. Procedures for deployment of intervention teams in the field to verify information, assess and stop the deforestation process identified in the protected area,
4. debriefing, reporting,
5. Rehabilitation of surveillance programs as appropriate to respond more effectively to observed trends.

No coordination with another institution is made. Though OIPR considers that coordination would improve its capacity to meet its objectives, notably on data sharing tools, including alerts, and this with CN REDD+, *Centre d'information géospatiale et numérique* (CIGN). Collaboration aiming to develop internal capacity on use of SAR data is welcome also, with universities, CURAT and other research centres.
The EW system is not recognised by the Legal system yet. The Legal system (*Parquet*) requests more

tangible evidences such as material/ physical evidences. The EW system is seen as a tool to guide persons towards such material/ physical evidences. Authorities interested by EW systems are:

1. *Ministère du Plan pour la gestion prospective de l'aménagement du territoire,*
2. *Gestionnaires des espaces naturels disposant d'un statut de protection* (*forêt classées, aires protégées),*
3. *Service des Mines*,
4. *Ministère de l'Agriculture*,
5. *Conseils régionaux*,

The EW system is not fully operational yet and no date for the completion of the development was provided. Main institutional barrier identified for the development of an operational EW system relates to data and resource sharing issues. Other barriers towards the development of an operational EW system are technical capacities (image processing, SAR notably), geolocation tools (tablets, GPS receivers), and GIS.

This EW system in development targets dry forests, savanna, mangroves, plantations, protected areas (incl. Surrounding areas). Main thematic classes are deforestation, forest degradation, and follow up land use. Forest, non-forest, degraded forest and bare soil are the most critical classes. Minimum mapping area is 0.5 ha with a revisit period of 16 days. Such a revisit period allows:

1. monitoring of Specific activities that are not necessarily of a long-term nature (gold mining),
2. knowing if the activity does not continue (gap due to a windfall, forest fire...).

Datasets used are optical data (>=10m spatial resolution) however these do not meet user's needs with limitations due to cloud cover and spatial resolution. No aerial data is used. Data collected on the ground are GPS coordinates, vegetation type, structure, and density, human activities, and pictures. Data is collected by OIPR. All datasets are used for change detection by the means of visual interpretation, change detection algorithms, classification, and accuracy assessment. OIPR is not opened to the use of commercial data.

Cloud computing resources (FAO System for earth observations, data access, processing & analysis for land monitoring (SEPAL) system) are used to obtain higher computational capacity. No datacube is used and the concept is not known to the OIPR. Suite of used software (beside SEPAL tools) is composed of ArcGIS, QGIS, ENVI, Erdas. This suite of software cover current needs and no diversification of the tools is considered. Use of open source solutions and having a country-owned EW system are seen as a priority and important, respectively.

OIPR participated in training activities on remote sensing, GIS, databases using free software notably. CURAT, CIGN, and consultants provide the training. Information communication to the public is an internal initiative of OIPR.

<u>Ghana</u>

The **Ghana Forestry Commission** (GFC) develops an EW system for activities related to REDD+ monitoring and reporting. Main applications are: investigate illegal logging, manage protected areas, and raise public awareness (internal initiative). Standard Operation Procedures have been defined. The EW system uses MODIS fire products for early detection of hotspots. Google Earth Engine is used to monitor illegal mining activities, and control bush fires. Work coordination is made with academic research, NGOs, and local authorities. Coordination includes data and resource sharing. The EW

system is recognised as an official source of information by Law enforcement. The Forestry Commission, the National Fire Service and local authorities use the EW system. Institutional barriers reported are commitment to activities and common understanding of issues.
Main forest types encountered within monitored areas are dry and rain forests, savannas, and mangroves. The monitored area includes plantations and protected areas. Most critical information to obtain includes deforestation, forest degradation, anthropic versus natural causes of change, land use change. A satisfactory level of accuracy of the results is above 70%. Early detection of fire is critical to mitigate impact on the vegetation. Illegal mining occurs randomly and sporadically, and can spread quickly. Therefore high temporal and spatial resolution data is needed.
The GFC is not an EW system developer and the EW system currently used is not fully operational. It is expected to become fully operational in four years (2022).
Training is needed on remote sensing and GIS applications, and forest inventory systems. Currently training is performed on use of MODIS fire products.
Open source software is considered as a priority while having a country-owned EW system is seen as important.

