Food and Agriculture Organization of the United Nations

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Integrating FOREST AND LANDSCAPE RESTORATION into national forest monitoring systems

Integrating **FOREST AND LANDSCAPE RESTORATION** into national forest monitoring systems

by
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Food and Agriculture Organization of the United Nations
Rome, 2021

REQUIRED CITATION:
Ramírez, C. and Morales, D. 2021. *Integrating forest and landscape restoration into national forest monitoring systems.* FAO. Rome. https://doi.org/10.4060/cb6021en

ISBN 978-92-5-134820-8

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Acknowledgements

This document was made possible thanks to the dedication of many people and institutions that contributed with time and expertise.

It was coordinated by Carla Ramirez Zea, FAO Regional Advisor for Latin America and the Caribbean on Forest Monitoring and REDD+. Lead authors were Carla Ramirez Zea and David Morales Hidalgo, both FAO officers. There were contributions from Manuel Rodas, Ogden Rodas, José López and Luisa Palacios from FAO Guatemala; as well as from, Rafael Ávila, Dánger Gómez, Estuardo Fuentes and Kevin Samayoa, from the National Forest Institute of Guatemala who developed the case scenario to show the integration of monitoring at different scales to develop the map of potential restoration areas of San Juan Chamelco, Guatemala.

The authors extend their gratitude to César Sabogal for his contributions, review and comments on forest and landscape restoration, as well as Julian Fox, Yoshihiko Aga, Javier García Pérez, Rocío Cóndor Golec, Carolina Gallo Granizo, Lucio Santos, María del Carmen Ruiz and Erith Muñoz, for their valuable comments and review.

At the country level, it is important to acknowledge and thank the national technicians responsible for the implementation of national forest monitoring systems and forest and landscape restoration monitoring in Latin America and the Caribbean, who contributed with their experiences and lessons learned on collecting information for national and international reports.

This publication was funded by the UN-REDD Programme, through support from Denmark, Japan, Luxembourg, Norway, Spain, Switzerland and the European Union, and the project "Mitigation potential of global actions to enhance forest carbon stocks," supported by the Government of Japan.

Finally, we are grateful for the support of Marie Jankovic for copy-editing, Maryia Kukharava in knowledge management, Zoe Klobus for proof-reading, Joy Taylor for the administrative support, and Lorenzo Catena for the graphic design of the publication.

Abbreviations and acronyms

BUR	biennial update report
CBD	Convention on Biological Diversity
CEOS	Committee on Earth Observation Satellites
FAO	Food and Agriculture Organization of the United Nations
FERM	Framework for Ecosystem Restoration Monitoring
FLR	forest and landscape restoration
FLRM	Forest and Landscape Restoration Mechanism
FRA	Global Forest Resource Assessment
FREL/FRL	forest reference emission level and/or forest reference level
GFOI	Global Forest Observations Initiative
GHG	greenhouse gas
GHGI	greenhouse gas inventory
IPCC	Intergovernmental Panel on Climate Change
KOICA	Korea International Cooperation Agency
LCCS	land cover classification system
LiDAR	light detection and ranging
NBR	normalized burn ratio
NDC	nationally determined contributions
NDFI	normalized difference fraction index
NDVI	normalized difference vegetation index
NFI	national forest inventory
NFM	national forest monitoring
NFMS	national forest monitoring system
NICFI	Norway's International Climate and Forest Initiative
OECD	Organisation for Economic Co–operation and Development
RAINFOR	Amazon Forest Inventory Network
REDD+	reducing emissions from deforestation and forest degradation
RedSPP	Subtropical Network of Permanent Grasslands (by its acronym in Spanish)
RS	remote sensing
SAR	synthetic aperture radar
SDGs	Sustainable Development Goals
SINCHI	Amazonic Institute of Scientific Research
UN	United Nations
UN–REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
VGNFM	voluntary guidelines on forest monitoring systems
WRI	World Resources Institute

Executive summary

The UN Decade on Ecosystem Restoration is a call to action to protect and restore ecosystems globally. It is an opportunity for national, sub-national and local governments, communities and anyone in society to come together to support restoration as a way to restore well-being and reduce risks from climate change.

The UN-REDD Programme and the Food and Agriculture Organization of the United Nations (FAO) have provided support to countries along the way to develop plans and actions for forest and landscape restoration (FLR) to improve the means of production, nutrition, the environment and people's lives.

FLR requires reliable data for planning, implementation, reporting and evaluation of progress at the global, regional, national, sub-national and local levels. The aforementioned represents a challenge for those responsible for restoration, so it is essential to provide comprehensive solutions to reduce costs and avoid duplication of efforts and inconsistency in reporting results.

In recent years, governments and international organisations and initiatives, including FAO and UN-REDD, have invested significant financial resources in the consolidation of national forest monitoring systems (NFMS); so, it is recommended that NFMS be strengthened to include data collection from FLR, rather than promoting independent monitoring structures.

This document is based on the Voluntary guidelines on national forest monitoring (VGNFM) developed by FAO in 2017. It includes more recent experiences from Latin American and Caribbean countries, whose forest systems require strengthening for integrating FLR monitoring.

Strengthening NFMS implies the integration of the institutions participating in FLR. Technical solutions are proposed for data collection at all scales to satisfy stakeholder needs. Some solutions may be implemented in the short term, whereas others will require more extended periods; hence the process of strengthening capacities must be progressive so that the needs for immediate information are satisfied while also moving forward with strategies that require longer implementation.

This document provides a series of good practices organized into sixteen steps to facilitate the integration of the monitoring process to officers responsible for FLR and NFMS. An inter-institutional work is proposed with key stakeholders to discuss the new information needs according to the approach and modalities of FLR implementation. Based on these needs, indicators, metrics and monitoring attributes are organized.

Integration is also approached through different technical aspects such as improvements in the definitions of land use and land cover categories to ensure an appropriate measurement of the increase in the number of trees in restored areas. These areas should be measured at the national, sub-national and local levels, which involves integrating monitoring scales to obtain consistent and comparable information. Besides, solutions are provided to obtain information with low uncertainty, through an appropriate integration of ground-based data with remote sensing data.

Each monitoring component should contemplate certain adjustments to address FLR needs, which can progressively be implemented according to the country's capacities. The use of technological tools is necessary to assist the processes of data compilation, management, analysis and dissemination. A description of the main tools and technological platforms developed by FAO is included, such as Collect, Collect Mobile, Collect Earth, System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL), the Framework for Ecosystem Restoration Monitoring (FERM) and the Hand-in-Hand Geospatial Platform. The document ends with recommendations for capacity building aimed at maintaining the quality and sustainability of NFMS.

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Key messages

1

Integrating forest and landscape restoration (FLR) into national forest monitoring systems (NFMS) is necessary to:

- maintain the consistency of national statistics on forests and trees;
- avoid duplication of efforts; and
- reduce monitoring costs.

2

The baseline of FLR monitoring should include all land uses in the national territory to measure new areas with forests, and the expansion of tree cover in other land uses.

3

To reduce monitoring costs, key institutions must be integrated to work on a single NFMS that responds to national, sub-national and local information needs.

4

National forest inventories (NFI), forest socioeconomic surveys and community forest monitoring are fundamental data sources for evaluating biophysical, environmental and socioeconomic indicators, as well as for producing high-quality thematic maps of FLR progress.

5

Collect Earth and Collect Earth Online are Open Foris tools that improve statistics on the changes in land use and land cover with very high-resolution satellite images.

6

The System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL) is a FAO tool that increases the capacity of analysis and satellite data management to produce maps for FLR planning and implementation.

7

The Framework for Monitoring Ecosystem Restoration (FERM) facilitates the monitoring of the progress of the restoration of degraded ecosystems, provides methodological guidelines and a platform for building capacity and enables knowledge and technology transfer.

8

The Hand-in-Hand Geospatial Platform is an evidence-based FAO platform to compile and transform data such as those collected by the NFMS, to accelerate the implementation of actions, such as FLR, to meet the Sustainable Development Goals (SDGs).

9

Improvements in NFMS should be implemented in short, medium and long-term phases to allow immediate responses to FLR information needs.

10

Social inclusion must be ensured in NFMS and FLR monitoring by allowing equal participation of women and men to raise awareness and create collective knowledge on the progress of FLR with a gender perspective.

1

Chapter 1

Introduction

1.1 FOREST AND LANDSCAPE RESTORATION

Forest and landscape restoration (FLR) is understood as the process of productive, ecological, functional recovery and improvement of livelihoods in deforested or degraded landscapes. FLR means to recover, improve and maintain the productive, ecological, economic and social long-term functions that lead to more resilient and sustainable landscapes (FAO, 2019).

According to FAO (FAO, 2009), around 20 percent of the overall vegetation-covered surface worldwide shows a decreasing trend in productivity, with fertility losses related to erosion, reduction in productivity and pollution. By 2050, degradation and climate change could reduce agricultural yields between 9 and 21 percent worldwide.

Although the rate of forest loss decreased in the last decade (2010-2020), 4.7 million hectares per year are still lost (FAO, 2020a). Forests and trees are vital elements in the restoration of degraded ecosystems while offering products for human consumption and ecosystem services, such as improving soil fertility and water flows, mitigating climate change and conserving biodiversity (FAO, 2020b).

A recent study, including direct forest cover measurement used to generate a potential global restoration model, has shown that there are 0.9 billion hectares outside of forests, agricultural land and urban spaces that are appropriate for continuous forest restoration (Bastin *et al.*, 2019). However, if the complete landscape is included, more than two trillion hectares worldwide would benefit from restoration interventions (GPFLR, 2011).

Several international initiatives help create greater awareness on the importance of forest and landscape restoration. The Parties of the Convention on Biological Diversity (CBD) approved the Aichi Biodiversity Targets in 2010; target number 15 urges countries to restore at least 15 percent of their degraded ecosystems before 2020.

The Bonn Challenge was launched in 2011 with the aim to restore 150 million hectares by 2020 and 350 million hectares by 2030, which is expected to capture between 13 and 16 giga-tonnes (Gt) of carbon dioxide and produce USD 9 billion in estimated net benefits (Besseau *et al.*, 2018). These goals were endorsed in the New York Declaration on Forests of 2014 by 189 governments, Indigenous communities, private companies and civil society organisations (United Nations, 2017). Some regional initiatives were also launched to support the goals, such as the 20x20 Initiative, which committed to the restoration of 20 million hectares by 2020, and the African Forest Landscape Restoration Initiative AFR100, which seeks to restore 100 000 hectares in Africa by 2030.

The Sustainable Development Goals (SDGs) were launched in 2015; SDG 15 (Life on Land) calls upon countries to “sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss,” which is directly linked to FLR. Its fulfilment will contribute directly to SDG 1 – No Poverty, SDG 2 – Zero Hunger, SDG 3 – Good Health and Well-Being, SDG 11 – Sustainable Cities and Communities, and SDG 13 – Climate Action.

Within the sphere of the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, through the submission of the Nationally Determined Contributions (NDC), Parties have reported restoration efforts, such as mitigation actions and/or adaptation to climate change, for example the protection and restoration of forests or the restoration of wetlands to promote the absorption of greenhouse gases (UNFCCC, 2016; UNFCCC, 2021; FAO, 2016).

In March 2019, the United Nations General Assembly announced the UN Decade on Ecosystem Restoration (2021-2030), aimed at setting efforts to prevent, halt and reverse the degradation of ecosystems throughout the world and raise awareness on the importance of successful ecosystem restoration (United Nations, 2019). The declaration also emphasises that forests, wetlands, arid lands and other natural ecosystems are essential for sustainable development, reducing poverty and improving human well-being. Also, it emphasizes the need for cooperation, coordination and synergies among multiple institutions (United Nations, 2019). The initiative is led by the UN Environment Programme and FAO, in coordination with other partners. It is a global call to action that will draw together political support, scientific research and financial capacity to massively scale up restoration from successful pilot initiatives to covering millions of hectares of land.

Since 2020, FAO and partners created the monitoring taskforce, which brings together technical experts, international organisations, NGOs, governmental agencies, academia and organisations implementing restorations for a collaborative development of the Framework for Ecosystem Monitoring (FERM) for the UN Decade on Ecosystem Restoration. This initiative will bring operational support for tracking the progress of the ecosystem restoration activities following the existing international, regional and national actions and indicators. Through a web platform, FERM builds capacity, provides technical guidance, knowledge and technology transfer.

The FLR initiatives have increased at the national level. Several countries have formulated their national strategies for FLR, included FLR in their forestry policies and, in many cases, share the mitigation goals of the nationally determined contributions (NDC) within the Paris Agreement on Climate Change (Government of Chile, 2020; Government of Colombia, 2020).

FLR projects can be compensated, financed or subsidised through various sources, including private investment, public investment, credits and climate-financing mechanisms such as reducing emissions from deforestation and forest degradation (REDD+). According to the UNFCCC, REDD+ strategies or action plans should include five fundamental activities: reducing deforestation, reducing forest degradation, carbon conservation in forests, sustainable forest management and enhancement of forest carbon stocks (UNFCCC, 2016b). This last activity is directly linked to FLR actions which have been implemented in countries around the world under UN-REDD and other initiatives.

1.2 FOREST MONITORING SYSTEMS AT THE NATIONAL LEVEL

Historically, national interest in forests was centred on wood production (forests as a resource), which facilitated the conversion of forest land to other land uses. This was also the starting point for the first national forest inventories (NFI) in European Nordic countries – Norway from 1919 to 1930; Finland from 1921 to 1924; and Sweden from 1923 to 1929 (Kangas y Maltamo, 2007; Tomppo *et al.*, 2010).

After the Second World War, the basic motivation of generating updated information on worldwide timber resources led the newly founded FAO to establish the Global Forest Resource Assessment Programme (FRA) (FAO, 2018c). Since then, FAO has developed a general report every ten years on the state of the world's forests based on a compilation of national forest information. Starting in 2010, this report is published every five years. Since 2000, FAO has also supported national forest monitoring (NFM) through capacity development for the establishment and management of national forest monitoring systems (NFMS) (FAO, 2012a).

According to FAO (FAO, 2017), a national forest inventory (NFI) is defined as a technical process of data collection and analysis of forest resources at the national level. The NFI may be based on multiple data sources, including field inventories and remote sensing, to estimate the relevant characteristics of forests at specific times. Additionally, it determines that NFM is a broader process that derives from repetition in the analysis, evaluation and interpretation of information to

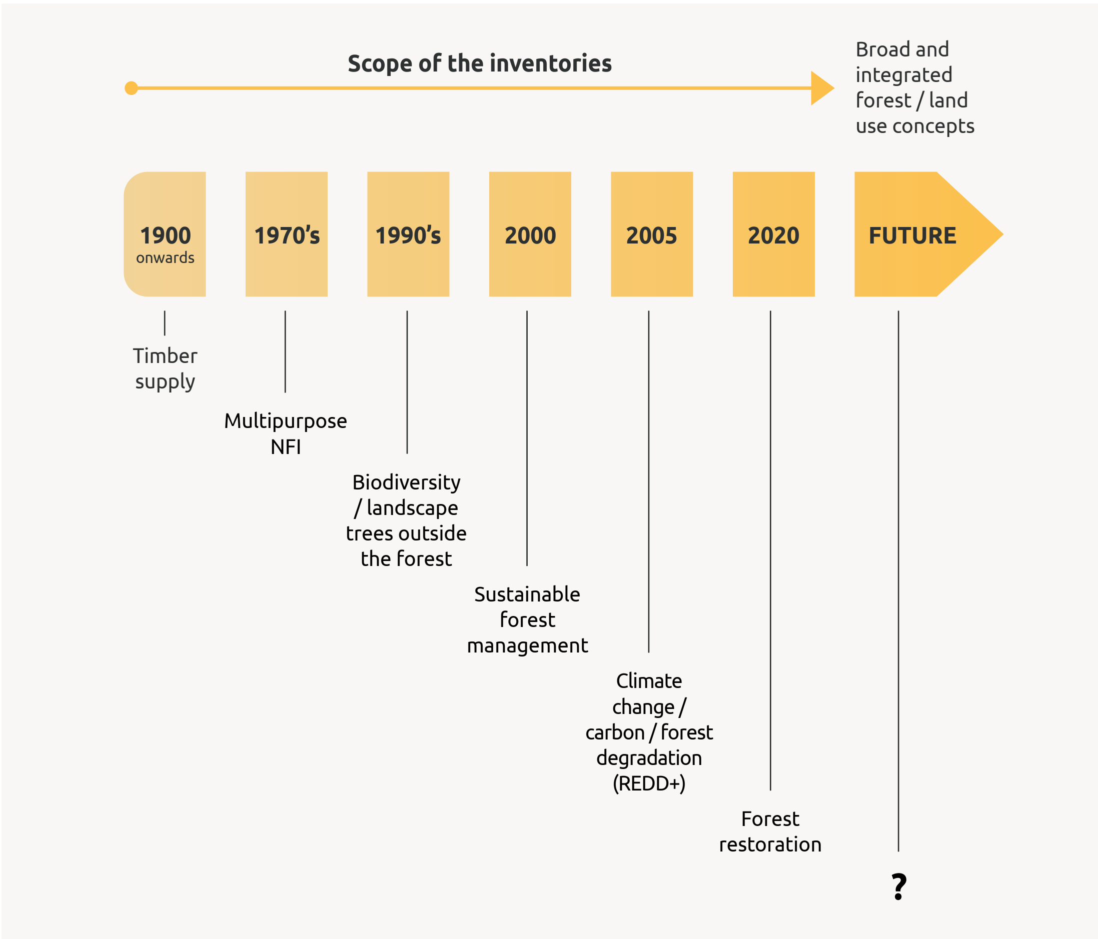
monitor trends over time, which means it contains repeated NFI as main technical components.

NFM tasks are commonly incorporated into the NFMS, a term that refers to the entire monitoring environment, including people, institutions and resources that allow NFM to be performed in collaboration with other interested parties. Generally, an NFMS is led by a governmental body responsible for its conceptualisation, planning and execution within a clear and well-defined mandate, based on the principles and elements introduced in the VGNFM (FAO, 2017).