SOUTH AMERICA

Argentina

The ***Dirección de Bosques - Ministerio de Ambiente y Desarrollo Sustentable*** of Argentina is developing (non operationl yet) an EW system for activities related to REDD+ and national Law on native forests. Main information needs relate to illegal logging, public awareness, concessions' monitoring and compensation programs. Standard Operation Procedures have been defined. Work is coordinated with investigation institutions and the National Commission on Spatial Activities (*Comisión Nacional de Actividades Espaciales*). However the EW system is not recognised by the Legal system yet. The EW system is currently going through an evaluation process. Main interests for authorities relate to provision of transparent information on forest management to the public, including native populations, control deforestation, notably in the context of conservation and sustainable development policies for which economic incentives have been put in place. Argentina as a Federal State, has a decentralised environmental (incl. forest) monitoring scheme which makes difficult the implementation of monitoring systems. Additional institutional barriers are related to limited human and economic resources.
Dry, tropical, Andean, and savanna forests along with protected are monitored, with particular interest to deforestation and forest degradation within this classes. A minimum mapping accuracy of 70% is sought. Desired minimal mapping area (MMA) is five hectares and revisit time period is 16 days. Though, minimum mapping area is 50 ha in Chaqueno Park. In the jungle areas, MMA must be smaller and varies depending local average deforested patch size. The EW system system is expected to become operational (partially at least) in three years. Human resources, good internet bandwidth, and technical knowledge are cited as the main barriers to achieve the completion of the EW system.
Datasets used comprise optical data below and above 10m spatial resolution, and SAR data. These datasets are considered satisfactory. No airborne data is used and no interest is given to commercial

data. No ground data is collected yet. Cloud computing is used, however datacube technology is not known. Suite of used software is composed of ArcGIS, QGIS, ENVI, Erdas, and Python programming language. The software configuration meets user needs although an update of the system is planned (system still in development). Developers are interested in following training sessions. Use of open source solutions is considered as a priority and having a country-owned system is seen as important. A legal framework binds the *Dirección de Bosques* to communicate information to the public.

Peru

The ***Servicio Nacional Forestal (SERFOR)*** *of the Ministerio de Agricultura y Riego* (MINAGRI) uses EW information to support activities related to REDD+, the Sustainable Development Goals (SDG), and the forest wildlife law. Coordination of the activities is made with PNCBMCC (MINAM). Main applications are monitoring of illegal logging (within concessions notably), forest fire, plantations (palm oil), and migrating agriculture. Rain forest (60% of country's landmass), dry forest (northern coast), Andean forests (relics), mangroves in the North, but also plantations are the main thematic classes of interest. Most critical information to obtain within these classes is change and follow-up land use.

Since information obtained from MINAM was not provided early enough, a new information system has been developed (operational in 2017). Satellite Monitoring Unit (UMS) focuses on the use of EW for rapid action against deforestation. The UMS EW information to analyse and identify the activity that has caused the forest use change, in addition to the affected area and forest heritage, among other analyses. The main objective is, as a forestry governing body, to provide detailed and timely information to generate adequate control actions for decision makers at the local, regional and national levels. The *Sistema Nacional de Información Forestal y de Fauna Silvestre* (SNIFFS) includes the PNCB's EW System (a.k.a. *Módulo de Monitoreo de la Cobertura de Bosques* (MMCB) in SNIFFS) and the GLAD alerts. SNIFFS will produce soon its own EW information based on Sentinel-2 data but also PeruSat-1 data (similar to SPOT). If no Sentinel-2 data is available then Landsat data will be used. This system is made in coordination with local authorities that contribute to monitoring activities. SERFOR centralises the information (change, location, driver). Communication to the public is made by local authorities. Coordination is made also with NGOs such as WRI and the *Associación para la Conservación de la Cuenca Amazónica* (ACCA), and Japan International Cooperation Agency (JICA). The EW system is recognised by the Legal system as one source of information among other evidences. Difficulty to coordinate activity (data module linkage) with MINAM has been cited as an institutional barrier.

SERFOR is opened to commercial data if no alternative is available. Airborne data is used for validation and inventory (incl. species identification) purposes with the support of ACCA and JICA. Drones will be given soon to regional authorities to support validation, surveillance, control actions, and inventory activities. Budget to procure motorbikes is now available to facilitate fieldwork activities. An ongoing study with JICA aims to investigate on how complementary optical and SAR satellite data sources can be to optimize the EW system. This includes MINAM's information, and study is led by SERFOR. Technical issues relate to cloud coverage and shadows in optical imagery. A lower change detection error rate is needed.

Cloud computing is used to facilitate data storage. ArcGIS, QGIS, and Erdas software are used. Practically, warnings are received from the ground or from satellite imagery. Then, a proper mapping step is performed. JJ-FAST is used as change detection method but the system has only a 45-day reporting time period. As a result, the GLAD Alert system is also used for change detection. Sentinel-2 data is subsequently used to map more precisely the changed area.

Having a country-owned system is considered as important in a mid-term perspective. SERFOR is bound by law to release information to the public. GeoSERFOR Service was launched in March, 2018, to meet increasing needs for information on forest cadastre, qualifying titles, among other information that is generated and administered by SERFOR.

The ***Programa Nacional de Conservación de Bosques para la Mitigación del Cambio Climático*** (PNCBMCC) of MINAM uses an EW system linked to a Forest programme related to REDD+ that includes also an annual monitoring system (developed since 2012 with support from UMD, USA, and in coordination with SERFOR (Legal decree N 1220)). SDGs are also taken into consideration. Forest rights and ecosystem services management are also part of the applications of the system. Main information needed relates to deforestation, forest degradation, and driver of land use change (anthropic versus natural).

GLAD Alert system has been proven efficient in Peru and this in coordination with local communities that help validating detected changes. However a new country-owned EW system is used since 2017. One reason for Peru to move away partially from GLAD Alert system is the uncertainty related to its availability over time. Note that Terra-I is a fire and vegetation cover change alert system that was used in the past, however the system was discarded due to insufficient level of reliability. OSINFOR benefits from the new EW system receiving information to be checked on the ground (within forest concessions). OSINFOR is in charge of legal matters related to timber production. Work is coordinated also with SERNANP, and FEMA (prosecutor agency).

To date, three types of information are produced: the first one helps developing bi-yearly reports for REDD+ activities with validated data (incl. land use change following IPCC classes), then information is produced for yearly reporting, also with validated data, while the third type of information (coming from the EWS) helps building weekly reports with non-validated data (country-made system now replacing GLAD Alert system). Overall, this is difficult to track changes since most of them occur at a scale smaller than five hectares.

Use of the EW system to its full potential faces barriers such as lack of information/ communication, corruption, and training notably for local stakeholders. The EW system is recognised by Legal system but still needs to demonstrate full operational capacity. Furthermore, the long processing of the information across Ministries and Offices is too long to fight deforestation efficiently. A new initiative aims to develop a dedicated team of experts that can interpret monitoring data and prepare information for follow up legal steps. Three regional governments are part of this initiative that is supported by USAID.

Use of Sentinel-2 is considered notably for forest degradation, however usability still needs to be

assessed. Planet data considered as useful for validation purposes. PeruSat-1 data can be useful but access is difficult. The issue of cloud cover in optical imagery is reported and SAR data is seen as a potential solution. However, use of SAR data becomes difficult over mountainous areas present in Peru. Optical airborne data is used for validation purposes. PNCBMCC is opened to commercial data but system needs to remain affordable, especially since monitoring activities will be transferred to regional governments. PNCBMCC reports also an issue related to the capacity to distinguish anthropic from natural causes of change within short periods of time. Internet access in the Amazon region is also an issue.

ArcGIS desktop and online versions, and ENVI are used. PNCBMCC considers moving to QGIS and Geoserver to reduce licensing costs. Change detection method is based on decision trees. A stronger move to Google Earth Engine is planned. Overall, increase in the use of Cloud resources is considered to facilitate processing activities. No datacube is used so far but this technology is seen as potentially useful. Note that the *Sistema Nacional de Información Ambiental* (SINIA) from MINAM is currently building a datacube which incorporates data from PNCBMCC.
Field plots and mobile applications (offline mode under development) help validation process also. Field plots are being used for yearly monitoring and reporting (baseline dates from year 2000) in the frame of a National Forest Inventory.
Training is a continuous process at PNCBMCC and most critical needs identified relate to monitoring of Andean forests, and mountainous areas in general. Use of SAR data is also mentioned.
Open-source solutions are considered as a priority, for cost purposes notably. Having a country-owned system is important, notably due to sustainability reasons (see comment above regarding GLAD Alert system).
PNCBMCC needs to comply with legal framework that requests communication towards general public. Websites and mailing lists are notably used to disseminate information.

The ***Servicio Nacional de Areas Naturales Protegidas del Ministerio del Ambiente*** (SERNANP) uses an EW system to address national policies related to the UNCBD. Monitored natural reserves include rain, dry and Andean forests, but also wetlands, pasture lands, deserts, and marine areas. Activities on the ground that need to be monitored are illegal activities in protected areas. Identifying change and discriminating anthropic and natural causes are the most important tasks to perform within the natural reserves. Public awareness of local populations is also part of the mandate of SERNANP. EW system activities are coordinated with PNCBMCC, ACCA, the Amazon Cooperation Treaty Organization (ACTO), *Instituto del Bien Común* (IBC), and local authorities.

The EW system is recognised for legal actions. Prosecutors accept EW system information as a source of evidence.

The EW system covers forests in the Amazon. Information is provided by MINAM through the GeoBosques platform. To date limitations come from the use of optical data which efficiency is hampered by presence of clouds. Furthermore, the system does not differentiate anthropic and natural causes of change. There is a need to extend the system to Andean forests also.

SERNANP plans to develop a team dedicated to the use of GeoBosques information. The inclusion of

high-res. PeruSat-1 data that is useful to discriminate anthropic and natural causes of change is considered. Furthermore spatial resolution of Landsat and Sentinel-2 is sometimes not sufficient to detect changes. PeruSat can be an asset in such circumstances also. To date current version of GeoBosques provides too many change alerts. Lower commission error rate is strongly needed. SERNANP is not interested in commercial data. Current policy does not allow purchase of images. SERNANP is developing also an online system to produce information and generate reports on forest change in natural protected areas. The system will consider different sources of information (see above-mentioned ones). The system is expected to become operational in three years (2021).