At the beginning of the 20th century, the central focus of forest monitoring was tracking timber resources. The integration of assessing biodiversity indicators became an additional focus in the 1990s, as did the monitoring of sustainable forest management. These improvements of NFI led to developing a framework of criteria and indicators for sustainable forest management. As of 2005, countries with tropical forests began monitoring efforts in order to respond to the REDD+ mechanism linked to the Greenhouse Gas Inventory (GHGI) and the NDCs reports (Figure 1).

FLR monitoring marks another evolutionary point for NFMS given the importance of expanding data collection related to forests to encompass all land uses within territories. Restoration is expected to increase tree coverage in degraded forest ecosystems and areas that are currently occupied by other land uses or deforested. FLR requires integrating forest and tree-related information with data of other resources such as water and soil, as well as social and economic data. Finally, it also requires an improvement in the integration of information occurring at the national, subnational and local levels.

Figure 1 **Progressive evolution of national forest monitoring systems according to changes in environmental policies and information needs**



Source: Elaborated by the authors.

1.3 INTEGRATION OF FOREST AND LANDSCAPE RESTORATION MONITORING IN NATIONAL FOREST MONITORING SYSTEMS

FLR initiatives and strategies require baseline information and continuous monitoring for regular reviews on success in implementing activities and complying with stakeholders' objectives. The goals to measure progress in restoration are extensive. They integrate environmental aspects, such as biodiversity and land conservation, and the protection of water sources; social elements such as the supply of nutritious foods; economic elements such as the supply of goods and services; and cultural aspects such as the recovery and preservation of ancestral practices (FAO and WRI, 2019).

Monitoring of FLR progress is necessary to develop national and international reports. It is critical to take into consideration that restored areas will be part of forests, in addition some areas will increase the tree cover in a relatively short time, which must be monitored and evaluated through the NFMS.

In most countries, the office responsible for monitoring FLR is different from the NFMS office, and there is often little coordination. Therefore, integration will help to avoid duplication of efforts and will benefit the sustainability of monitoring processes, given the limited resources available to government institutions. Also, it will facilitate the consistency and transparency of information, and reports will be similar as they will be built from a single source of information. These changes will significantly impact the reporting of goals achieved and grant greater credibility and trust to donors or investors.

To integrate FLR issues into NFMS, short-term actions are suggested to respond to immediate needs. Simultaneously, longer-term actions should be developed to improve less pressing aspects of FLR. In general, it should be considered that the process of strengthening national capacities should be organized into three approaches:

I. Governance for the involvement of multiple institutions, actors and technical specialties

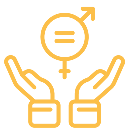
II. Development of institutional capacities in human resources, financing and infrastructure

III. Comprehensive methodological and technical solutions to respond to multiple information needs at multiple spatial levels (national, sub-national or local).

1.4 ABOUT THIS DOCUMENT

The recommendations in this document are primarily based on FAO's Voluntary guidelines on national forest monitoring (VGNFM) (FAO, 2017). The experiences of Latin American and Caribbean countries in the design, planning and implementation of NFMS are also included. This region has accumulated experience in the last 20 years with the support of FAO and other international organisations, and in most countries, NFMS are in a phase of institutional consolidation, with professional expert teams making constant development possible.

The following steps for integrating FLR into NFMS can be implemented in order or selected according to the specific topic of interest.



The following icon appears throughout the document, indicating guidance on integrating gender and equity to enable NFMS to evolve towards inclusion.

As support material, it is suggested to use the NFMS assessment tool, which is based on the VGNFM, reinforced by the REDDcompass of the Global Forest Observation Initiative (GFOI), an online resource that supports the development of NFMS for REDD+ measurement, reporting and verification (FAO, 2020c).

The NFMS assessment tool is available in lesson 2 of the course "Forests and Transparency under the Paris Agreement."

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Chapter 2

Steps to integrate forest and landscape restoration monitoring into national forest monitoring systems

For the implementation of the following steps, it is assumed that there is an NFMS under development. Also, it is understood that FLR is performed to respond to national reports and not to particular projects.

2.1 **STEP 1** IDENTIFY KEY INSTITUTIONS AND STAKEHOLDERS

The restoration monitoring process must be participatory, in which all stakeholders involved take part. Sound stakeholder participation and engagement is key to the overall success of an NFMS and contributes significantly to national ownership (FAO, 2017).

To develop participatory processes, it is essential to identify all the institutions and key stakeholders that are or should be involved in developing restoration activities and monitoring their progress. Participation mechanisms for institutional integration must also be defined, establishing a governance mechanism for the restoration action itself and for monitoring. The objective of stakeholders' participation is for them to express the actual needs and concerns regarding information, as well as to participate in the identification and prioritisation of the indicators, metrics, and data to be collected (FAO and WRI, 2019).

According to the VGNFM, to ensure effective participation of different stakeholders in the integration of FLR monitoring, the NFMS should:

a. Carry out a stakeholder analysis to identify partners and other stakeholders willing to participate in the NFMS process, including different national institutions (especially those involved in policies related to forests and land-use planning), the private sector, academic institutions, civil society, groups representing women and minorities (including indigenous groups) and communities that depend on forests for their livelihoods. The stakeholder identification and engagement process should be transparent and clarify the intentions of the various stakeholders who wish to participate in the NFMS.

b. Encourage key planners and decision-makers to incorporate participation in the NFMS process into their plans and programmes. In particular, the involvement of other sectors (agriculture or urban development) is mandatory when an information needs assessment identifies the need to carry out an inventory of lands outside the forest administration mandate.

c. Encourage intersectoral participation of academic and research institutions.

d. Strengthen stakeholders' capacity and knowledge on the benefits and use of an NFMS and the resulting information.

e. Promote the creation of a working group or a technical advisory committee, to which the NFMS must submit annual reports on its activities.

Establishing a governance mechanism on technical design decisions is a good practice that will allow a feedback process between stakeholders. It must be developed under procedures that will enable the story to be told about decision-making and facilitate accessibility through a document repository.

When adjusting the monitoring design, institutional mandates should be analysed to determine implementation of responsibilities. Having shared responsibilities will reduce monitoring costs. For example, restoration monitoring often requires high-resolution satellite images.

Access to this type of image is subject to argument between the different responsible entities of natural resources monitoring. The resolution is that these institutions can participate through shared responsibility in the purchase of satellite images at the national level, led by geographic institutes or other relevant entities. Collecting field data on different land uses is another example; this task is carried out for the NFI or for agricultural censuses or surveys. A methodological integration process can result in the ability of responsible entities to share financial responsibility for collecting this data, distributing support for monitoring FLR among the different stakeholders.

Further details on the institutionalisation of forest data from a legal and financial perspective can be found online (FAO, 2021).

2.2 **STEP 2** REVIEW NATIONAL TERMS AND DEFINITIONS

Stakeholders participating in the design and implementation of FLR monitoring and NFMS must review the terms and definitions of restoration. An initial exhaustive process to define or adjust national terms to implement FLR monitoring is not recommended. Still, it is advisable to consider some initial concepts to facilitate communication among stakeholders.

The concept of forest and landscape restoration is evolving and based on two approaches. On the one hand, an ecological approach, which guides the restoration of an ecosystem to conditions similar to the initial ecosystem; on the other hand, a productive approach, whose main objective is to improve the ecosystem services of productive areas such as forests, agricultural and livestock systems, or even in urban areas.

Box 1 provides guidance on fundamental concepts to facilitate a common understanding of stakeholders. Some definitions included are from the restoration strategies or plans of Latin American and Caribbean countries.

During stakeholder identification, social inclusion should be considered to ensure equitable participation in terms of gender, age and culture. Equitable and participatory planning from the perspective of women and men of different ages and cultures is an important step to raise awareness, reflect and create collective knowledge for the integration of the needs, values and principles of each group in planning and implementing forest monitoring.

The starting point is accepting inequality in human capacities in monitoring issues due to the lack of educational opportunities. These opportunities are different between women and men, and between communities and ethnic groups (UNESCO, 2017).

Furthermore, forest monitoring should be seen as a cross-generation job. The integration of young people is essential (FAO, 2017) because it is a continuous activity that aims to measure actions on present generations' territory that will affect future generations. On the other hand, it must integrate past and present methodologies and technologies that point towards the future.

Box 1 **Terms and definitions related to forest and landscape restoration**

Deforestation	The conversion of forest to other land use independently whether human-induced or not. With the following explanatory note (FAO, 2018c): a. Deforestation refers to the long-term or permanent loss of forest cover and implies transformation into another land use. Such a loss can only be caused and maintained by a continued human-induced or natural perturbation. b. It includes areas of forest converted to agriculture, pasture, water reservoirs and urban areas. c. The term specifically excludes areas where the trees have been removed as a result of harvesting or logging, and where the forest is expected to regenerate naturally or with the aid of silvicultural measures. Unless logging is followed by the clearing of the remaining logged-over forest for the introduction of alternative land uses, or the maintenance of the clearings through continued disturbance, forests commonly regenerate, although often to a different, secondary condition. In areas of shifting agriculture, forest, forest fallow and agricultural lands appear in a dynamic pattern where deforestation and the return of forest occur frequently in small patches. To simplify reporting of such areas, the net change over a larger area is typically used. d. Deforestation also includes areas where, for example, the impact of disturbance, over-utilization or changing environmental conditions affects the forest to an extent that it cannot sustain a tree cover above the 10 percent threshold.
Forest degradation	Reduction of the capacity of a forest to provide goods and services (FAO, 2002; Simula, 2009). This definition is broad and can serve as a common umbrella and framework to develop specific definitions (FAO, 2011). Forest degradation represents changes in ecosystem processes and a continuous decline in services from primary forests (namely, undisturbed by humans except for traditional forest uses) through various human and misuse management forms, up to deforestation (Thompson *et al.*, 2012). Given the need to have operational definitions to carry out monitoring activities (Lund, 2009), it is essential to define criteria and parameters that facilitate identification in the field or to resort to visualization in satellite images or the development of automated algorithms. Some definitional criteria developed by various sources have been compared (Schoene *et al.*, 2007; Lund, 2009; Simula, 2009; FAO, 2011; Thompson *et al.*, 2012).
Land degradation	Degraded land is considered to be land where there has been a temporary or permanent loss of productive capacity and ecosystem functions caused by human or natural activities, by which the land cannot recover for several decades (Seghal and Abrol, 1992; Eswaran *et al.* 2001).
Reference ecosystems	Refers to a model of characteristics of a particular ecosystem that serves as a reference point to define the goal of restoration (McDonald *et al.* 2016). It provides the ideal model that provides the values for the indicators to evaluate the degree of success of the restoration (Ruiz-Jaen and Aide, 2005).

Continuing **Box 1**

Sustainable forest management	A dynamic and evolving concept that aims to maintain and increase the economic, social and environmental values of all types of forests for the benefit of present and future generations (UNGA, 2012).
Landscape	Refers to an area that contains a mosaic of ecosystems or land uses (Millennium Ecosystem Assessment, 2003). A landscape is "a mosaic of ecosystems, land uses, and social and economic groupings that interact with each other. Its size does not necessarily define a landscape," in the context of FLR, the landscape's size is primarily determined by the scale of the FLR initiative and the possible or desired geographic scope of its impacts (ITTO - IUCN, 2005).
Recovery or reclamation	Recovery or reclamation is used for situations where productivity or structure is recovered, but not biodiversity (Lamb and Gilmour, 2003). The main aim is to recover some ecosystem services of social interest (Ministry of Environment and Sustainable Development of Colombia, 2015; CNRE, undated). Reclamation typically applies to severely degraded land, usually without vegetation, often as a result of the extraction of underground resources, such as mining or work platforms associated with drilling for oil and gas (Denier *et al.*, 2017).
Impact reduction	Refers to maintaining the potential for conservation of biodiversity and other ecosystem services in restored areas while seeking to improve both production and lifestyles that are ecologically sustainable (SER Australasia, undated).
Rehabilitation	Process of reinstating degrees of ecosystem functionality in degraded sites, where restoration is not the chosen option, to allow a continuous supply of ecosystem goods and services (McDonald *et al.*, 2016). It seeks to bring the degraded system to a level similar — or not — to the system before disturbance; a self-sustaining system that preserves some species and provides some ecosystem services (Ministry of Environment and Sustainable Development of Colombia, 2015).
Restoration	Process of assisting, through human intervention and actions, the recovery of an ecosystem that has been degraded, damaged or destroyed (SER, 2004). IPBES (IPBES, 2018) defined restoration as "any intentional activity that initiates or accelerates the recovery of an ecosystem from a degraded state."
Forest and landscape restoration	Process of productive, ecological and functional recovery to improve livelihoods in deforested or degraded landscapes. FLR is a means to recover, enhance and maintain vital long-term productive, ecological, economic and social functions that lead to more resilient and sustainable landscapes (FAO, 2019). It has also been defined by the Global Partnership on Forest and Landscape Restoration (GPFLR, 2011) as an "active process that brings people together to identify, negotiate and implement practices that restore an agreed optimal balance of ecological benefits, social and economic aspects of forests and trees within a broader pattern of land use" (Besseau *et al.* 2018).
Ecosystem restoration	Process of assisting in the recovery of degraded, damaged or destroyed ecosystems, with emphasis on establishing ecological procedures necessary for terrestrial and aquatic ecosystems to be sustainable, resilient and healthy, both under current and future conditions, as well as improving human well-being (FAO, 2020b).

Continuing **Box 1**

Ecological restoration	Natural or anthropic assistance process for the recovery of the ecosystem services of an ecosystem that has been degraded, damaged or destroyed (McDonald *et al.*, 2016). It seeks to restore the degraded ecosystem to a condition similar to the ecosystem before disturbance, concerning its composition, structure and operation (Ministry of Environment and Sustainable Development of Colombia, 2015).

2.3 **STEP 3** DETERMINE THE SCOPE OF MONITORING

The monitoring scale is related to the size of the territory's surface, where activities associated with the FLR will be carried out. It can also be related to the scale of work and, therefore, to the indicators' level of reporting. The scale of restoration monitoring can be:

Administratively limited, at the following levels:

- **Global:** all countries in the world;
- **International regional:** geographic or geopolitical regions such as North America, Central America, South America, West Africa, Southeast Asia;
- **Biogeographic regions:** such as the Amazon, Chaco or African Miombo, or socioeconomic or cultural regions, such as Mesoamerica;
- **National:** actions throughout the territory of a country;
- **State, provincial, regional-national or departmental:** primary administrative divisions of the countries;
- **Municipal, district or cantonal:** local administrative divisions;
- **Indigenous or rural communities:** if this degree of local division applies;
- **Farm, property or lot:** circumscribed to the limits of a property.

Not administratively limited:

- **Basin**
- **Ecosystem**

FLR projects can be developed at any of the above scales. Hence, an integration process that addresses the different scales will help reduce costs and increase transparency of information. The recommendations provided throughout this document can improve the design at any of these scales or propose some integration solutions.

It is advisable to discuss the scope and limitations of monitoring small areas and how these can be integrated into an NFMS (FAO, 2017). The scope of a system is defined by the country and will depend on the technical opportunities and also on the institutional arrangements that may be developed in a process of continuous improvement, as well as the objectives of the monitoring process: whether they respond to an individual, local, municipal, regional or national project.

When working at different national scales, terms and definitions should be harmonised, especially when using the same land use, land cover and ecosystem categories; national terms and definitions should even be harmonised with those used at the international level. Specific methodologies can also be harmonised between scales, such as measurement plot configuration, definition of attributes and specific methods of each attribute. However, some aspects of monitoring design and planning may probably not be integrated between national scale and farm-or-land scale.

2.4 **STEP 4** EVALUATE INFORMATION REQUIREMENTS FOR INTERNATIONAL REPORTING

The international environmental and climate change agendas motivate countries to improve internal policies, seeking joint solutions to issues such as ecological degradation and climate change. At this step, it is recommended to review the indicators related to different international commitments, such as the Sustainable Development Goals (SDGs), the NDCs for the UNFCCC, the Aichi Targets of the Convention on Biological Diversity (CBD), the Convention of the United Nations to Combat Desertification (UNCCD), the World Forest Resources Assessment (FRA), among others.

Since NFMS are a pillar of the preparation processes for implementing the REDD+ mechanism, countries have focused their improvements in responding to the need to report emissions or removals of the activities discussed and established in the REDD+ national action plan or strategy. These activities are: reducing deforestation, reducing forest degradation, conserving carbon in forests, sustainable forest management and increasing forest carbon stocks (UNFCCC, 2016). These activities are also part of the FLR monitoring; however, the information needs must be evaluated to respond to additional international and national indicators based on the FLR monitoring objectives.

On the other hand, identifying international needs must ensure correspondence between international, national, sub-national and local indicators.

2.5 **STEP 5** IDENTIFY INFORMATION NEEDS BASED ON RESTORATION OBJECTIVES

If the country has a national restoration strategy or plan, the strategic restoration objectives and indicators must be analysed. Based on them, and on the reference scale used to plan restoration actions (namely, national, provincial, municipal, basin, ecosystem, community project or farm), it is necessary to determine whether these objectives and indicators are relevant or not and, if necessary, complement or improve them. If the country does not have a national strategy, it is recommended that those responsible for monitoring participate

Gender equality is included in the three United Nations conventions and the Bonn Challenge. Therefore, it is recommended to take the following aspects into consideration:

- Women commonly face higher risks and greater burdens from the impacts of climate change (UNFCCC, undated).