Route planning tool to optimize ranger activities on the ground based on detected changes is needed also.

Airborne data from planes and drones is used to control alerts from GeoBosques (validation and anthropic/ natural cause discrimination). SERNANP is in charge of the field activities in protected areas, but NGOs and local populations can help sometimes. Mobile phones are not used due to limited signal strength.

The suite of software used comprises ArcGIS, QGIS, and ENVI is about to be purchased. No cloud computing is done currently but this may change with the improvement of the internet bandwidth.

Training is needed to develop capacity to use PeruSat data, and image processing in general. ACCA provides support. Interest in following SAR training from/ in foreign countries was expressed.

Having a country-owned system is important due to the uncertainty of the availability of some EW systems over time (e.g., GLAD Alert system).

The ***Organismo de Supervisión de los Recursos Forestales y de Fauna Silvestre*** **(**OSINFOR) uses an EW system (GLAD Alert system) to supervise use of natural resources, including wildlife, to guarantee its sustainability. OSINFOR checks that land use is in line with legislation. Most critical information needed relates to land cover change resulting from illegal activities. Empowerment of local communities is also part of the mandate of OSINFOR. Information from the GLAD Alert system is complemented by information from GeoBosques System from MINAM. The SISFOR System, which became operational in 2012, allows online publication of spatial information over supervised areas. SISFOR is dedicated to public awareness activities. Geolocated data can be represented at tree level. Test is ongoing to integrate SISFOR with GLAD Alert and GeoBosques. An evolution of SISFOR was supported by WRI in 2014.
Forest types encountered in monitored areas are rain, dry, and Andean forests. Mangroves are not incorporated yet due to a lack of guidelines.
Detected change is verified with satellite imagery but also on the ground with fieldwork that allows identification of follow up land use. OSINFOR has the duty to carry out oversight activities and coordinates activities with SERNANP, SERFOR, and PNCBMCC. Drones were purchased to facilitate fieldwork activities (over flooded areas notably).
GLAD Alert system is considered as useful however efficiency can be limited due to cloud coverage and spatial resolution of Landsat data can be insufficient. To date, changed surface is overestimated.

Accurate estimation of changed surface is important since fines are based on this figure. Precise date of change is important notably when landownership changes. The correct person responsible for the change must be identified.
Landsat (GLAD Alert system), CBERS, Sentinel-2, resourceSAT satellite data are used. PeruSat data is not available yet for OSINFOR. SAR data is considered as potentially useful to alleviate limitations due to weather conditions.
OSINFOR uses Cloud resources for data storage, and a certification process for information security is ongoing (ISO 27001). Software used are ArcGIS desktop and server versions, and ENVI. No action taken to move to open source-only solutions.
Overall, objective for OSINFOR is not to have a new, better EW system, but one that demonstrates better resource management (e.g., information from GLAD Alert and GeoBosques systems).
Capacity development activities are performed and current interest relates to distinction between anthropic and natural changes, use of SAR data, and species identification.

Brazil

The ***Centro Nacional de Monitoramento e Informações Ambientais*** (CNMIA) (belongs to IBAMA) uses an EW system for activities related to REDD+), UNCBD and UNSDGs. The EW system targets illegal logging activities and is used also for raising public awareness (legal commitment). Standard Operation Procedures have been defined. At IBAMA all data received from different platforms (DETER A, DETER B, JJ-FAST, SAD-IMAZON, SAR-SIPAM, GLAD Alert system) are treated in SISCOM database to give the possibility to prioritize detected changes. Inside the database active disturbances are identified (deforestation, degradation, fire, etc.) and their velocity is characterised. Changes can occur in indigenous land, protected areas, public areas, private areas, etc). Then the information on the disturbances is put on the intranet. Work is coordinated as follows: INPE and SIPAM produce the data and ICMBio tackles deforestation inside protected areas. Change detection is notably performed by visual interpretation. The EW system is recognised by the authorities as evidence in court, and for Law enforcement. IBAMA has used EW system information since 2004, and ICMBio since 2006. Environmental regional offices use EW system information also. Lack of people to enforce Law is reported as an institutional barrier.
Main types of forest types and contexts are: dry and rain forests, savannas, mangroves, plantations, and concessions. Most critical information to obtain within these areas relates to deforestation, forest degradation, natural/ anthropic change distinction, land use change, fire, and mining. Deforestation speed is a key parameter to estimate. Best minimum mapping area is one hectare and optimal time resolution is one day. A few omission errors can be considered as acceptable while commission errors shall be at the lowest possible rate. Fast growing deforestation usually turns into a massive deforestation event. Therefore time resolution is really crucial to accurately estimate speed of deforestation. The developed EW system is considered as operational. This has been the case for 10 years. Improvements are needed regarding how field data is collected and transmitted to the servers for processing.
Optical satellite data (>=10m and <10m spatial resolutions) and SAR data are used with satisfaction. No airborne data is collected, and field data is collected by IBAMA to confirm detected changes and estimate accuracy. IBAMA is opened to the use of commercial data such as Planet data for temporal

resolution and SAR data to monitor cloudy areas. Cloud computing resources (Google Earth Engine) are used for higher data storage and computing capabilities. No datacube is used and no plan has been defined to use one. Used software are QGIS, GRASS, SNAP, Orfeo Toolbox, R, Python, Geoserver, Leaflet, and Carto. An upgrade of the EW system is planned to meet new needs: oil spill detection.
Training is desired on spatial database operations, use of Google Earth Engine, and BFAST.
Use of open source solutions is a priority while having a country-owned solution is not seen as important.