Sijapati (Sijapati, *et al.* 2017) emphasize that:

- FLR is, and will be, implemented in countries and contexts with structural discrimination against women and indigenous communities, highlighting the need for gender-responsive approaches.
- Women and men must have equal influence on FLR decisions, which contributes to equitable outcomes. Equitable participation in consultations on information needs should be monitored.
- It is crucial to formulate indicators and collect differentiated information from women and men on:
  - equitable governance mechanisms,
  - capitalisation on knowledge management of forests and tree and plant species,
  - alternatives on how to approach restoration,
  - preferred and selected tree and plant species,
  - equitable distribution of benefits,
  - costs associated with restoration,
  - access to credits to develop projects,
  - restored areas with equitable gender balance.

in the development process. There are several guides to generate strategies, such as those described by Chazdon and Guariguata (Chazdon and Guariguata, 2018). FAO and the World Resources Institute (WRI) have recently conducted a consultation process on indicators for restoration monitoring with more than 100 experts who supported the development of a guide to facilitate the selection of objectives and indicators (FAO and WRI, 2019). The guide includes a restoration goal wheel (Figure 2), which helps to identify the broad range of subjects of the restoration strategy or plan. The topics on the edge of the wheel correspond to the possible dimensions or goals that FLR can achieve. Each goal must be analysed to create sub-goals, for which the question to be answered is generated. The indicator and the metric must also be defined based on the monitoring question. The guide emphasizes the importance of a forward-looking approach but of low cost, which implies prioritizing the goals, indicators and attributes to be measured in the NFMS. An FAO online course is available for the application of the guide.

2.6 **STEP 6** IMPROVE DEFINITIONS OF LAND USE AND COVER CATEGORIES

It is essential to analyse the definitions of land use and land cover since the indicators on the progress of FLR will be measured according to the different land uses in a selected landscape or area. To monitor forest and landscape restoration, it is recommended to differentiate the concepts of "land use"

Figure 2 **Restoration Goal Wheel to help answer the question: Why restore?**

Source: FAO and WRI, 2019, adapted by the authors.

and "land cover," presented in Box 2. These concepts are often used in an integrated way when conducting analyses with mid-resolution satellite images (for example, Landsat) because it is impossible to separate forested areas from areas with other heavily forested land uses (for instance, agroforestry systems). However, with high-resolution images and field measurements, it is possible to differentiate land cover from land use. Obtaining separate statistics of land use and land cover is essential to measure restoration progress more precisely because a significant variable will be the percentage of trees recovered in different land uses, that is, the increase in the number of trees in cultivated areas, grasslands or urban areas. Understanding this, the NFMS must incorporate measurement of all land uses and land cover in the national territory because they must be able to measure all the restoration options defined in the national strategies or plans. This change is a good practice because when NFMS focus on measuring a territory, delimited exclusively within forest areas, limitations are generated to understand the causes of the changes and why the environment is not analysed.

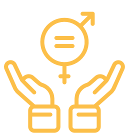
In Box 2, definitions of land use, land cover, and others related to forests and trees are provided to facilitate the review of land use categories.

During the analysis of the definitions of national classes, to be reported in FLR monitoring, it is advisable to generate operational definitions, for which it is necessary to determine criteria and thresholds for classification according to the observation resource and analysis (remote sensing of mid or high-resolution, or field). The Land Cover Classification System (LCCS) (Di Gregorio and Leonardi, 2015) is recommended, which offers an orderly way to define the characteristics and properties of land uses, and the land cover elements that can identify each one. It is also recommended to review the FRA terms and definitions (FAO, 2018c) to determine the thresholds for classification and the increase in tree cover in different land uses.

It is suggested to start by organising the operational definitions of forest, other wooded lands and other lands. FRA proposes three fundamental criteria: minimum area, tree height and canopy cover, whose thresholds are summarised in Figure 3. Thresholds and criteria are exclusive between categories. For example, forest and other wooded lands are not under agricultural or urban use; the main difference between them are the thresholds of tree cover; natural areas with less tree cover than forest are classified as "other wooded lands."

The term "other lands with tree cover" indicates areas with predominantly agricultural or urban use with trees that have the same coverage threshold as forest.

Further analysis should help generate operational definitions of forest types based on their state or condition. Box 2 provides some definitions of forest types that can serve as a starting point. However, due to their complexity, it is recommended to start by making a catalogue of different typologies of forest transitions, taking into account the definitions provided and selecting remote sensing of different spectral and temporal resolutions, using visual interpretation methodologies, analysing data from other vegetation indices with remote sensing and using field information.



Why is the inclusion of gender and cultural diversity perspectives important for forest monitoring?

- Because there are differences between women's and men's roles and needs and the configuration of the territory according to their community.
- Women, men and communities have different uses of forest goods and services.
- It is necessary to capture gender-differentiated socioeconomic information to understand equity and planning interventions in the territory.
- Collecting data and making available sex-disaggregated information on the management and use of forest goods and services is essential to allow inclusive policies concerning equitable access to forest resources.

Adapted from FAO, 2017.

Box 2

Terms and definitions related to forests and trees, that are useful for reviewing national categories for FLR monitoring

Land cover	The biophysical elements on the earth's surface, which are in a vertical projection when observed from aerial or satellite views (Di Gregorio and Jansen, 2000; Bellefontaine *et al.*, 2002; Coffey, 2013).
Land use	Categories based on anthropic decisions established in agreements, operations and activities that people carry out on a portion of land according to their functions to obtain products or benefits from its resources (Di Gregorio and Jansen, 2000; Bellefontaine *et al.*, 2002; Coffey, 2013).
Forest	Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use (FAO, 2018c).
Other wooded land	Land not classified as "forest," spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds *in situ*; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use (FAO, 2018c).
Other land with tree cover	Land considered as "other land," spanning more than 0.5 hectares with a canopy cover of more than 10 percent of trees able to reach a height of 5 meters at maturity. Includes palms for oil production, tree orchards, agroforestry (crops and pastures) and trees in urban areas (FAO, 2018c).
Primary forest	Naturally regenerated forest of native species, with no clearly visible indications of human activities and where the ecological processes are not significantly disturbed (FAO, 2018c). It can also be defined as forest which has never been subject to human disturbance, or has been so little affected by hunting, gathering and logging that its natural structure, functions and dynamics have not undergone any changes that exceed the elastic capacity of the ecosystem (ITTO, 2002).
Managed primary forest	Primary forest in which sustainable wood and non-wood harvesting (for example, through integrated harvesting and silvicultural treatments), wildlife management and other uses have changed the forest structure and species composition from the original primary forest. All major goods and services are maintained (ITTO, 2002).
Degraded primary forest	Primary forest in which the initial cover has been adversely affected by the unsustainable harvesting of wood and/or non-wood forest products so that its structure, processes, functions and dynamics are altered beyond the short-term resilience of the ecosystem; that is, the capacity of these forests to fully recover from exploitation in the near to medium term has been compromised (ITTO, 2002). Another related definition is "degraded forest" from IPCC (2003), as a direct human-induced long-term loss (persisting for X years or more) of at least Y percent of forest carbon stocks [and forest values] since time T and not qualifying as deforestation.

Continuing **Box 2**

Secondary forest	Woody vegetation growing back on land that was largely cleared of its original forest cover (that is, carried less than 10 percent of the original forest cover). Secondary forests commonly develop naturally on land that was abandoned after shifting cultivation, settled agriculture, pasture, or failed tree plantations (ITTO, 2002). Secondary forests regenerate mostly through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or tree canopy species composition with respect to nearby primary forests on similar sites (Chokkalingam and Jong, 2001).
Naturally regenerating forest	Forest composed predominantly of trees established through natural regeneration. Planted trees do not constitute more than 50 percent (FAO, 2018c).
Planted forest	Forest predominantly composed of trees established through planting and/or deliberate seeding. Planted/seeded trees are expected to constitute more than 50 percent (FAO, 2018c).
Forest plantation	Planted forest is intensively managed and meets ALL the following criteria at planting and stand maturity: one or two species, even age class, and regular spacing (FAO, 2018c).
Degraded forest land	Former forest land severely damaged by excessive timber and/or non-wood forest products (NWFP) harvesting, poor management, repeated fire, grazing or other disturbances and land uses that damaged soil and vegetation to a degree which inhibited or severely delayed forest regrowth after abandonment (ITTO, 2002).

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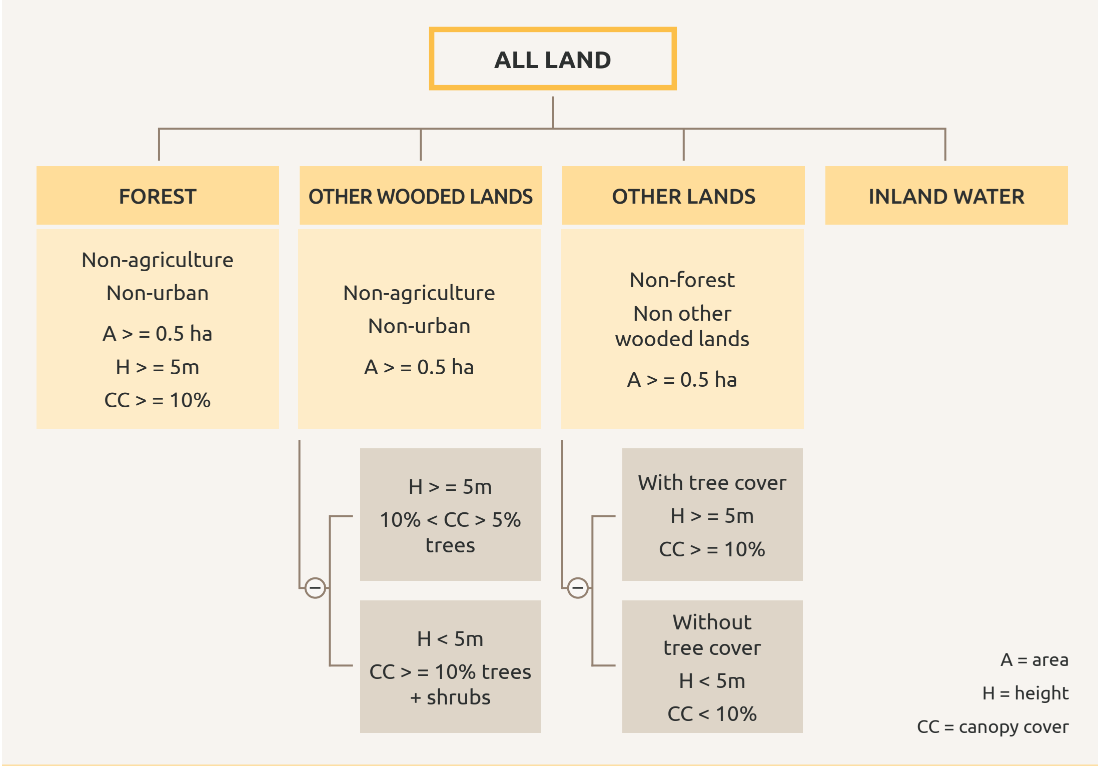
Figure 3 **Categories and definitions offered by FAO that can be used for FLR monitoring**



Source: Elaborated by the authors.

2.7 **STEP 7** LOCATE POTENTIAL AREAS FOR RESTORATION

The identification of potential areas for restoration depend on several criteria, namely, economic, social, ecological, and political, among others. Likewise, the scale can vary from the farm/property to municipal, sub-national, national, or global levels. The definition of these areas does not necessarily correspond to degraded land, since they could involve areas with high agricultural or forest productivity, but that for ecological or political reasons are destined to be restored; for example, because an aquifer recharge area is found, or because they are located within national parks. For the purposes of this guide, we will focus on FLR at the national and sub-national level, where potential restoration areas will be defined by criteria established by the government and stakeholders, generally derived from national FLR plans.

Box 3 shows the experiences of Guatemala and Colombia in the preparation of maps of potential areas for restoration. The maps all identified degraded areas.

Some causes of degradation were also identified in Colombia, such as mining, agricultural expansion and pastures, forest fragmentation, and urbanization. In both cases, only biophysical variables were used to define the priority areas, so improvement actions could include socioeconomic criteria (Mendez-Toribio *et al.*, 2017).

Box 3

National maps of potential areas for restoration activities

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Guatemala

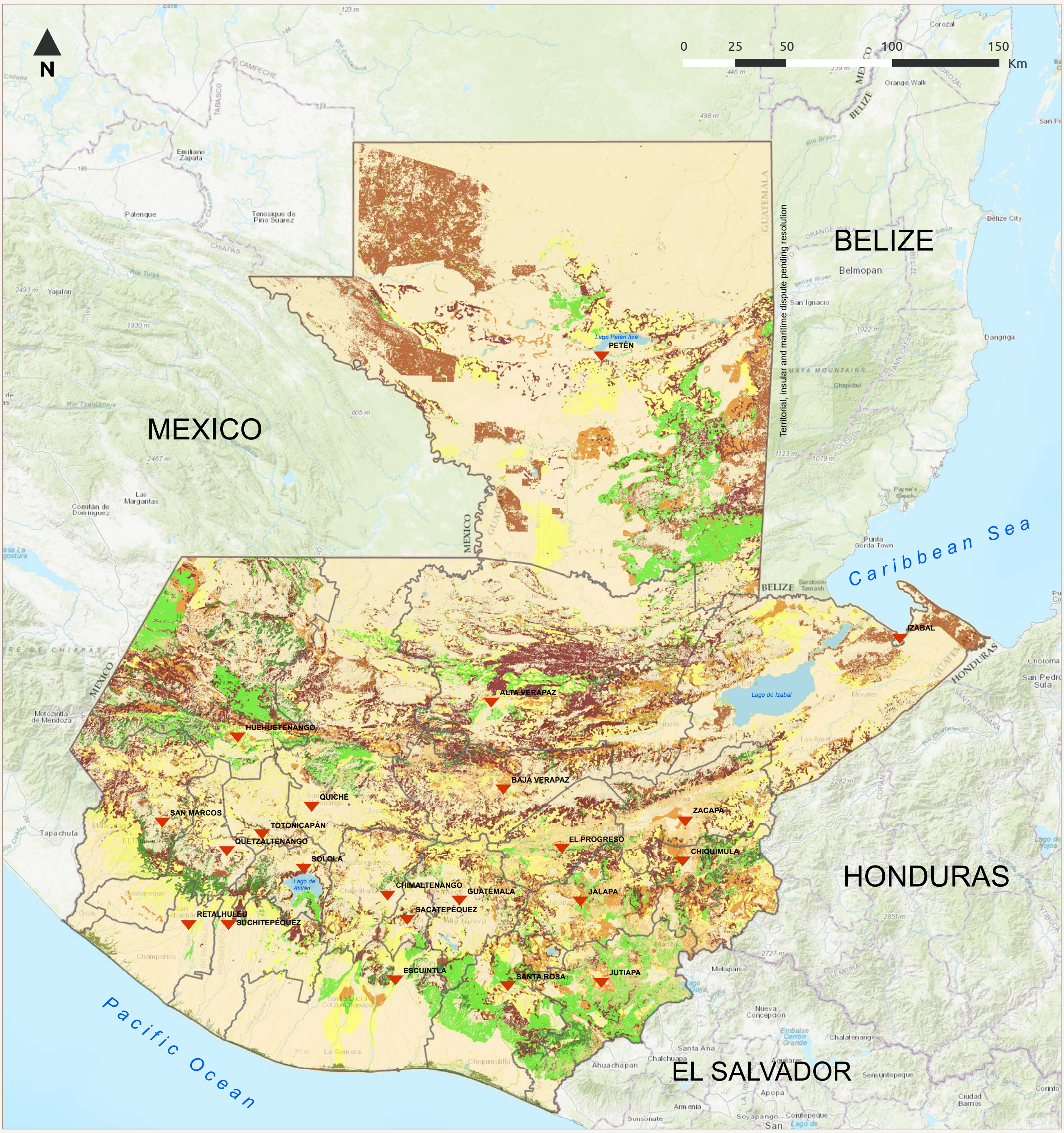
A map of potential areas for restoration was constructed to support the National Strategy for Forest Landscape Restoration (Forest Landscape Restoration Board, 2015), combining classes of the forest cover dynamics map 2010-2016 (GIMBUT, 2019), the classes of the land use capacity map (INAB, 2002), classes of dry forest and mangrove forest of the forest cover map and forest types (INAB and CONAP, 2015) and a 50-meter buffer in the rivers of Guatemala.

An algorithm with conditioning criteria was applied to obtain the nine potential categories of restoration: agroforestry with annual crops, agroforestry with permanent crops, silvopastoral systems, production forest lands, protection forest lands, protected areas, riparian forest areas, mangrove areas and dry forest areas.

The last two categories are specific forest ecosystems that were ranked for their socioeconomic importance and high vulnerability.

The boundaries and names shown and the designations used on the following map do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Map of potential areas for forest landscape restoration in Guatemala



LEGEND

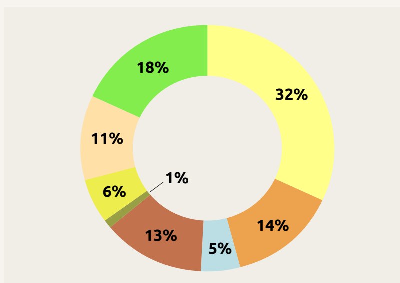
- Departamental capital
- Territorial dispute
- Administrative division*

Potential for restoration

- Agroforestry with annual crops
- Agroforestry with permanent crops
- Water
- Mangrove forest
- Riparian forest
- Dry forest
- Silvopastoral system
- Production forest land
- Protective forest lands
- Area not selected
- Protected areas

*Limits are not authoritative

Percentage of restoration by category



Source: INAB, 2021, adapted by the authors.

Continuing **Box 3**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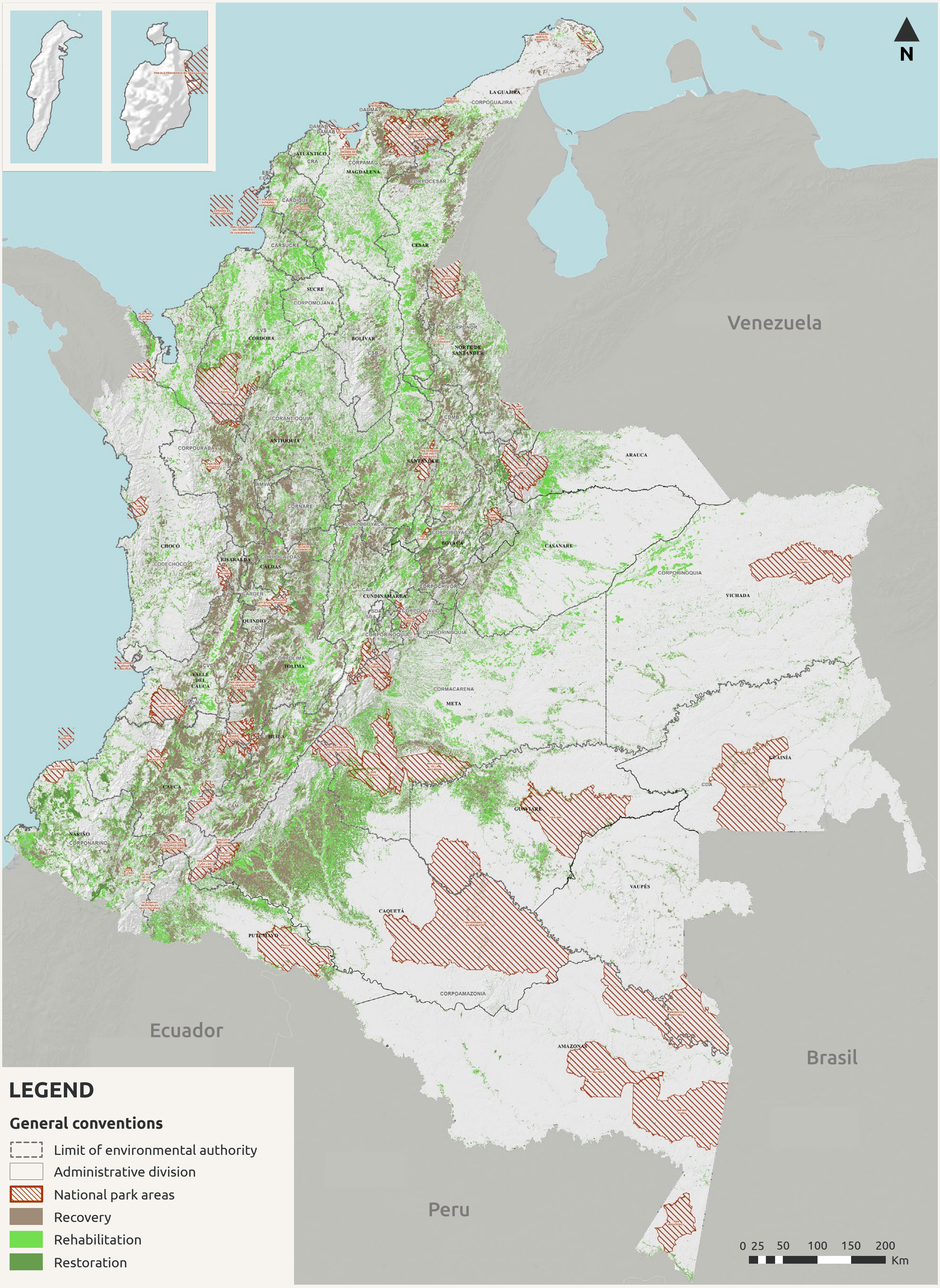
Colombia

During the development of the National Plan for Ecological Restoration, Rehabilitation and Recovery of Disturbed Areas (MADS, 2015), a map of areas susceptible to restoration processes was generated. This map is based on changes in cover with a degradation perspective and management of areas with a planning perspective. The cover land changes of the 2000-2002 period were compared with the territories or ecosystems transformed by human activities, such as agricultural areas and open areas with little or no vegetation detected in the 2005-2009 period. The following changes were detected: increased mining, land degradation, dynamics of water bodies, expansion of agriculture, forest fragmentation, grazing gain, and urbanization. Subsequently, the most appropriate restoration strategy was applied to each change under the premise that the stronger the disturbance, the greater the restoration efforts.

A similar exercise was carried out with the land use conflict map to include characteristics beyond natural covers. Variables on land use and the inappropriate use of burned areas were included. A buffer area (100 m) was defined in areas adjacent to natural covers, drains and water bodies. The final map included the three options or defined objectives: restoration, rehabilitation and ecological recovery.

The boundaries and names shown and the designations used on the following map do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Map of suitable forest restoration sites in Colombia



Source: MADS, 2015, adapted by the authors.

2.8 **STEP 8** GENERATE AND PRIORITISE MONITORING QUESTIONS, INDICATORS, METRICS AND ATTRIBUTES

Starting from the identification of information needs and the types of land use where the restoration will be carried out, it is suggested to generate the questions to be answered through monitoring; this will facilitate the generation of indicators and metrics.

Examples of monitoring questions and the name of the indicator that will help answer them are presented in Table 1. It is suggested to start with a question that provides stakeholders with a clear understanding of what is to be measured. From the questions, the keywords that define the name of the indicator are identified. The indicators aim to measure both positive and negative effects on the landscape since both must be considered in the reports. Each indicator must be accompanied by the metric or elements to be measured, including units to report the information.

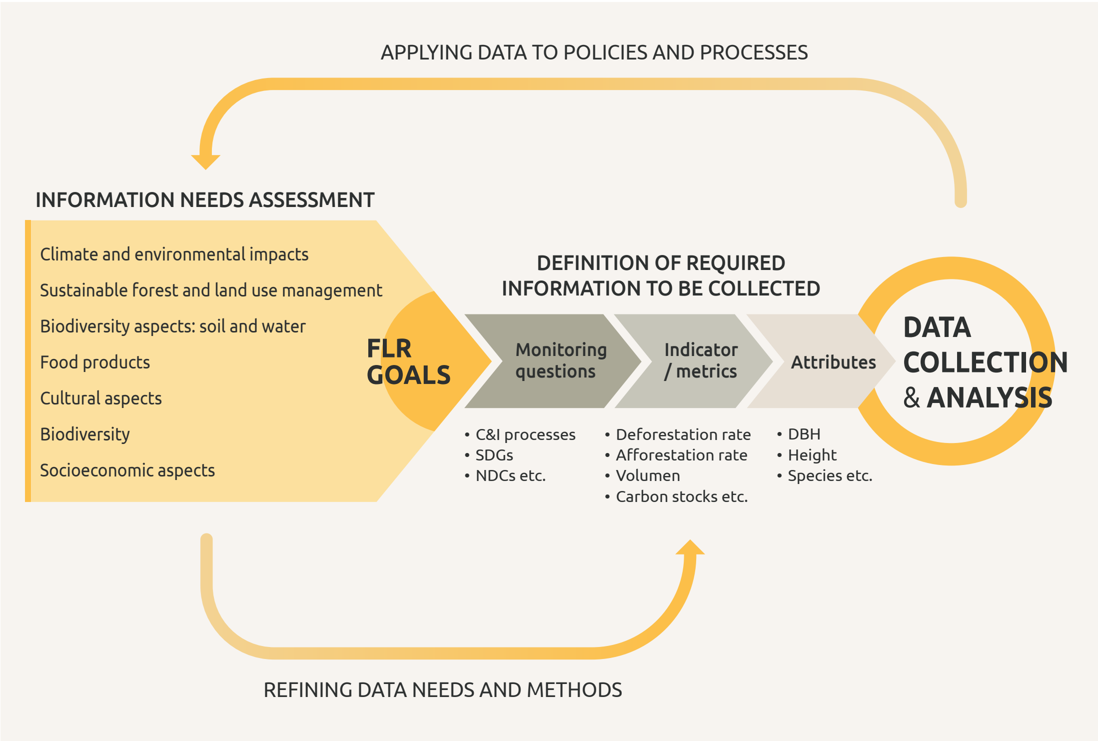
The source of information must also be identified, which will later be used to determine the monitoring components.

The attributes that will be measured in the territory or that will be asked of the beneficiaries must be also selected. Table 2 shows examples of attributes associated with the metrics, indicators, and goals.

In addition to the indicators on restoration progress, it is also important to ask the question on barriers to sustainability (FAO and WRI, 2019). These barriers refer to understanding what affects restoration efforts. Identifying these barriers will make it possible to determine the causes that make degradation prevail, and that should be measured in the indicators.

The barriers can be the existence of a disturbance in a particular land use or the application of legal norms or financing to develop the restoration. The indicators corresponding to these barriers can be the surface of the disturbed area and the type of disturbance, the number of illegal incidents or the amount of funds allocated.

Figure 4 **Process for defining indicators and variables to be collected in the restoration monitoring process**



Source: Elaborated by the authors.

Table 1 Sample of monitoring questions for a group of selected goals

Goal	Question	Indicator	Metrics	Information source
Culture	What is the restoration area for the protection of cultural/ spiritual sites?	Protected cultural/spiritual areas	Surface of the protected cultural/spiritual area (ha)	NFMS/NFI
Economy	What are the economic benefits for women in the communities?	Benefits of restoration for rural women	Economic income for rural women from restoration actions	Socioeconomic survey/ population census
Production	What is the impact on agricultural production?	Harvested products	Volume of products harvested per year (tonnes/ha; m^3/ha)	Agricultural census or registry by project
Climate	What are the emissions removed by the restoration?	Increase in carbon stocks	Tonnes of carbon removed by restoration actions (tonnes/ha)	NFMS: remote sensing monitoring/ NFI/ agricultural census
Soil	Have soil conservation practices been applied?	Soil conservation	Percentage of producers practicing soil conservation	Agricultural census/projects repository
Water	What is the sedimentation in water reservoirs?	Quality of water	Sedimentation level in water reservoirs	Water monitoring system
Energy	What is the amount of firewood harvested per year?	Amount of firewood harvested	Amount of biomass burned (m^3/year)	Population census /socioeconomic surveys
Biodiversity	What is the state of the restored ecosystems?	Composition of flora/fauna species	Diversity indicators of flora/fauna species	NFMS: NFI and fauna inventories
Governance	Have the forest monitoring capacities been strengthened in the communities?	Community capacity building	Sex-disaggregated number of people/ communities	Restoration projects

Source: FAO and WRI, 2019, adapted by the authors.

Table 2 Example of goals, indicators, metrics and attributes for landscape transformation

Goal	Sub-goal	Indicator	Metrics	Attributes
Restoring forest ecosystems	Reduce deforestation	Deforestation rate	ha/year	Forest area => 0.5 ha CC trees + 5m > 10 percent No agricultural or urban use
	Reduce degradation of primary forests	Deforestation rate	ha/year	Forest type
	Restore by forest type	Restoration rate by forest type	ha/year	Origin of regeneration is natural Percentage of exotic species Evidence of significant anthropic disturbance Species composition Structure Regeneration/mortality
	Reduce deforestation by forest type	Deforestation rate	ha/year	Forest area => 0.5 ha CC trees + 5m> 10 percent No agricultural or urban use
	Increase the area by type of forest	Restoration rate by forest type	ha/year	Forest type Origin of regeneration is natural from areas with <5 percent CC Percentage of exotic species Species composition Structure Regeneration/mortality Age
	Increase the area of planted forests and/or forest plantations	Growth rate of planted forests and/or forest plantations	ha/year	Planted forest Origin of regeneration planted Percentage of exotic species Species composition Structure Regeneration/mortality Age
Restoring productive landscapes	Increase the percentage of trees in crops, pastures and settlements	Percentage of trees in crops, pastures and settlements	Percentage	Land use classification It is not forest Percentage of tree cover Trees/ha Species composition

Source: FAO and WRI, 2019, adapted by the authors.

2.9 **STEP 9** DEFINITION OF PERIODICITY TO MEASURE INDICATORS

The periodicity of each indicator must be taken into account when planning restoration monitoring processes. The monitoring process depends on the intervention activity, the indicators and the selected metrics. There is no fixed rule to carry it out, and it could vary at different times. For example, it could be at a specific time of the year, month, quarter, semester, or every 2 or 5 years, depending on the type of interventions being carried out or evaluated. If the restoration includes firebreak activities, monitoring those activities may need to be done before the fire season. On the other hand, if it is desired to observe increasing biomass in trees, this could be carried out for more extended periods of time.

2.10 **STEP 10** IDENTIFY THE COMPONENTS OF MONITORING

Previously, Table 1 identified the potential sources of information to measure and monitor the selected indicators. Some of these sources are components of the NFMS; others are not, so it is recommended to analyse the information collected and offered by each source or component to respond to the selected indicators.

For the REDD+ readiness stages, most countries developed two components for NFMS: satellite monitoring and NFIs. These two sources of capture and analysis are the most important at the national level. However, they must be linked to other components that complement the information necessary for FLR monitoring. The VGNFM (FAO, 2017) divides monitoring into three dimensions: biophysical-environmental, social-economic, and governance and management. This report suggests considering some identified components for FLR monitoring from each dimension.

Within the biophysical-environmental dimension, the following components are described below.

2.10.1 National forest inventory

The NFI is the process of measurement, collection and analysis of field data, combined with remote sensing, for specific periods of time to produce accurate national statistics on the status and trends of a country's forest resources (FAO, 2017; Tomppo *et al.*, 2010). The NFIs provide multipurpose and continuous information to support forest policies and the strategic planning of forest products and services (INAB and CONAP, 2020; SERFOR, 2016; CONAFOR, 2009). NFIs are data sources, at the national level, of biomass and carbon stocks, disturbance histories, land tenure, state of forest management plans, statistics on harvesting timber and non-timber forest products, fire area data, fuelwood extractions, forest health and pest impacts, among others (GFOI, 2020).

2.10.2 Permanent monitoring plots

These are measurement areas permanently installed for research on the management of forests of a given site (Camacho, 2000; Alder and Synnott, 1992) and the research of ecological processes of ecosystems at different scales and temporalities (SINCHI, undated). Permanent plots are a source of specific information about the areas where they are established and to meet the objectives for which they were created. In Latin America, there are networks of permanent plots for various research purposes; for example, the Network of permanent forest measurement plots in plantations, natural broadleaf and coniferous forests of Guatemala (Marmillod, 2012); the network of the Amazonian Scientific Research Institute (SINCHI, by its acronym in Spanish), the Subtropical Network of Permanent Plots (RedSPP), or the Amazon Forest Inventory Network (RAINFOR).

2.10.3 Satellite monitoring system

In the REDD+ and climate change framework, this system refers to the process of collecting and processing satellite image data to develop historical and consistent trends on the evaluation of land use and cover changes (FAO, 2018d). However, the use of satellite data is extensive since it is the basis for planning other resources such as water, soil and agriculture, as well as for the management of early warning for the safety of communities and their resources (Paganini *et al.*, 2018).

This component can be divided as follows:

- Thematic maps: These are a geographical representation of a topic and area of interest obtained from identifying objects or areas, classified through procedures to recognize spatial patterns (Lillesand and Kiefer, 1994; Borrough and McDonell, 1998). Thematic maps, also called wall-to-wall, are essential instruments for political decision-making, strategic planning and implementation of actions in the territory (GFOI, 2020). They also detect early warning of risks in forests and restored areas such as deforestation, illegal logging, and forest fires. They can be developed by supervised or unsupervised classification. For supervised processes, field data or high-resolution remote sensing are required to train algorithms and obtain high-quality results (Enderle and Weih, 2005). Classifications can also be based on pixel or object counts: the first classifies pixels directly based on their spectral similarity, and the second uses segmentation algorithms to group homogeneous pixels, and classifies individual objects according to spectral, geometric and textural characteristics (Veljanovski *et al.*, 2011; Liu and Xia, 2010). Automated systems typically require adjustments of the resulting polygons through visual interpretation. Final maps must be validated by calculating the accuracy of the classification to provide information on the result quality (Olofsson *et al.*, 2014).

- Visual interpretation using sampling techniques: These are human observation techniques in satellite images to quantify elements on the earth's surface (Avery and Berlin, 1992). Since the 1950s, they have been used to improve the efficiency of national forest inventories (Goodbody *et al.*, 2019). Recently, its use has increased due to improvements in the accessibility of high and very high-resolution satellite images, allowing the application of sampling techniques to improve the estimates of land use areas, land cover, and changes. (Corona *et. al.*, 2018; Schepaschenko *et al.*, 2019). These techniques have become an efficient data source for producing area estimates with their direct confidence intervals or for calculating the accuracy of use and coverage change maps (Domke *et al.*, 2012; Webb *et al.*, 2012; Olofsson *et al.*, 2014; Corona, *et al.*, 2015 Olofsson *et al.*, 2020). In the context of REDD+, this technique has strengthened estimates of deforestation and historical degradation to generate reference levels or baselines (Government of Panama, 2018; Government of Guatemala, 2019; Government of Mexico, 2020; Government of Nicaragua, 2020). It has also been used to monitor forest and landscape restoration at the project level with different restoration objectives in countries such as El Salvador, Ethiopia, India, and Rwanda (Reytar *et al.*, 2021).

The socioeconomic dimension is of great importance in FLR strategies or action plans. Méndez-Toribio *et al.* (2018) indicate that strengthening the measurement of FLR success with socioeconomic criteria is essential for prioritising areas. Therefore, the measure of socioeconomic indicators should be included in the protocols. On the other hand, FLR strategies and action plans must consider the governance and management dimension that will allow them to work in the long term and ensure that the benefits of restoration reach communities, families and citizens.

The primary data sources for the socioeconomic, governance and management dimension are associated with the components described hereinafter.

2.10.4 Socioeconomic surveys in forestry

National surveys to collect data on metrics related to dependency on forest and wild products for families and communities (FAO, *et al.*, 2016). FAO, under the National Forest Monitoring and Assessment programme (NFMA), assisted several countries intending to develop socioeconomic surveys as part of their NFI, including Guatemala, Honduras and Nicaragua (Ramírez and Rodas, 2004; Ramírez and Salgado, 2006; INAFOR, 2009); and of integrated inventories of land use (Branthomme *et al.*, 2008). These surveys can also be associated with population censuses or agricultural censuses; however, data collection is reduced to few variables (FAO, *et al.*, 2016). In Ecuador, an example of this approach can be observed to determine the relationship between people and forests (MAE, 2013).