The ***Centro Gestor e Operacional do Sistema de proteção da Amazônia*** (CENSIPAM) develops an EW system (SIPAMSAR) for activities related to deforestation monitoring with focus on illegal logging, management of protected areas. Standard Operation Procedures have been defined. CENSIPAM aims to develop a system to process, analyse and interpret SAR images that extracts monthly-based deforestation alerts and delivers results to IBAMA, who investigates and acts against illegal activities. Work coordination with IBAMA is performed via meetings and data provision procedures. SIPAMSAR is not recognised by the authorities (still in evaluation phase by IBAMA). The EW system has been considered as operational for one year.
Main forest type encountered in the monitored region is rain forest within concessions and protected areas. Most critical information to obtain is deforestation, forest degradation and mining activity. Best minimum mapping area is 0.5ha and optimal time resolution is 15 days. An accuracy of 90% and higher is sought.
SAR data is employed by the EW system and is considered as meeting developers' needs. Airborne data is also used (airplane, drone) for monitoring and validation activities. Data is collected by CENSIPAM. Field data (pictures notably) help validation of detected changes. CENSIPAM is open to the use of commercial data and uses data like COSMO-SkyMed X-band imagery (3m-spatial resolution, 30-day revisit period). No Cloud computing service is used nor datacube technology. Change detection method is based on coefficient of variation, minimum values and gradient between 2 SAR images from different dates. An upgrade of the system is planned in order to detect mining activities and forest degradation. Automation of deforestation is also sought.
Lack of specialists is reported as a barrier. Other issues reported relate to implementation of semi-automatic chains to extract deforestation alerts, satellite ground station operations, forest degradation and mining detection. Training from Sarmap was followed in 2016 on use of ENVI Sarscape.
Use of open source solutions is seen as a priority while having a country-owned system is considered as important.
No information is released to the public yet however such an activity is planned for 2019 (legal commitment and internal initiative).

SOUTHEAST ASIA

<u>Vietnam</u>
The **Forest Inventory and Planning Institute** (FIPI) uses an EW system for activities related to REDD+ ,

the UNCBD, and monitor some SDGs. Main applications of the EW system are: management of protected areas, empowering local landholders, enforcing conservation compensation programs, raising people awareness (by Law but also internal initiative). No Standard Operation Procedures have been defined. Coordination is performed with SilvaCarbon (USGS), University of Maryland, and JAC through training activities.
The EW system is recognised by Law enforcement as a source of evidence. Vietnam Forest rangers use the EW system as a source of information.
Forest types encountered in the monitored areas are dry, and rain forests, mangroves. Plantations and protected areas are also found in the monitored area. Most critical information to obtain relates to deforestation, forest degradation, natural versus anthropic change distinction, and land use change. Best minimum mapping area is one hectare and optimal time resolution is seven days. A satisfactory level of accuracy starts at 80%. Such values relate to forest plots' surfaces which correspond to 0.5ha in natural forests, and 0.2ha in plantation forests.
FIPI is not an EW system developer and the EW system currently used is not fully operational yet. The EW system is expected to become fully operational in five years. Programming and image processing capacities are needed to develop/ maintain, and adjust the EW system for Vietnam specific case. The EW system is expected to consider free optical data such as Landsat and Sentinel-2 data.
Limitations also reported relate to the lack of equipment, and capacity to use satellite imagery and other forest monitoring technologies in general.
Open source software is considered as a priority while having a country-owned EW system is seen as important.

Indonesia

The **Indonesian National Institute of Aeronautics and Space** (LAPAN) is developing an EW system for activities related to REDD+ monitoring and reporting activities. Main applications are management of forests and raising public awareness (internal initiative). No Standard Operation Procedure has been defined. Coordination is performed with the Ministry of Environment and Forestry (MoEF) Indonesia, WRI, and UMD. MoEF is the user of the EW system. LAPAN together with UMD and WRI Indonesia develop models and products based on the requirements from the Ministry of Environment and Forestry (MoEF). The process usually consists of several activities, such as seminars, workshops, and FGDs. The EW system is not recognized by authorities yet. The process is in progress since the MoEF has the mandate to report on forest state on an annual basis. Agreement on which monitoring system will be used is reported as an institutional barrier.
Forest types and areas of interest reported are rain and peat forests, mangroves, but also plantations, concessions, and protected areas. Most critical information to obtain relates to land use change and associated drivers. Best minimum mapping area is 10ha and optimal time resolution is eight days. The EW system is expected to become fully operational in one year (2019).
Spaceborne optical (>=10m and <10m spatial resolutions) and SAR data are used and considered satisfactory. No airborne data is used. An external partner (MoEF) collects field data for validation purposes. LAPAN is opened to commercial data and considers SAR data as a potential solution to overcome issues related to cloud coverage. No Cloud computing is performed to date however this