2.10.5 Census and agricultural surveys

The agricultural census is the statistical process aimed at collecting, processing and disseminating data on the structure of the agricultural sector of an entire country or a significant part of it. It is a data source that can be linked to assess restoration information. Censuses are based on surveys to farmers of the population of interest at approximately 10-year intervals, although some countries conduct surveys more frequently. The selection of the sample can be based on lists of census farms or through a framework of geographical areas similar to those of NFIs (FAO, 2015).

2.10.6 Administrative and restoration project records

Refers to the records made by the forest services of the countries to report on the institutional goals and indicators of the management of forest resources, for example, records of fire or pest control, areas of planted forest or forest plantations, management plans, forest incentive projects, authorisations for the use of forest products, transportation authorisations, among others.

2.11 **STEP 11** DEFINE THE BASELINE FOR FOREST AND LANDSCAPE RESTORATION MONITORING

Once the areas to be restored, the indicators, metrics and attributes, and the monitoring components have been defined, the baseline must be generated, which will be the comparison framework to evaluate the change in the various restoration activities. The baseline must be carried out in year zero, that is, prior to developing the interventions.

The complete monitoring design must be taken into account to build the baseline, which is often complex due to the time it takes to collect data from some sources such as NFIs or surveys. However, the recommendation is that if the NFMS do not have complete and robust data sources at the time of developing the baseline, the construction of the baseline should progress with the existing data and a further plan can be created to improve the information for the next period of measurements. To do this, it is recommended to consider integrating the monitoring components and the design of each component described in steps 12 and 13 below. Within the context of REDD+, countries that include the enhancement of carbon stock, which involves FLR activities must develop a

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reference level or baseline on the historical average of a period prior to starting the results report. Until 2020, only five countries presented a reference level that includes removals due to the increase in carbon stocks (FAO, 2020d).

2.12 **STEP 12** INTEGRATE THE COMPONENTS IN THE NATIONAL FOREST MONITORING SYSTEM

The prioritisation of monitoring components should be linked to the selection of indicators and metrics and depend on the time and costs available. Due to the complexity in developing an NFMS, it can be planned in stages and modules, identifying finance sources according to the mandates and opportunities of the interested parties. The integration of the components is suggested from various approaches or points of view:

2.12.1 **Interinstitutional integration**

Integrated planning of the monitoring components will enable the statistics generated to be more understandable, comparable and transparent, and will also reduce costs.

This step can be reinforced if the design and implementation are developed through responsibilities shared by several institutions, for which strong inter-institutional coordination is essential. The integration of monitoring components provides many advantages for institutions, for example, a continuous training plan can be prepared and implemented among institutions and organisations that want to collect data for FLR-related indicators. Cost reduction and duplication of efforts can be achieved, which will provide greater sustainability for continuous and long-term monitoring.

If each restoration project executes the monitoring independently, budgets will increase. Therefore, a common framework is an advantage for a coherent presentation of results at a lower cost for all.

2.12.2 **Integrating forest and landscape monitoring scales**

Integration between national government institutions with subnational and local governments is of utmost importance since FLR strategies are implemented at the local level but must be reported at all levels. Thus, everyone should seek integration in the way monitoring will be carried out. For example, the NFMS can offer a space for discussion to develop a common framework of indicators to measure at national, sub-national and local project levels, and even more detailed indicators for sub-national and local project levels.

The most detailed data will be for the project level, which, due to the scale, is more complex when it comes to seeking integration from the point of view of sampling design. However, it is recommended to maintain consistency in the definitions, names and metrics of indicators, land-use classification, restoration activities, and some of the data collection methods. Defining national guidelines to be applied harmoniously at sub-national levels is key to avoid duplication and inconsistency in the information published about the country.

Many FLR projects will be associated with communities; in some of them, participatory community forest monitoring processes can be found. This type of monitoring is defined as a continuous process in which local forest users systematically record information about their forest, reflect on it, and carry out management actions in response to what they have learned (Kristen and Guariguata, 2008).

Several authors have shown that integrating the participation of local communities in data collection for forest monitoring shows good results, emphasising advantages such as allowing participation and empowerment, and reducing transport costs of experts from external locations (Danielsen *et al.*, 2010; Morales-Barquero *et al.*, 2014). Monitoring should be driven by local information needs for monitoring forest management plans, life plans, and ethno-development plans (IDEAM *et al.*, 2018).

2.12.3 Integrating field components with remote sensing

Dividing NFMS into components has evolutionarily taken place due to the technical and technological advances achieved. This section explains in detail the importance of integrating field data with remote sensing data to produce more robust statistics, as recommended in the VGNFN (FAO, 2017).

Figure 5 shows an integration structure of the components. The components from ground-based data collection are located at the base of the pyramid, such as the NFI, permanent plots, forest socioeconomic surveys and agricultural censuses or surveys are located there. Administrative records can also be found in this group. such as fire and pest control, or from FLR projects.

Ground-based data constitute the foundation of a good NFMS. In addition to being the data source to produce tabular statistics on the indicators for FLR monitoring, it should be the primary data source for both the training or calibration of the interpreters or algorithms and the validation of the resulting thematic maps.

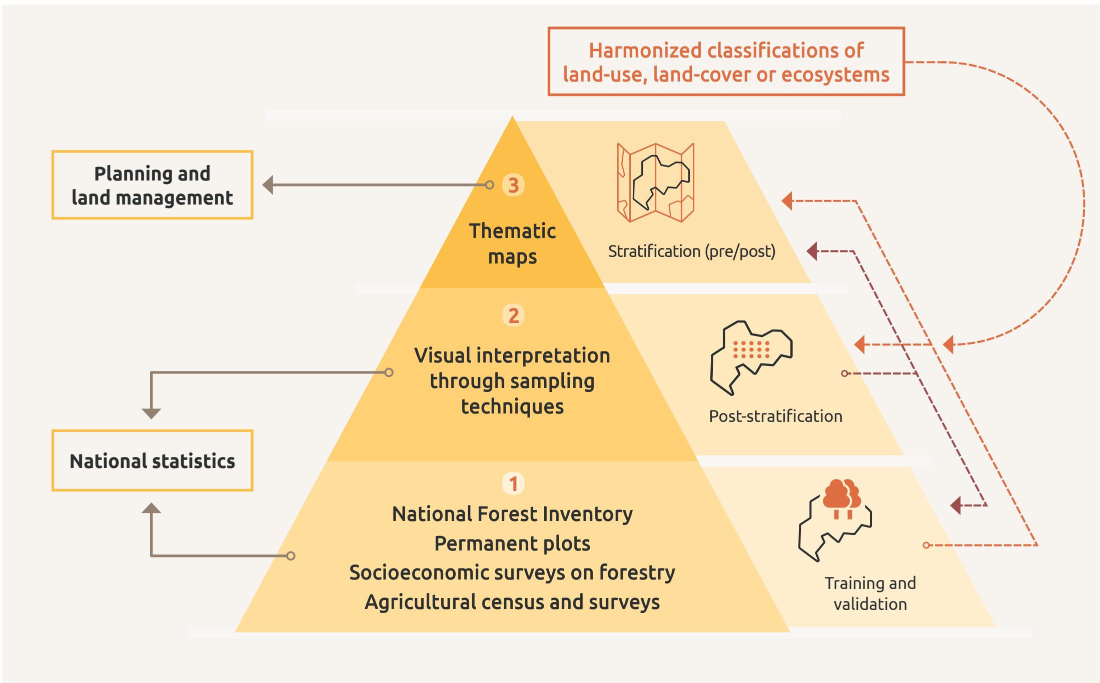
To produce robust data and statistics, ground-based components should be designed under a sampling frame that enables data collection at multiple monitoring scales.

The middle part of the pyramid shows the component of the terrestrial satellite monitoring system through visual interpretation by sampling techniques. When accessibility to high-resolution satellite images is sufficient, this component is extremely useful to:

- Produce statistics of the change from areas without restoration to restored areas. Meaning that tabular statistics on area changes and the increasing percentage of coverage in each of them can be generated through sampling techniques.
- It has been used to optimize the NFIs, as for example, the decision for the plots to be measured at the field, based on the presence or absence of trees, also in double sampling techniques for post-stratification, where data from the interpretation is used for grouping the plots with similar characteristics to reduce the variance (Westfal *et al.*, 2019, Cochran, 1977).
- Train and calibrate algorithms for the production of thematic maps and their validation (Olofsson *et al.*, 2020).

At the top of the pyramid, we can find the thematic mapping component of the satellite monitoring system, the most used means to measure natural resources because it offers a wider temporary

Figure 5 **Integrated structure of the components of a national forest monitoring system**



Source: Elaborated by the authors.

and spatial frequency than field data. The main variables that can be obtained are the location and extension of the areas of interest. Thematic maps are an advantageous visual medium for territory planning and management and to communicate the progress of FLR in a graphic form (GFOI, 2020; Reytar *et al.*, 2021). However, it is essential to recognise that maps represent surface areas that are indirectly interpreted by techniques that use the reflectance of light emitted by objects on Earth; therefore, the results normally have errors (Olofsson *et al.*, 2014). For these reasons, the more field data or visual interpretations that are used with remote sensing for algorithms calibration, the more accurate thematic maps will be. It should not be forgotten that these maps will be required to calculate accuracy; thus, they will need an additional data set from the visual interpretation or collected in the field.

An example of monitoring systems with an enlarged comprehensive approach to all land uses is the National System for Monitoring Land Cover, Land Use and Ecosystems of Costa Rica (SIMOCUTE) (Monge *et al.*, 2020). This system was designed so that institutions who develop natural resource statistics in the national territory use a homogenous classification of all lands for the monitoring components similar to those described in this report. These components have been designed in working groups by public institutions. This integration approach seeks to improve inter-institutional capabilities to provide more robust and efficient data.

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2.12.4 Harmonising land-use and land cover classes

Comprehensive NFMS must ensure that their components use a coherent land use and land cover classification (FAO, 2017, IPCC, 2006). All institutions that make elaborate maps and statistics on natural resources must use the same categories and definitions to ensure consistent results of estimates. For homogenisation, the definitions of land use and land cover, based on the criteria and thresholds that help measure FLR changes (Section 2.6), should be improved. Once the definitions are improved, harmonisation involves analysing the previous classifications to understand the differences in the definitions resulting from the improvements.

The criteria and thresholds of the definitions must describe the reality of the field. From these definitions, the next step should be to analyse what can be measured with high or medium resolution satellite images. In addition, new criteria can be established that link field information with information analysed from satellite images, such as the vegetation rates index (NDVI, NDFI or NBR). It is also advisable to make decision–tree analysis to facilitate the interpretation of categories in each of the monitoring components that require it, both from the field and remote sensing.

Using hierarchical classifications will facilitate harmonising categories for different reporting needs, as they enable the clustering of specific categories into more general ones. To report at the local project or subnational level, very detailed categories can be used, and these can be organized into groups to form national categories.

When the objective is to develop international reports, the more general categories will be international classes, which must also be analysed to seek harmonisation in reports. Figure 6 shows a scheme to support the harmonisation of classes and definitions of the IPCC (IPCC, 2003) with those of FRA (FAO, 2018b). According to the definitions that most countries have used as a reference, IPCC's "forest lands" class usually corresponds to "forest" for FRA. However, some countries include forest plantations, and others do not. On the other hand, FRA groups crops, pastures and settlements into the "other lands" category. What is interesting about making the correspondence for FLR monitoring is that FAO classifies these lands according to the presence or absence of tree cover (see thresholds of Figure 3).

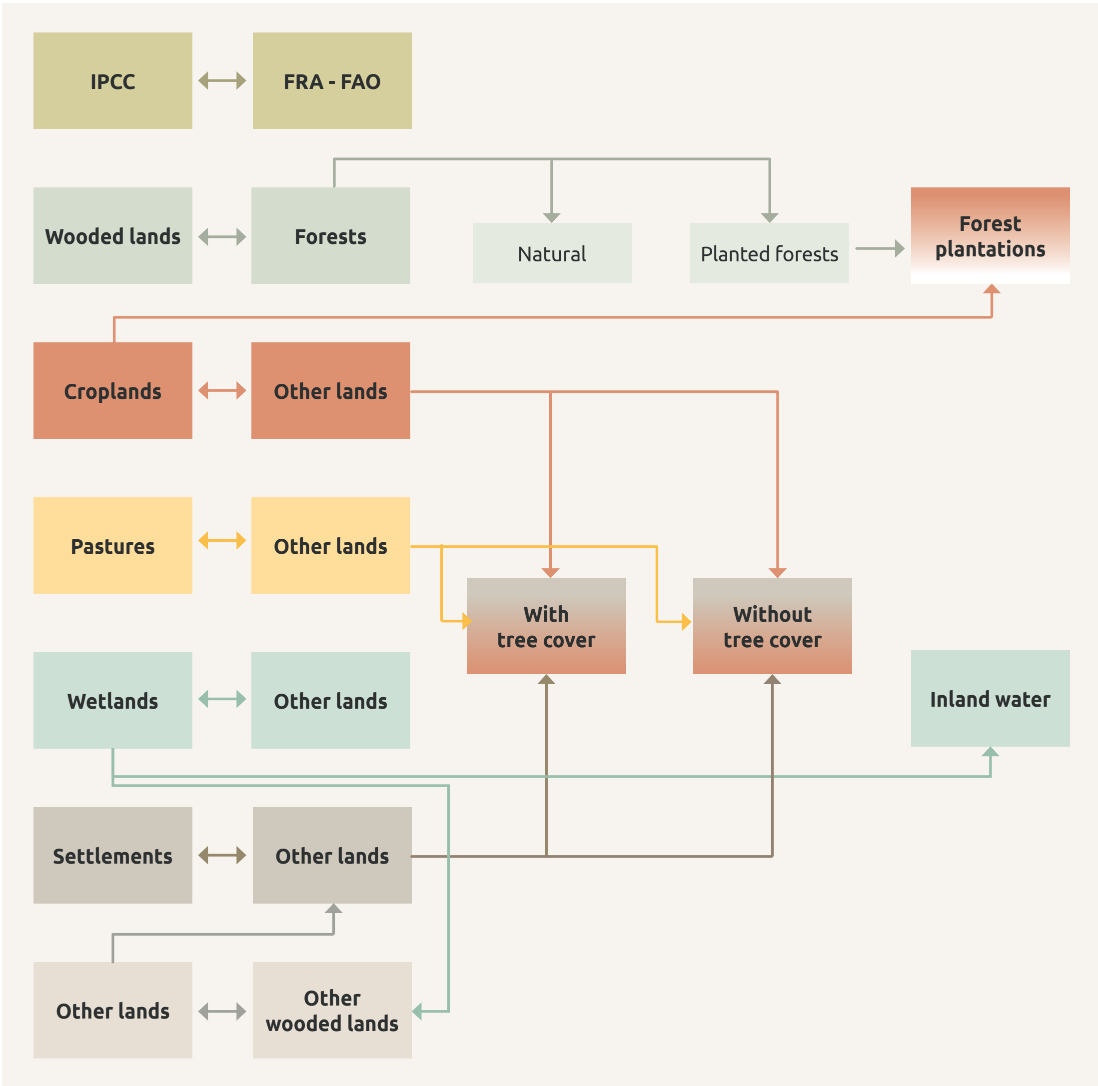
In the same way, the wetland IPCC category can be classified as mangrove forests when the definition of forest is met; otherwise, they can be classified according to FRA as "other wooded lands," which involves the presence of trees and shrubs that can be measured as a result of an FLR project. Finally, if they do not comply with the FRA definition of forests and other wooded lands, they are classified as "inland water." The last category of IPCC is "other lands," referring to those not classified in the previous categories. In some cases, they can be from the same category as the FAO definition of "other lands." Still, they can also be natural ecosystems that do not comply with the definition of forest.

The harmonisation of FAO categories with IPCC will substantially improve the knowledge and report of the national inventory of GHG emissions and allow better accounting within the NDCs.

Countries such as Brazil, Guatemala, Honduras, Nicaragua, and Peru developed classifications of land use and forest types to classify and label the NFI plots and obtain statistics from very specific categories about forest types (Ramirez and Rodas, 2004; Ramírez and Salgado, 2006; INAFOR, 2009; Vibrans *et al.*, 2010; SERFOR, 2016; ICF, 2017).

These methodologies used classes defined from FRA terms and definitions. They were organized into a hierarchical classification system where the national categories are included in the global categories. A more recent example is the SIMOCUTE's classification, which uses the concepts of land use and land cover similar to those of this document. As a result, two classification keys were built for the classification: one for land use and the other for land cover (CENIGA, 2020).

Figure 6 **Correspondence of IPCC categories and FAO Forest Resources Assessment categories**



Source: Based on the terms and definitions of Global Forest Resources Assessment (FAO, 2018c) and IPCC (IPCC, 2003).

2.12.5 Sample selection using integrated sampling grid

Sampling design seeks a sample selection in an integrated and unbiased manner (FAO, 2017). Some authors, like Olofsson (Olofsson *et al.*, 2020), recommend the design to be based on a probabilistic sampling that responds to multiple information needs and is also flexible to allow changes in the sample size. To this effect, a sample frame serving many purposes can be selected, which in turn provides a solid selection that avoids the bias. The sample frame refers to dividing the population of interest into units to select a sample (Cochran, 1977). In the case of the NFMS, the population of interest and the sample frame are practically the same since the total number of points that make up the country's territory is usually considered (Olofsson *et al.*; 2020, McRoberts *et al.*, 2015). Components with area-based sample frames (NFI, sample-based satellite monitoring or some agricultural surveys) may seek a system that allows selecting the sample in an integrated manner. The integrated selection facilitates inter-institutional work and reduces costs. Sampling designs must stick, as much as possible, to simple random sampling; in practice, however, systematic sampling is used to measure large areas because a vast homogeneous distribution in the territory can reduce the variance between observations, and equidistance may maintain a low correlation between the observations (FAO, 2017). The NFIs of many countries apply systematic sampling for sample selection using a grid of regular polygons distributed throughout the territory. This design has been applied in countries such as Finland, France, Germany or the United States of America, among others (Tomppo *et al.*, 2010) and also in Latin American countries such as Guatemala (Ramírez and Rodas, 2004, INAB and CONAP, 2020), Honduras (Ramirez and Salgado, 2006, ICF, 2017), Nicaragua (INAFOR, 2009), Mexico (CONAFOR, 2009), Brazil (SFB, 2015), Costa Rica (SINAC, 2015) and Peru (SERFOR, 2016).