may change due to data storage limitations. No datacube is used and the software suite is composed of ArcGIS, QGIS, ENVI, and PCI Geomatica. A self-developed change detection method is used. No detail reported. The current software configuration is not satisfying, notably due to speed processing issues.
LAPAN participates in training activities, notably on identification of drivers of deforestation with UMD.
Use of open source solutions is seen as a priority while having a country-owned system is considered as important.

The **National Forest Resources Monitoring** (NFRM) of the Ministry of Environment and Forestry (MoEF) develops together with LAPAN an EW system for activities mainly related to REDD+. Needs for an EW system include activities related to illegal logging and raising public awareness. No Standard Operation Procedure has been defined. LAPAN is developing the EW system based on MoEF's needs. . Though, interest in coordination with relevant entities is expressed. The EW system is not recognised by authorities but is seen as a first step towards collection of evidence on the ground. Communication with higher levels in the institution, and political issues are reported as institutional barriers.
Rain, dry, peat forests, mangroves are the forest types encountered in the monitored areas with deforestation as the main event to be tracked. Best minimum mapping area is one hectare and optimal time resolution is one day. The reported satisfactory targeted accuracy is of 80%. High revisit frequency of Earth Observation platform is important for early identification. The EW system is expected to become fully operational in one year (2019).
Satellite optical data (>=10m spatial resolution) and SAR data is used. No airborne data is used and field data is collected by NFRM and partners such as NGOs, Universities and civil society. Field data is used to validate detected changes. No interest in commercial data is expressed. No Cloud computing is performed and no change is planned regarding this technology. Datacube technology is not known. Software suite is composed of ArcGIS, ENVI and Erdas, however it does not fulfil current needs. Computation of accuracies is reported as difficult. Overall, limitations reported relate to human, software and hardware resources. No participation in training activity is reported.
Use of open source solutions is seen as a priority while having a country-owned system is considered as important.
Reporting on activities to the public is planned for 2020.

The NGO ***Hutan Alam dan Lingkungan*** (HaKA) uses an EW system (GLAD Alert system, cited as *Global Forest Watch platform*) for forest monitoring activities in the region of Aceh. These activities contribute to support monitoring of illegal activities, manage protected areas, raise public awareness, and manage concessions. HaKA is an NGO that supports the Government to protect the forest area and Leuser ecosystem in Aceh. HaKA uses following Standard Operation Procedures:
- GIS team provides information from EW system to field data collector on a monthly basis,
- Data collector goes to the location and collects field data (photos, information etc),
- Data collector comes back from the field, gives field data to database team,
- Database team handles the data and gives it to the GIS team,
- GIS team will make maps to be provided to management,

- Management (incl. supervisor, manager, coordinator and director) discusses how to follow up,
- Law enforcement team will follow up with the police and related stakeholders.

Therefore coordination is performed with Environment and Forestry Agency (MoEF), Conservation Agency, National Park Agency, Police, Partner NGO, and Research Institute. Coordination is performed through provision of reports and data. The EW system is recognised by the Law Enforcement unit in MoEF as preliminary evidence. Institutional barriers reported come sometimes from main stakeholder, management body for forestry sector at provincial level, and the Law enforcement unit.

Main forest types and areas of interest are rain and peat forests, but also plantations, concessions and protected areas. Main activities to be monitored over these areas are deforestation, forest degradation, and land use change (incl. drivers). Best minimum mapping area is one hectare and the optimal time resolution is eight days. A satisfactory level of accuracy is 90%.

HaKA is not an EW system developer and the system used has been considered as operational for one year. Information is released to the public as an internal initiative.

Training is received on how to use Global Forest Watch tools (online platform and Forest Watcher App). Training is also performed by HaKA towards Government and NGO in Aceh and North Sumatra. HaKA has performed training on Forest Watcher App.

Using open source solutions is considered as a priority and having a country-owned system as rather important.

The **Natural Resources Corruption Eradication Unit for Natural Resources at the Corruption Eradication Commission** (KPK) uses an EW system for activities related to REDD+ monitoring and reporting. Main applications of the EW system are linked to investigating illegal activities, managing protected areas, and empowering local landholders. No Standard Operation Procedures have been defined. Work is coordinated with Ministries of Environment & Forestry (MoEF), Mining, Plantation, Spatial Planning & Land Agency, Home Affairs, Ocean & Fisheries, Law Enforcement Agencies, Geospatial Information Agency (BIG), LAPAN, Local Governments, NGOs, and Academia. Coordination is performed via meetings, system reviews and feedback. The system is not recognised by the authorities. Though, MoEF is working on integrating an EW system to support some activities. Also as recommended by KPK, the MoEF should install a forest monitoring system. Yet the EW system feature remains underdeveloped.