The NFI grid of regular polygons were designed to respond to continuous monitoring, allowing a selection of the most homogeneous samples over the entire territory (SERFOR, 2018). To enable flexibility conditions, such as variations of the sample size according to needs, some countries — such as Costa Rica — have designed very intense grids over which they have selected the necessary samples to meet the information needs and precision objectives of their NFIs (SINAC, 2015). In other cases, it has been chosen to intensify the NFI basic grid as many times as necessary to open more intense selection options in selected areas, such as Guatemala's case (INAB and CONAP, 2020).

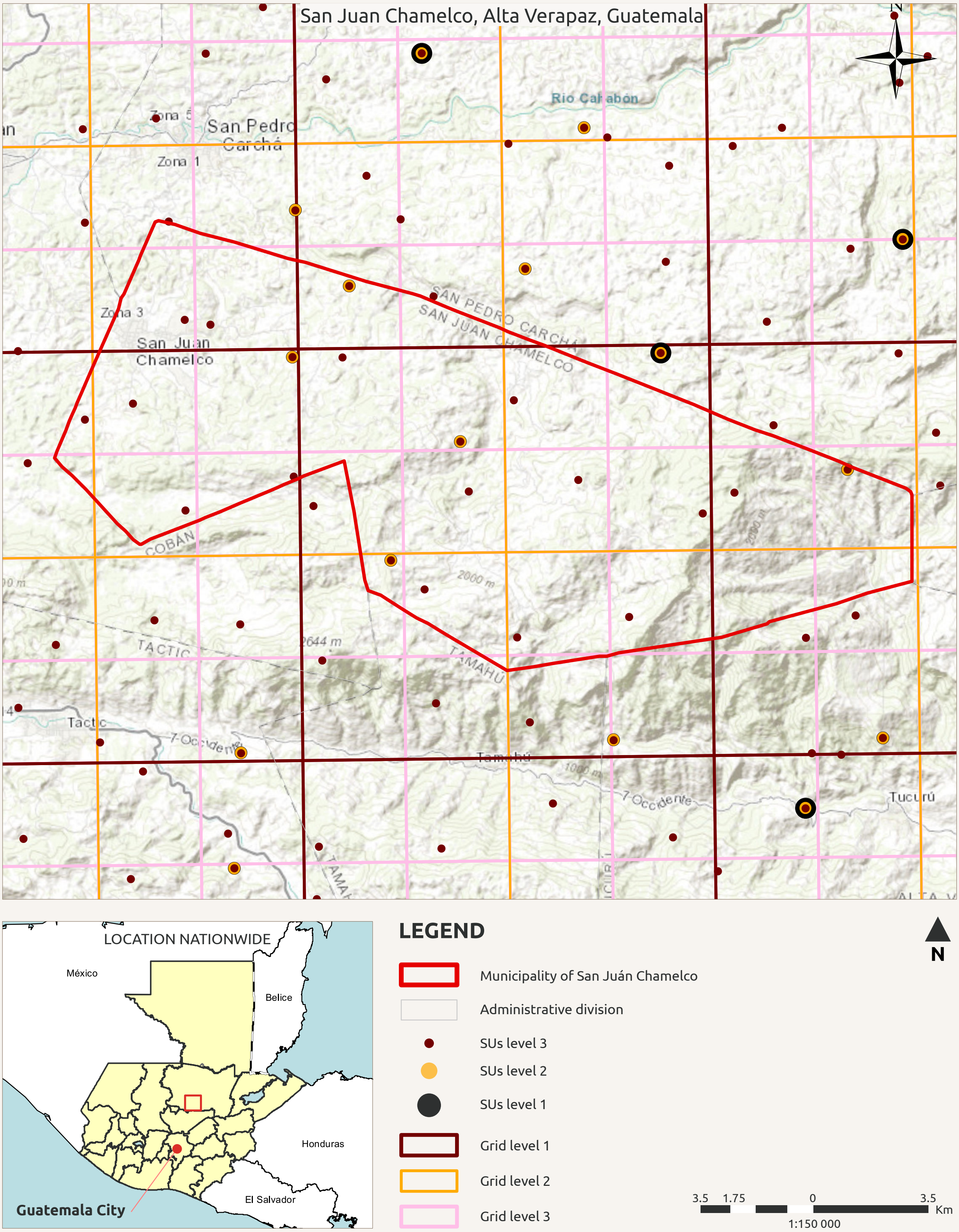
Sampling grids with different intensities and integrated between each other can have several uses, such as applying a double sampling design for stratification in NFIs (Westfal *et al.*, 2019); in this case, a sample is selected in a first phase to classify the strata, and in a second phase, a subsample is selected from the first one for more detailed data collection. For the first phase, a visual interpretation analysis with satellite images or a map can be used, and field measurements can be used for the second phase.

Another opportunity to use an integrated sampling grid system is the flexibility to select sample points more intensively in areas of interest. This can be particularly useful to harmonise field data collection between national monitoring and sub-national monitoring (states, provinces, municipalities, districts or cantons). It can also be helpful when the sampling intensity is insufficient to provide information with less uncertainty. In these cases, it may be necessary to do a pre-stratum with the support of a map (for example, mangrove map, map of potential areas for restoration or map with areas of higher change probability) where a greater or lesser intensity is required, according to the needs of cost and precision. For this case, it must be taken into account that the pre-stratum must have limits that do not change over time for a more consistent sampling.

Integrated sampling grids allow a statistically sound database to be established and can be used by different projects, both at the national and sub-national levels. The data can be more consistent and transparent, especially if other recommendations are met, such as definitions of harmonised land use categories and data collection methodologies for multiple purposes.

Box 4 shows an example of an integrated grid used to respond to the information needs at the municipal level of the Guatemala National Strategy for Forest Landscape Restoration.

Box 4 Building the map of potential areas for forest landscape restoration for planning at the municipal level



The boundaries and names shown and the designations used on the following map do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Source: INAB, 2021, adapted by the authors.

Continuing **Box 4**

San Juan Chamelco, Alta Verapaz, Guatemala.

The Guatemala National Strategy for Forest Landscape Restoration (ENRPF, by its acronym in Spanish) and the Law to promote the establishment, recovery, restoration, management, production and protection of forests in Guatemala - PROBOSQUE (Congress of the Republic of Guatemala, 2015) constitute the regulations for compliance with the commitment to restore 1.2 million hectares by 2045 under the Bonn Challenge and the 20x20 Initiative. The strategy defines that:

> **"Forest landscape restoration is the process aimed at recovering, maintaining and optimising biological diversity and the flow of ecosystem goods and services for development, adjusted to the local value and belief system, and implemented with an intersectoral approach" (MRPF, 2015).**

For the planning of approved projects, it is necessary to detail at the municipal level the national map of potential FLR areas described in Box 2. With the support of the project on Adaptation of rural communities to climate variability and change to improve their resilience and livelihoods in Guatemala (*Adaptación de comunidades rurales a la variabilidad y cambio climático para mejorar su resiliencia y medios de vida en Guatemala*), FAO, together with the Korean Agency for International Cooperation (KOICA), developed the methodology to build the municipal maps. It required field data on effective depth, stoniness, slopes, drainage, physiographic region, current use and forest fragmentation; these data were used to update the land use capacity map.

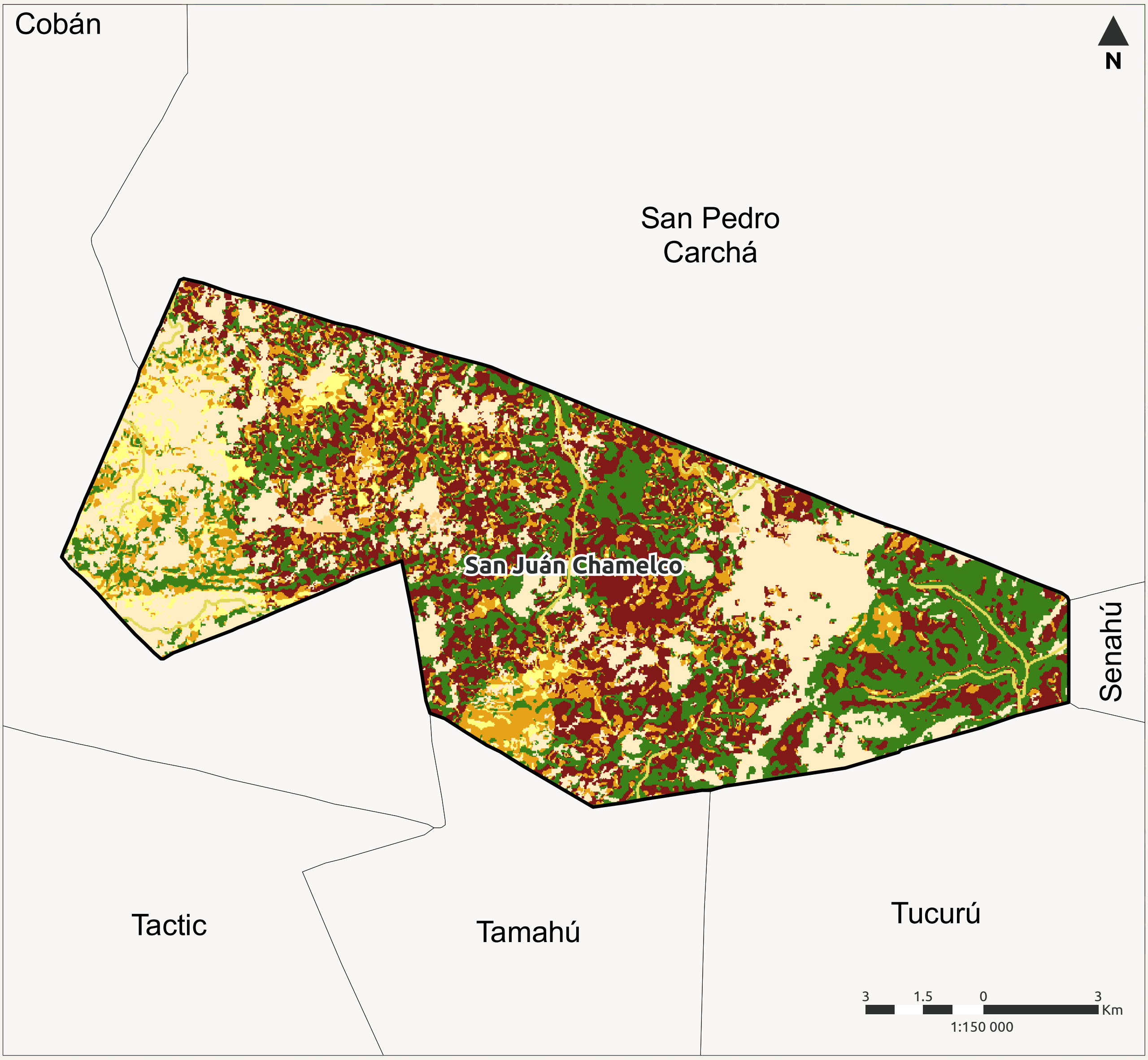
The data collection sites were selected using NFI sampling grids, which consist of a 12.4 x 12.4-kilometre grid. In each cell of the grid, a sampling point (715 points) was randomly selected. This number of samples is sufficient to produce statistics at the national level. Still, higher-intensity nested grids were created to allow flexibility in the selection of samples for sub-national purposes. Each cell of the grid was divided into four cells of equal size for 2 860 points (level 2). The level 3 grid derives from the division into 16 parts containing 11 639 points; and level 4 in 64 parts, corresponding to 45 426 points in the national territory (INAB and CONAP, 2020). This ordered point selection system allows the user to select the intensity that best suits his/her purposes. For the municipality of San Juan Chamelco, the level 2 grid was established, which corresponded to 20 sampling points (Box 4).

For data collection, digital forms were designed in the Survey123 application from ArcGIS online (Chivite, 2016), administered by the SIG department of the National Forest Institute (INAB, by its acronym in Spanish). The measurements were developed with INAB technicians, students from the University of San Carlos de Guatemala and FAO technicians.

With field data, an interpolation analysis (ArcGIS kriging) was performed to generate three base layers: effective depth, stoniness and drainage, which were combined with the map of physiographic regions, the map of slope percentages and the elevation model and orthophotos, to obtain an updated land use capacity map at the municipal level, which was the basis for executing the algorithm of conditioning criteria to generate the map of potential restoration areas at the municipal level.

The resulting map is a planning tool for the implementation of FLR actions. Management plans have been drawn up in the selected areas and constitute a set of restoration modality plans. These plans were validated in a participatory manner with communities' stakeholders or the productive units involved. For the follow up of the management plans, monitoring is to be carried out, allowing to assess the results based on the different incentive programmes. The monitoring plan must include intermediate measurements to define corrective actions.

Resulting map of the municipality of San Juan Chamelco



LEGEND

- Municipality of San Juán Chamelco
- Administrative division

Potential for restoration

- Agroforestry with annual crops
- Agroforestry with permanent crops
- Water
- Area not selected
- Dry forest
- Production forest land
- Protective forest lands
- Riparian forest
- Silvopastoral system

The boundaries and names shown and the designations used on the following map do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers and boundaries. Dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Source: INAB, 2021, adapted by the authors.

2.13 **STEP 13** DESIGN THE MEASUREMENT OF EACH MONITORING COMPONENT

The VGNFM provides a guide for designing the measurement of forest variables. It is also recommended to review volumes of the World Programme for the Census of Agriculture (WCA) (FAO, 2015 and FAO, 2018a) and the socioeconomic surveys in forestry (FAO *et al.*, 2016), the NFIs methodological frameworks and field manuals, as well as censuses and national agricultural surveys existing in several countries. This document does not aim at presenting design details for each of the components; nonetheless, some helpful guidance and examples for measuring FLR progress are presented below.

2.13.1 **National forest inventories for monitoring restoration**

The NFI design should allow a continuous measurement of forest resources over the entire national territory. This will enable meeting the information needs for FLR since it will be possible to include the tree and vegetation measurement both in forests and in other land uses and ecosystems that can be restored.

The NFI involves mobilising human and logistical resources of great scope and, therefore, requires a stepped and participatory process. It is advisable that the institutions in charge also commit to work with and train local and communal governments so that local experts participate and benefit from the information collected at all levels.

NFIs enable collecting a set of biophysical attributes related to trees, shrubs and other life forms, mainly within forests. Most of the countries in Latin America and the Caribbean have already designed their first NFIs, so it is recommended to analyse the existing methodologies and manuals to identify and organise the indicators and metrics selected to measure FLR progress. Those responsible for the NFIs and FLR monitoring should ponder the relevance of adding attributes for the selected indicators. Table 3 shows examples of indicators, metrics and attributes related to restoration monitoring measured in NFIs. The measurements can consider wild fauna and invertebrates and physical, chemical and biological attributes of soils because the restoration of ecosystems is totally dependent on their recovery (Aguilar-Garavito and Ramirez, 2015).

For field measurements, the type and size of the plot or measurement area must be decided. There are multiple solutions for these measurements in NFIs, for which it is essential to develop efficient designs. There are single plot designs, as in Argentina (Government of Argentina, 2019), Costa Rica (SINAC, 2015) and the Dominican Republic (Milla *et al.*, 2014); other designs are organized in clusters and plots, as in Guatemala (Ramírez and Rodas, 2004; INAB and CONAP, 2020), Honduras (Ramírez and Salgado, 2006; ICF, 2017), Nicaragua (INAFOR, 2009) and Brazil (Vibrans *et al.*, 2010). For the measurement of multiple land-uses, Guatemala (Ramírez and Rodas, 2004; INAB and CONAP, 2020), Honduras (Ramírez and Salgado, 2006; ICF, 2017), Nicaragua (INAFOR, 2009) and Brazil (Vibrans *et al.*, 2010), have used large sample plots (up to 2 hectares) to measure trees in all land uses (Figure 7). The measurement of trees outside the forest can also be done in smaller plots, provided that the population includes all land uses in the territory. Each tree is identified at the species level and associated with a land use, classified according to criteria based on measurable thresholds.