Institutional barriers reported are a lack of capacity, coordination, system and information interconnection, and lack of leadership.

Forest types and areas of interest reported are rain and peat forests, mangroves, but also plantations and protected areas. Main activities to be monitored are deforestation, forest degradation, natural versus anthropic disturbance distinction, and land use change. Critical information to collect related to the drivers of change. Best minimum mapping area is one hectare, optimal time resolution is one month, and targetted accuracy is 90%. KPK is not an EW system developer and the system currently used is not considered as operational. The EW system is developed by the MoEF. There is no participation in training activity, however interest to participate in such activities is expressed with potential topics being Blockchain, and big data analytics. Use of open source software is considered as a priority and having a country-owned system is deemed important.

Release of information to the public is made as the result of an internal initiative.

Annex 2. Country Expert Questionnaire (Users and System Developers)

Introduction

The Early WarningWorking Group of the Global Forest Observations Initiative (GFOI) is performing a user needs assessment (UNA) on tropical forest cover change early warning systems (EWS) to determine how such forest monitoring technologies are being used, and to identify opportunities for improvements that can meet country users' needs. The assessment will seek to produce a series of recommendations on how GFOI partners may wish to support improved technical capability and usability of early warning technologies.

You are free to skip questions you do not want to answer.

Please provide email address(es) to identify yourself/ yourselves.

1- Policy and application context

Which policy, regulation or program (if any) does the forest cover change EWS support? *Multiple choice check boxes + Free text field (other)*

Which application(s) do you need an EWS for? *Multiple choice check boxes (investigate illegal activities, managing protected areas, empowering local landholders, enforcing conservation compensation programs, raising public awareness, concession management, certification) + Free text field (other)*

Do you have Standard Operational Procedures (SOPs) or equivalent in place for the operation of the EW system and/or the use of its results? *Y/N*

If Y,

Please briefly describe the role and structure of these procedures: *Free text field*

Do you coordinate actions with other institutions? *Y/N*

If Y,

Indicate the institutions you coordinate your work with (e.g., Ministries, Academia, research institutes, NGOs, private sector): *Free text field*

How do you coordinate your work/ share activities? *Free text field*

If N,

Would coordination improve your capacity to meet your objectives? *Y/N*

Please explain *Free text field*

Is the forest cover change EWS officially recognised by any legal system? *Y/N*

If Y,

What type of legal actions use EWS information? *Multiple choice check boxes (evidence in*

court, law enforcement) + Free text field (other)

Indicate which agency(ies) use(s) EWS information and for how long have they done so: *Free text field*

If N,

Indicate the reasons *Free text field*

Indicate the interest of government authorities to use the EWS information, how they plan to use it and when (if known): *Free text field*

Indicate the main institutional barriers you may face to meet your goals *Free text field*

2- Forestry context

Please list the forest types you are monitoring or interested in monitoring *Multiple choice check boxes (cloud forest, rain forest, dry forest, Andean forest, cerrado, miombo, savannah, peat forest, mangrove, plantation, concession, protected area) + Free text field other)*

What type of monitoring are you mostly interested in? *Multiple choice check boxes (defor, degrad, natural/ anthropic change distinction, land use change) + Free text field (other)*

Characterize most critical types of information you need to produce/ use?:

Most important thematic classes (e.g., deforested, degraded, driver of change) *Free text field*

Best minimum mapping unit (in hectares) *Free text field*

Optimal time resolution (observation frequency in days) *Free text field*

Satisfactory targeted accuracy (omission & commission errors/ missed occurrences& false occurrences) *Free text field*

Please explain briefly why these specifications are needed to meet your goals *Free text field*

3- Resources

Operational level

Are you an early warning system developer? *Y/N*

Sections 4, 5, 6 will be skipped if you are not an EWS developer

If Y,

Sections 4, 5, 6 displayed

Is the forest cover change EWS you are using/ developing operational? *Y/N*

If Y,

For how long has it been operational (in year(s))? *Drop down menu*

What skills does your institution still need to develop, maintain or use the EWS (if any)? *Free text field*

If N,

When do you expect it to become fully operational, even partially? *Drop down menu*

What skills does your institution need to develop, maintain or use the EWS? *Free text field*

4- Data sets (mostly for EWS developers)

Which space borne data do you (intend to) use? *Multiple choice check boxes*

Does space borne data meet your needs? *Y/N*

If N,

What challenges do you face (cloud cover, low observation frequency, spatial resolution, impossibility to discriminate some classes)? *Multiple choice check boxes + Free text field (other)*

Do you use airborne data? *Y/N*

If Y,

Select the type(s) of platform(s) you use (drones, airplane): *Multiple choice check boxes + Free text field (other)*

Indicate the type of application (calibration & validation data, monitoring, land use identification) *Multiple choice check boxes + Free text field (other)*

What field information do you collect for the EWS? *Free text field*

Who collects the field data (your institution, a partner)? *Multiple choice check boxes*

If partner,

Please indicate which partner(s) *Free text field*

How do you use these field data? *Free text field*

Are you open to the use of commercial data, if not already the case? *Y/N*

If Y,

Which data would you consider and for what purpose? *Free text field*

5- Infrastructure and platform (mostly for EWS developers)

Do you do cloud computing? Y/N

If Y,

What is/are the reason(s)? *Multiple choice check boxes (higher data storage, higher computation capabilities) + Free text field (other)*

What platform do you use (Google Earth engine, Amazon, Sepal, ESA TEP Forestry)? *Multiple choice check boxes + Free text field (other)*

If N,

Are you planning to use Cloud platforms? *Y/N*

If Y,

Indicate the reasons *(higher data storage, higher computation capabilities) + Free text field (other)*

6- Software (mostly for EWS developers)

Do you use a datacube? *Y/N*

If Y,

Which one do you use? *Multiple choice check boxes () + free text field (other)*

Does it meet your needs? *Y/N*

If N,

Indicate which improvement(s) you would like to benefit from *Multiple choice check boxes () + free text field (other)*

If N,

Do you know what a datacube is? *Y/N*

If Y,

Are you planning to use one in the future? *Y/N*

Which software do you use? *Multiple choice check boxes (ArcGIS, QGIS, Grass, ENVI, Erdas, IDRISI, SNAP, Orfeo Toolbox, PCI Geomatica, Definiens, R, Python)+ free text field (other)*

Which change detection method(s) do you use? *Multiple choice check boxes (BFAST, CCDC) + free text field (other)*

Does the current software configuration allow you to meet your objectives? *Y/N*

If Y,

Are you planning any upgrade of your system? *Y/N*

If Y,

Indicate which evolution(s) you are considering *Free text field*

If N,

What challenges do you face? *Free text field*

7- Capacity enhancement

Do you participate in any capacity development activities? *Y/N*

If Y,

What training program are you participating in and which entity provides you with this

support? *Free text field*

If N,

May you consider requesting support to fill in some knowledge gaps? *Y/N*

If Y*,*

What topics would you like to receive support on? *Free text field*

8- Complementary questions

Regarding the technology, is using open source solutions a priority? Y/N

How important is it for you to have a system that is "country owned"? *Drop down menu (Important, Rather important, Not important)*

Do you release information to the public, commit to any kind of transparency/ dissemination framework (e.g., public awareness activities)? *Y/N*

If Y,

Please describe the framework *Multiple choice check boxes (legal commitment, internal initiative)*

If N,

Are you planning to commit any transparency framework? *Y/N*

If Y,

When are you planning to commit to it (years)? *Drop down menu*

Please describe the framework *Multiple choice check boxes (legal commitment, internal initiative) + Free text field (other)*

Annex 3. Tool Developer Expert Questionnaire

1- Tool uptake by countries

In the context of forest cover change EWS, which country(ies) and/ or institution(s) use(s) your tool for operational purposes? Provide contextual information, if known (e.g., types of change, forest types) *Free text field*

2- User needs

Do you capture user feedback? *Y/N*

If Y,

How do you this? *Multiple choice check boxes*

What are the needs yet to be met? *Free text field*

Based on this feedback, are you planning any evolution of your tool? *Y/N*

If Y,

What are the main evolutions and foreseen release times? *Free text field*

If N,

What is the reason? *Free text field*

If N,

Are you planning any further update to the tool? *Y/N*

If Y,

What will be the main updates and foreseen release times? *Free text field*

If N,

What is the reason? *Free text field*

3- EO data

Which EO data can your tool handle (*optical, SAR, lidar, other*)? *Multiple choice check boxes*

Please specify *Free text*

Can your tool store/handle jointly some of these datasets? *Y/N*

If Y,

Please list datasets that can be stored/handled jointly (for each tuple, use "-" to connect datasets together, and use ";" to separate the tuples, if any. Ex: Landsat8-S2; S2-S1-ALOS2) *Free text field*

If N,

Are you planning any updates that will allow handling of different EO data sources? *Y/N*

If Y,

Please list datasets that will be stored/ handled jointly (for each tuple, use "-" to connect datasets together, and use ";" to separate the tuples, if any. Ex: Landsat8-S2; S2-S1-ALOS2) and foreseen release time *Free text field*2*

If N,

What is the reason? *Free text field*

4- Access

Is your tool publicly available and free to use? *Y/N*

If N,

Could you provide a cost estimation of your tool (e.g., licensing, operation, maintenance)? *Free text field*

Are you planning to make your tool publicly available and free to use? Y/N

If Y,

When is this expected to happen? *Free text field*

Is the code open source? *Y/N*

If N,

Are you planning to make your tool open source? Y/N

If Y,

When is this expected to happen (in years)? *Drop down menu*