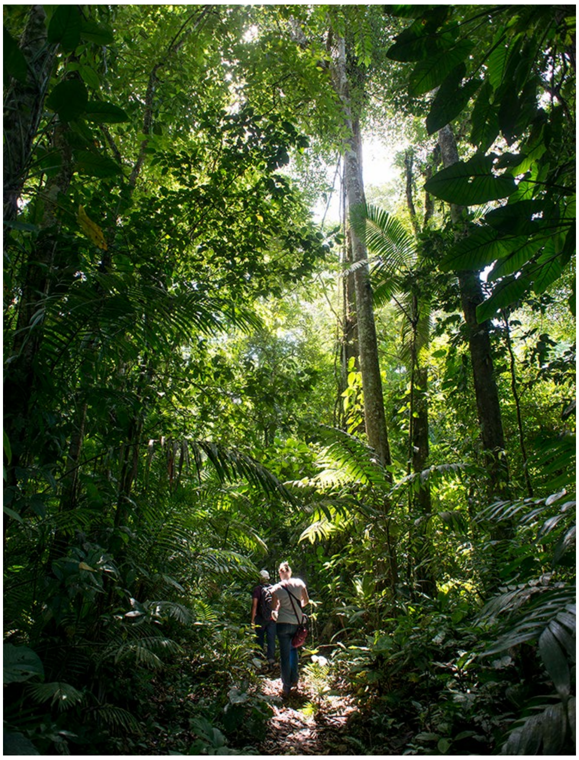


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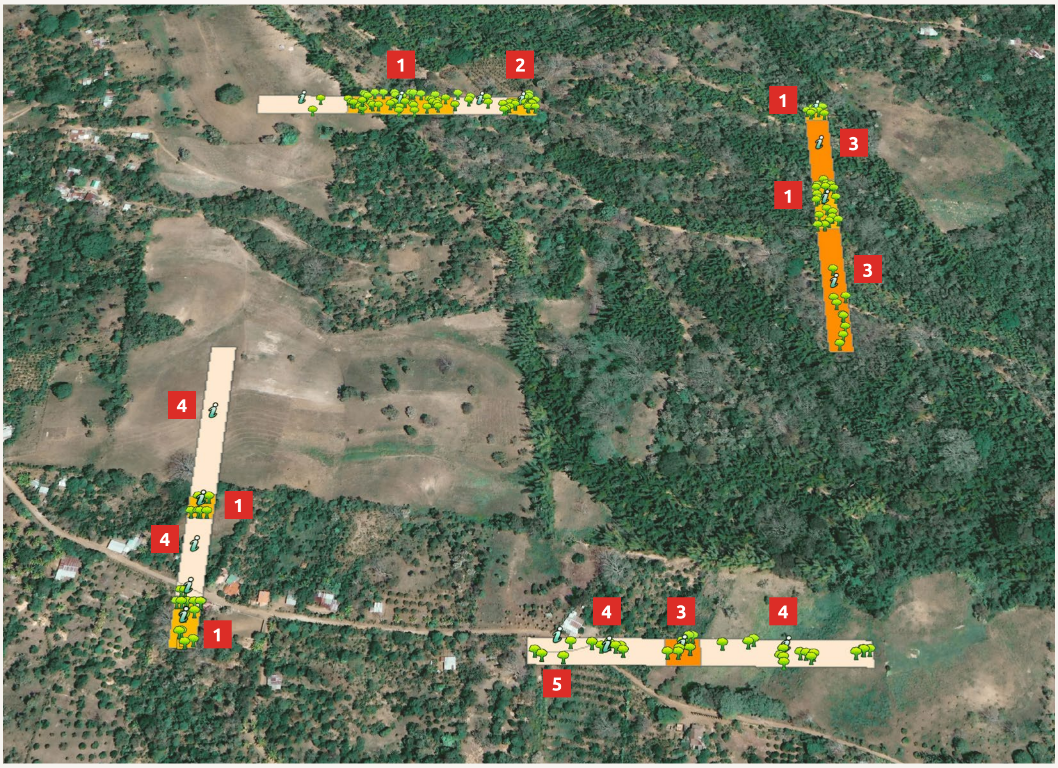
Table 3

Example of indicators, metrics and attributes to be measured from the National Forest Inventories, considering the goal of restoring forest ecosystems

Sub-goal	Indicator	Metrics	NFI Attributes
The composition and structure of tree species is similar to that of the reference ecosystem	Species richness index Specific wealth index Equity index Dominance index Importance value index (IVI)	Richness (R) Menhinik (M) Shannon-Wiener (H') Simpson (D) IVI Margalef	Species, tree abundance
	Presence of exotic species	Exotic/native species ratio	Species, tree abundance
	Horizontal structure	Basal area by diameter class	Species, DBH, tree abundance, spatial location
	Vertical structure	Percentage of coverage per altitudinal floor according to vegetation type	Species, height, spatial location, vegetation cover (herbaceous, shrubs, emerging and dominant trees)
	Tree density	Number of trees/ha	Species, tree abundance
Secondary forests are recovering to reach a condition similar to the reference ecosystem/Forest plantations are growing favourably/ In agriculture, livestock and urban areas, vegetation has recovered	Recruitment rate	Number of trees/ha	Number of regenerating trees
	Growth rate and mortality rate	m^3 /ha/year tonnes/ ha/year	Tree condition (alive, dead, stump, not found) species, height, DBH
	Biomass gain/carbon sequestration	Biomass/ha/year Carbon/ha/year	Species, height, DBH of standing and dead trees, diameter and amount of wood debris, litter and soil organic carbon
	Phytosanitary condition of trees	Number of trees/ ha according to phytosanitary condition	Condition and type of phytosanitary condition per tree
Disturbances in recovered natural ecosystems and landscapes	Anthropic disturbances	Surface with anthropic disturbance	Surface for harvesting of timber and non-timber forest products firewood, fires
	Natural disturbances	Surface with natural disturbances	Erosion, landslides, hurricanes

Source: Elaborated by the authors.

Figure 7 **Example of field measurement of trees in non-forest land uses**



1	Tree shade
2	Fruit trees
3	Fallow
4	Annual crop without trees
5	Settlement

Source: Elaborated by the authors.

2.13.2 Permanent monitoring plots

In the present context, permanent plots will be differentiated from continuous NFI. Measurements in permanent plots are generally carried out with a larger number of variables, in shorter periods of time, and in sites of specific interest. New permanent plots may be required in FLR projects; it is advisable to select them from an intense sampling grid, as described in section 2.12.15.

Besides, it is possible to analyse the use of the NFI plot design and develop the necessary adjustments for the variables of interest. Aguilar-Garavito and Ramirez (Aguilar-Garavito and Ramirez, 2015) present a complete guide on the information needs, indicators, and measurement techniques for FLR variables, including soils, vegetation, insects, and wildlife. It is important that NFI and restoration experts analyse the different options to achieve harmonisation in measurements that increase the coherence and transparency of the information produced at different scales (national, sub-national and local); this will enable obtaining more robust results. However, using permanent plot network data as an alternative to develop national statistics has to be done cautiously because the results will be biased if created for other purposes.

2.13.3 Socioeconomic surveys on forestry

Table 4 shows examples of indicators related to forest and landscape restoration and socioeconomic aspects.

Carrying out socioeconomic forest surveys is very important. Still, it may involve an additional cost, so it is suggested to resort to other components that also require the mobilisation of human resources in the territory.

Section 12.5.4 cited some countries that have developed this component integrated with NFIs or population censuses.

Projects or communities can also conduct surveys on socioeconomic data. Aguilar-Garavito and Ramírez (Aguilar-Garavito and Ramírez, 2015) provide a participatory monitoring guide and socioeconomic indicators of ecological restoration that can be considered for data collection at the local level.

2.13.4 National agricultural census

Those responsible for NFMS and FLR monitoring can approach the offices in charge of conducting agricultural censuses to jointly analyse the option of collecting information on some selected indicators.

Agricultural censuses are a component of the national statistical system and are linked to national statistical offices and ministries of agriculture (FAO, 2015).

The FAO WCA offers two volumes that guide the development of censuses: Volume 1 deals with the programme, definitions and concepts (FAO, 2015), while Volume 2 deals with operational guidelines (FAO, 2018a).

These volumes recommend the collection of data from agricultural units or farms on 15 items that can be linked to FLR monitoring:

Item 1:
Identification and general characteristics

Item 2:
Land

Item 3:
Irrigation

Item 4:
Crops

Item 5:
Livestock

Item 6:
Agricultural practices

Item 7:
Services for agriculture

Item 8:
Demographic and social characteristics

Item 9:
Work on the holding

Item 10:
Intra-household distribution of managerial decisions and ownership on the holding

Item 11:
Household food security

Item 12:
Aquaculture

Item 13:
Forestry

Item 14:
Fisheries

Item 15:
Environment/GHG emissions

Table 4 **Examples of indicators, metrics and attributes that can be recorded through socioeconomic surveys in the forest and landscape restoration**

Goal	Sub-goal	Indicator	Metrics	Attributes
Economy of communities	Improve the economy of women in the participating communities	Benefits of restoration to rural women	Economic income of rural women	Women in the community
Energy consumption	The firewood consumption is sustainable	Firewood consumption	m^3/ha	Amount of firewood consumed per family per day
Production	Positive impact on agricultural production	Harvested products	tonnes/ha; m^3/ha	Volume of products harvested per year

Source: Elaborated by the authors.

2.13.5 Administrative records of projects

Restoration projects must record information on the type of incentives or donation investments, number of women, men, young participants, number of direct jobs, number of organized business fairs, among others. Further, the entities with the determined mandate must record the number of claims attended for forest fires or illegal logging and the number and place of complaints.

Table 5 shows some examples of indicators and metrics related to project records. The use of these registers must be carefully analysed because there may be other more appropriate data sources to generate national statistics.

2.13.6 Terrestrial satellite monitoring using visual interpretation and sampling techniques

Visual interpretation with high-resolution satellite imagery is a valuable resource for measuring changes in tree cover and other vegetation in different land uses between given periods. Table 6 shows some examples of indicators that can be measured with this methodology. To implement this methodology, it is recommended to review "Mapping together: A guide to monitoring forest and landscape restoration using Collect Earth mapathons" (Reytar *et al.*, 2021). This guide can be adapted for use at the national level. However, for the NFMS, it is recommended to review section 2.12 for a comprehensive planning of this component, and mainly a reminder to adapt the sampling design to the NFI, which usually uses systematic sampling in grids with fixed-size polygons.

Box 5 illustrates how the visual interpretation method works with very high-resolution satellite images for area estimation and tree counting.

Table 5 **Examples of indicators, metrics and attributes that can be measured from project records or administrative actions**

Goal	Sub-goal	Indicator	Metrics	Attributes
Market	Fundraising for investment in FLR by municipalities	Municipalities that invest in FLR	% of municipalities /year	Number of municipalities investing in FLR
	Invest in FLR projects under the modality of payment for environmental services	Investment in FLR ratio	Thousands of USD/ year	Investment in USD
Community	Increase the participation of indigenous communities in FLR projects	Number of indigenous communities in FLR projects	% of indigenous communities/year	Number of indigenous communities participating in FLR
Land	Reduce the number of fires and tree-burning in FLR project areas	Fires attended	% of fires attended/year	Number of fires reported

Source: Elaborated by the authors.

Box 5

How does visual interpretation work for area calculation and tree count by land use?

Interpretation is carried out at each selected sampling point, which can be directed at the said point (Figure A) or by drawing plots of a fixed size, for example, 1 ha in a circle or a square or hexagonal polygon (Figure B). Single point interpretation is most often performed with high-resolution images (Landsat or Sentinel) as developed by FRA for monitoring coverage changes at global level (FAO, 2020a). When very high-resolution images are available, where each element covering the land is clearly observed, both the percentage of area per land use and the rate of tree cover within each plot can be estimated. Systematically arranged observation points are established for this purpose (Figure B).

Figure A

Figure B

In Figure A, only the land use indicated by the point is classified, which in this case is pasture. In Figure B, it is classified by point and we find: 100 percent pasture = 25 points.

Once the land uses have been classified, the coverage elements within the plot are measured, which can be trees, shrubs, herbaceous grasses, pavement, roofs, soil without vegetation. Following the example of Figure B, we find, 8 percent of trees = 2 points, 8 percent of shrubs = 2 points, 84 percent of herbaceous grass = 21 points. Total = 25 points.

Land-use change can be measured by temporal analysis to determine how much land use has changed between time periods. For this, very high-resolution images of each date must be available.

Figure B - 2010

Figure C - 2021

Comparison of Figure B, registered in 2010, with Figure C of the same site registered in 2021. The coverage results of each one as follows:

Continuing **Box 5**

The result of the land use change is the following:

2010–2021

Pasture – Forest = 4 points / 16 %

Pasture – Pasture = 21 points / 84%

The result of coverage change by land use is the following:

2010	2021
Pasture = 25 points, 100 % 8 % of trees = 2 points 8% of shrubs = 2 points 84% of herbaceous grass = 21 points	**Forest** = 4 points, 16 % 16 % of trees = 4 points **Pasture** = 23 points, 92 % 52 % of trees = 13 points 32 % of herbaceous grass = 8 points

In this example 16 percent of the trees were classified as forest because they join the surrounding forest. The remaining area has 52 percent of the trees that were classified as pasture because it is observed that there are gaps of grasses (32 percent) and a conservative point of view must be maintained, because the trees are of approximately 10 years. To improve visual classification, a field visit is recommended. The tools Collect Earth or Collect Earth Online, which will be described in 2.14, can be used for this type of analysis. The second tool is more practical for performing change analysis at the point level. The data set from the plots interpreted at the national level or the study scale can produce area estimates through proportion estimators (Cochran, 1977). The detailed procedure can be reviewed in Olofsson *et al.* (2014) and Olofsson *et al.* (2020).

Table 6 **Example of indicators obtained from visual interpretation with satellite images**

Goal	Sub-goal	Indicator	Metrics	**Attributes** of visual analysis using high-resolution images
Restoration of forest ecosystems	Increase the area of naturally restored forest ecosystems	Increase of the area of restored forest ecosystems	Ha/year	Percentage of area by type of forest
	Increase tree canopy cover in restored forest ecosystems	Increased of tree canopy cover	% coverage /year	Percentage of tree canopy cover in forest ecosystems
Planted forests and/ or forest plantations	Increase the area of planted forests and/or forest plantations	Increase of the area of forest plantations and / or planted forests	Ha/year	Percentage of plantation areas and planted forests
Restoration in agricultural lands	Increase in tree cover in agricultural and urban areas	Increased tree canopy cover	% coverage /year	Tree canopy cover percentage

Source: Elaborated by the authors.

Long-term access to very high-resolution satellite imagery is one of the concerns when conducting an analysis such as the one presented in Box 4 and for the sustainability of NFMS. Therefore, inter-institutional integration and agreements at the government level with image providers will be necessary. At the moment, the countries depend on open data such as Google Earth, Bing Maps and other free providers; or on cooperation agreements of donor countries such as the one currently provided by the Norway International Climate and Forest Initiative (NICFI), thanks to which, users in tropical countries can access high and very high-resolution images recorded since 2015.

To obtain more precise estimates of area change, it is recommended to use maps of areas with a higher probability of change, previously stratifying these areas to intensify the sample. The design would be based on a pre-stratified sampling, which can be systematic or simply random (Olofsson *et al.* 2014; Olofsson *et al.* 2020), although there are also other efficient designs such as two-stage sampling (Corona *et al.* 2015; Gallun *et al.* 2015). However, if visual interpretation is used as an auxiliary data source to improve forest inventory estimates, double sampling for post-stratification can be a useful technique (Westfal *et al.*, 2019).

2.13.7 Terrestrial satellite monitoring using wall-to-wall thematic mapping

Satellite monitoring systems with field data or visual interpretation collected under a robust sampling design and good quality control will achieve greater accuracy of the interpreted categories. These data can be used in supervised techniques to calibrate geographic models of empirical methods or based on generic, Bayesian, or machine learning algorithms (GFOI, 2020). Maps can also be elaborated using unsupervised methods when no good sources of reference data are available. However, these maps may be imperfect; hence caution is recommended in their use when reporting statistics (Olofsson *et al.*, 2020).

The primary use of these maps should be to support restoration planning or sampling design for field data collection. In conclusion, to achieve a good NFMS, the field components and remote sensors must be complementary and dependent on each other.

For the implementation of this component, a decision on the use of thematic maps must be made. Here are examples based on some basic needs:

- **Maps for restoration planning:** These maps are used for the location of areas to be restored, such as the ones described in Box 1 for the national level and in Box 3 for the subnational level. Other maps or information layers shall be used depending on the methodology used; for example, land use and land cover, ecosystems, biological corridors, effective depth, stoniness and drainage, water resources, physiographic regions and percentages of slopes, among others. Other examples are maps of vulnerability, risks, forest degradation, land degradation, fragmentation, as well as other predictive maps and trends.
- **Maps to support sampling design** for visual interpretation, national forest inventory, census, agricultural surveys or socioeconomic surveys: maps that support the stratification of the sample to improve statistical precision. For example, if the objective is to measure tree cover changes resulting from restoration activities, a map of land cover change, degradation or the same location map of potential areas for restoration can be used.
- **Early warning maps:** These maps provide support during the execution of actions in the territory and must be part of an immediate response system. Among other examples, these maps can be for droughts, fires, illegal logging, deforestation, degradation and other disasters.
- **Maps for displaying restoration results:** Here again, maps showing changes in land cover or productivity increases are helpful; these can be segmented by administrative regions, land use by ecosystem, etc. Other maps can display the location of restoration projects at the national level, in administrative areas or by community, among others.

In the NFMS assessment tool (FAO, 2020c), there is a compilation of good practices for the implementation of remote sensing monitoring (sections 5.2b and 5.3). These are summarised in the following steps:

- **Selection of remote sensing resources:** involves an analysis of the availability of resources according to their spatial, spectral and temporal resolution to foresee the system's sustainability.
- **Selection of remote sensing and mapping methods**: mapping products are identified according to existing needs. They are based on consultations with national and international experts to define the most suitable methodologies and document decisions on the methodology, pre-processing and procedures.
- **Uncertainties and quality assurance methods:** develop a robust sampling design for accurate calculation and document the estimators for a precise analysis. All sources of error are identified, data quality is recorded, and corrections are applied.
- **Validation methods:** field validation is expected and, where possible, is linked to the NFI or other national statistical resources (such as agricultural censuses or surveys).
- **Supervised remote sensing analysis:** methodological protocols are applied according to the products to be achieved; decision rules for classification, limitations and assumptions are documented; and integrated work between remote sensing and survey specialists and survey fieldwork is pursued.

The methods and guidance of the Global Forest Observations Initiative (GFOI, 2020) describe in detail the remote sensing resources available to date for monitoring land use and land cover changes: optical data, synthetic aperture radar (SAR) data, ground LiDAR and airborne LiDAR. Additional resources are also provided for processing and documentation on the methodologies for their use.

Other valuable resources for accessing satellite images and publications are:

- The Committee on Earth Observation Satellite (CEOS) is a mechanism that unites 61 agencies to collaborate on space missions, data systems, and global initiatives.
- Copernicus is the European Union programme for earth observation through the Open Access Centre and provides the following products: Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P.
- NASA Landsat Science is the programme with the most extensive continuous distribution of Landsat satellite images by the National Aeronautics and Space Administration Agency (NASA) and the United States Geological Survey.

2.13.8 Data management, data analysis and reporting

This component refers to the compilation and data analysis from the previous components and other sources linked to the NFMS, for example, official spatial data such as transport and infrastructure, topography, digital elevation models, population centres, land registry of properties, among others.

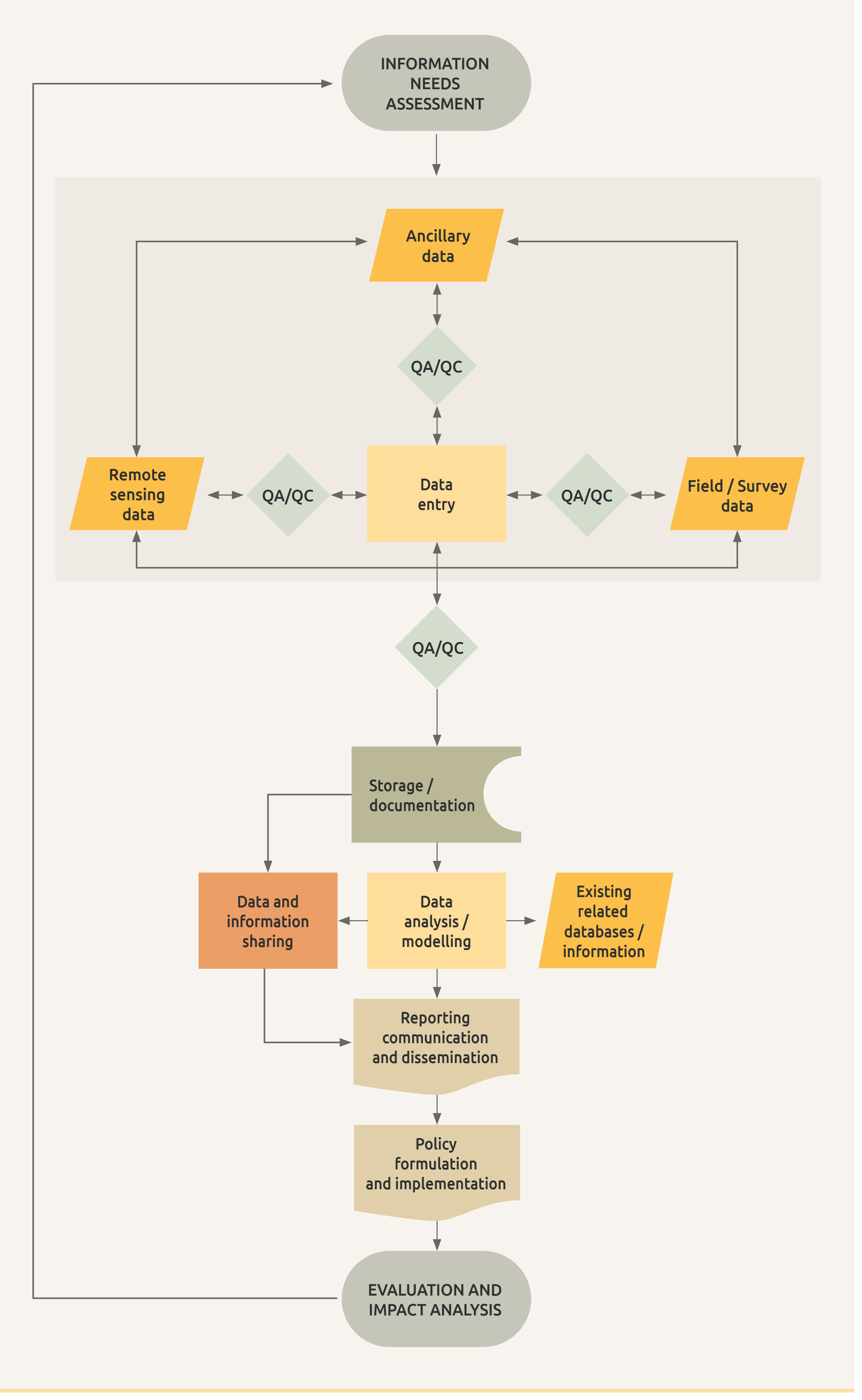
Figure 8 shows an NFMS data management model (FAO, 2017), which involves field data and remote sensing. Data management must include quality control and assurance, which must be initiated and documented from each monitoring component at the time of data collection, and continue through a final quality control process before final database storage on official servers.

The data outputs can be consulted with the restoration monitoring stakeholders. It is essential to clearly define the change to be measured based on the monitoring questions previously defined.

Calculation and data analysis must be designed to formulate the indicators and consider the metrics, attributes, and sources. The type of data outputs must also be considered, whether it will be tables, graphs or maps. Depending on the above, the types of analysis should be identified, which can be simple statistical estimates, the development of mathematical and geographic models, or an analysis of multiple indicators through a restoration index.

For example, Zamora (Zamora *et al.*, 2020) developed a sustainability index for landscape restoration as a tool to measure the biophysical and socioeconomic impacts of restoration actions of a priority landscape in El Salvador.

Figure 8 **NFMS data management model**



Source: FAO, 2017, adapted by the authors.

Reporting the distribution of results is the final process for evaluating FLR's progress. It is critical to identify the mass media according to the different target audiences.

NFMS provides tools applied to make decisions concerning actions in the territory. They can also serve other tools that require robust data to analyse different needs within the FLR process, as for the FERM platform. Box 6 shows a description of FERM and some other platforms available on the Web as examples of NFMS communication.

The development of a dialogue process on the results with the different stakeholders should also be an important step in the FLR process since monitoring is essential for adaptive management – defined as a "cyclical process made up of a management action, a monitoring process of this action's impact, and subsequent adjustments based on the monitoring results" (Aguilar-Garavito y Ramirez, 2015).

2.14 **STEP 14** SELECT AND CUSTOMISE TECHNOLOGY TOOLS

NFMS are highly complex institutional, technical and logistical processes, which require a set of technological tools to assist in the management model of the system, from planning to the dissemination of results. For this reason, FAO created the Open Foris initiative, a set of free and open-source tools that facilitate data planning, collection, processing, analysis and reporting. They help to save resources and produce information. Open Foris is aimed at personnel from national and local governments, communities, research centres, non-governmental organisations and companies that support forest monitoring.

Open Foris tools are available online Box 7 describes each tool.

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Box 6

Platforms of national satellite monitoring systems

Global resources

FAO Framework for Ecosystem Monitoring Restoration

Enhance monitoring systems to generate quality data and resource-efficient and fit-for-purpose information; supports domestic restoration needs and the reporting of progress with strong ownership by governments, relevant national entities, sub-national entities, NGOs, the private sector and civil society organizations.

FAO Hand-in-hand geospatial platform

Based on geographic information systems with information on agroecology, water, land, soils and GHG. It is an evidence-based tool led by countries to support agricultural transformation, sustainable rural development and the SDGs, especially SDG1 "No poverty" and SDG2 "Zero Hunger."

Global Forest Watch

Web forest monitoring and warning system platform that offers a wide range of data and allows for customizing maps, carrying out forest trends analysis, and identifying warnings.

National satellite land monitoring systems portal

This platform provides access to the systems developed with the UN-REDD Programme support.

National resources of Latin America and the Caribbean

Mexico

National forest information and management system and early warnings of forest fires

Guatemala

Forest information system of Guatemala

Honduras

Integrated system for forest management and monitoring

El Salvador

Forest and landscape restoration monitoring system

Costa Rica

National system for monitoring land cover, land use and ecosystems

Colombia

Forest monitoring system

Argentina

National forest monitoring system of the Republic of Argentina

Brasil

Brazilian National Research Institute

Suriname

National forest monitoring system

Box 7

Description of Open Foris tools

Collect	Entry point for data and storage. Facilitates the development of user-friendly forms and validation rules to enable quality control. It is used to collect field data for NFI and other socioeconomic uses and surveys.
Collect Mobile	Collect mobile app. Enables field data entry that connects directly to the central database and can replace paper forms while reducing costs and improving quality control of on-site data collection.
Calc	Tool for calculation and estimation. It provides a flexible way to produce aggregated data that can be analysed and visualised with other free applications, such as Saiku. It provides the option to perform customised analysis modules in the free access application "R" for statistical analysis, making data analysis possible according to the variety of sampling designs.
Collect Earth	Local installation tool for terrestrial satellite monitoring through visual interpretation and sampling techniques. Uses Collect to design the form and works in connection with Google Earth, Bing Maps, and Google Earth Engine servers.
Collect Earth Online	Online tool for terrestrial satellite monitoring through visual interpretation and sampling techniques. Multiple users can collect data simultaneously. It connects to servers like Google Earth Engine, Bing Maps, and local servers through the WMS service.
SEPAL	Enables users to query and process satellite data quickly and efficiently, tailor their products to local needs and promptly produce sophisticated and relevant geospatial analysis. It connects to cloud-based supercomputers and modern geospatial data infrastructures like Google Earth Engine. It allows users to access and process historical satellite data, more recent Landsat data and higher resolution data from the European Copernicus programme. Facilitates FLR planning, considering biophysical variables of the ecosystem and socioeconomic variables such as benefits, costs and risks.
Earth Map	Tool developed in association with Google, very user-friendly. It allows for visualising, processing, and analysing satellite images and global data sets on climate, vegetation, fires, biodiversity, geo-social, and other topics. Users do not need prior knowledge of remote sensing or geographic information systems.

2.15 **STEP 15** STRENGTHEN CAPACITIES FOR QUALITY MAINTENANCE

Throughout the document, we have learned that NFMS require a set of integrated capacities through multiple actors from central and subnational government institutions, accompanied by academic and research institutions, to determine the most appropriate methodologies. Capacity development must also consider organized communities and the institutions that support them. International technical assistance from organisations such as FAO, bilateral cooperation agencies, and other international agencies also play an important role in technology transfer and to present solutions to the complex forest and landscape monitoring challenges. The NFMS entail a continuous capacity-building strategy due to the constant evolution of information needs and the requirement to improve methodologies using the best technology to deliver fast and reliable solutions.

FAO uses the Organization for Economic Cooperation and Development (OECD) definition for capacity building, as "the processes whereby people, organisations and society as a whole unleash, strengthen, create, adapt and maintain capacity over time" (FAO, 2012b). For continuous NFMS to be successful, the capacity-building approach must pay attention to the integration of individual and organisational capacities, seeking a favourable environment.

Personnel training is an essential dimension in strengthening capacities for NFMS success, ensuring the high-quality performance of personnel dedicated to planning, collecting, processing, analysing and reporting information. Thus, the capacity-building strategy must contain a continuous technical training plan with the international community's support, including the transfer of knowledge and best practices nationally and internationally. For best results, the technical training plan should consider both North-South and South-South transfer, since conditions in tropical developing countries are different from conditions in temperate countries.

To develop a capacity-building strategy, it is recommended to review the VGNFM (FAO, 2017) on:

- national capacity development (3.2);
- development of partnerships and collaborations (3.2);
- strengthening research and scientific research institutions (3.3);
- integration of young experts (4.5).

Concerning the technical capacity training plan, it is recommended to review the guidelines related to operational design (FAO, 2017):

- formulation of manuals and protocols (5.3.1);
- establishing work teams (5.3.3);
- training (5.3.4).

To pursue and ensure the best data quality, review the guidelines (FAO, 2017):

- field work supervision (5.3.7);
- documentation (enhanced transparency) (5.4.4);
- dialogue on the NFMS and its results (5.4.7);
- impact assessment and analysis (5.4.8).

The role of gender in capacity development

It is recommended to raise awareness on the importance of promoting women's training in order to increase their participation in processes involving NFMS. The UN-REDD Programme developed a simple checklist for gender-sensitive workshops, which can be adapted for technical training workshops because it makes it easier for trainers to maintain active awareness to promote greater inclusion of women.

Gender-sensitive workshops can be found on the UN-REDD website.

2.16 **STEP 16** DEVELOP A SHORT AND LONG-TERM SUSTAINABILITY STRATEGY

NFMS sustainability is a challenge that always concerns the decision makers responsible for different components, hence it is crucial to develop a short and long-term strategy for implementing adjustments to NFMS for FLR monitoring. The country may not have integrated planning of the different components of NFMS. Some recommendations of the VGNFM on essential elements to launch or improve NFMS management are specified as follows (FAO, 2017):

- Effectively integrate NFMS into existing national policy and legislative frameworks and government structures (organisations) and funding systems (for example, the national budget). This integration will create the legal justification and the formal basis for a long-term operation of the NFMS.
- Develop a capacity assessment to plan the development of improvements in a phased manner, establishing priorities.
- Ensure sufficient funds through sustainable/relevant financing mechanisms for the realisation and continuation of the NFMS to guarantee updated information at regular intervals.
- Establish the most appropriate coordination mechanisms to carry out general management, as well as the collection, management and exchange of data between institutions and information users.
- A clear designation of the responsibilities and functions of all entities involved in achieving the objectives and goals of the NFMS, usually coordinated by a single central entity. When the NFMS is executed in a decentralised manner, a lead entity should harmonise, coordinate, and maintain coherence among the decentralised entities.
- An explicit commitment to impartiality, free from undue influence or potential conflicts of interest that could lead to biased/compromised results;
- The specification of the means, including resources (human, financing, infrastructures, etc.) for establishing the NFMS.

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Bibliography

Aguilar-Garavito, M. & Ramírez, W. eds. 2015. *Monitoreo a procesos de restauración ecológica, aplicado a ecosistemas terrestres.* Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH). Bogota. 250 pp. (also available at http://repository.humboldt.org.co/bitstream/handle/20.500.11761/9281/monitoreo_restauracion_baja_1.pdf?sequence=1).

Alder, D. & Synnott, T. 1992. *Permanent sample plots techniques for mixed tropical forest.* Oxford Forest Institute. Oxford University, UK. 124 pp.

Avery, T. & Berlin, G. 1992. *Fundamentals of Remote Sensing and Airphoto Interpretation.* Prentice Hall. Fifth edition. New York. 465 pp.

Bastin, J. F., Finegold, Y., García, C., Mollicone, D., Rezende, M., Routh, D., Zohner, C. & Crowther, T. 2019. The global tree restoration potential. *Science* 05 Jul 2019: Vol. 365, Issue 6448, pp 76-79.

Bellefontaine, R., Petit, S., Paint, O., Deleporte, P. & Bertault, J. 2002. *Trees Outside Forest: towards a better awareness.* FAO. Conservation Guide 35. Rome. 233 pp. (also available at http://www.fao.org/3/y2328e/y2328e00.htm).

Besseau, P., Graham, S. & Christophersen, T. eds. 2018. *Restauración de bosques y paisajes: la clave para un futuro sostenible.* The Global Partnership on Forest and Landscape Restoration, Vienna. (also available at https://ribm.net/wp-content/uploads//2020/02/GPFLR_ES_web.pdf).

Branthomme, A. Vunning, S. Kamelarcz, K. Rodas, R. Anyango, S. & Amos, C. 2008. *Integrated Natural Resources Assessment in Kenia. Field Manual.* 201 pp. (also available at http://www.fao.org/forestry/fma/73410/en/ken/).

Brazilian Forest Service (SFB). 2015. *Manual de campo: procedimientos para la coleta de dados biofisicos e socioambientais.* National Forest Inventory. Brasilia. 67 pp.

Burrough, P. & McDonnell, R. 1998. *Principles of Geographical Information Systems.* Oxford, UK. 333 pp.

Camacho, M. 2000. *Parcelas permanentes de muestreo de bosque tropical. Guía para el establecimiento y medición.* Tropical Agricultural Research and Higher Education Centre - CATIE. Turrialba, Costa Rica. 52 pp.

Chazdon, R. & Guariguata, M. 2018. *Decision support tools for forest landscape restoration. Current status and future outlook.* Occasional paper 183. Bogor, Indonesia. CIFOR. (also available at https://www.cifor.org/knowledge/publication/6792).

Chivite, I. 2016. *Introducing Survey123 for ArcGIS.* [online]. [Cited on 16 March 2021]. https://www.esri.com/arcgis-blog/products/survey123/announcements/introducing-survey123-for-arcgis/

Chokkanlingam, U. & de Jong, W. 2001. Secondary Forest: a working definition and typology. Center for International Forestry Research (CIFOR). *International Forestry Review* 3(1): 19-26. (also available at https://www.cifor.org/publications/pdf_files/secondaryforests.pdf).

Cochran, W. G. 1977. *Sampling Techniques.* New York, USA. John Wiley & Sons. 428 p.

Coffey, R. 2013. The difference between land use and land cover. *Michigan State University Extension.* (also available at https://www.canr.msu.edu/news/the_difference_between_land_use_and_land_cover).

Cohen, W., Yang, Z. & Kennedy, R. 2010. Detecting trends in forest disturbance and recovery using yearly Landsat time series 2: Timesyinc – tools for calibration and evaluation. *Remote Sensing of Environment*: 114: 2911-2924. (also available at https://www.sciencedirect.com/science/article/abs/pii/S0034425710002269?via%3Dihub).

Congress of the Republic of Guatemala. 2015. *Decreto Legislativo 02-2015. Ley de fomento al establecimiento, recuperación, restauración, manejo, producción y protección de bosques en Guatemala* (PROBOSQUE). Congress of the Republic of Guatemala. (also available at https://www.undp.org/content/dam/guatemala/docs/prodocs/undp_gt_probosque.pdf).

Corona, P., Fattorini, L. & Pagliarella, M. 2015. Sampling strategies for estimating forest cover for remote sensing-based two-stage inventory. *Forest Ecosystems*: 2:18. (also available at https://forestecosyst.springeropen.com/articles/10.1186/s40663-015-0042-7).

Danielsen, F., Skutsch, M., Burgess, N., Jensen, P., Adrianadranasana, H., Karky, B., Lewis, R., Jovett, J., Massao, J., Ngaga, Y., Phartiyal, P., Poulsen, M., Singh, S., Solis, S., Sorensen, M., Tewari, A., Young, R. & Zahabu, E. 2010. At the heart of REDD+: a role of local people in monitoring forest? *Conservation letters*: 00 (2011) 1-10. (also available at http://monitoringmatters.org/articles/REDD-Heart-Paper-2011.pdf).

Denier L., Scherr, S., Shames, S., Chatterton, P., Hovani, L. & Stam, N. 2017. *The Little Sustainable Landscapes Book: Achieving sustainable development through integrated landscape management.* Global Canopy Programme (GCP), EcoAgriculture Partners, the Sustainable Trade Initiative (IDH), The Nature Conservancy (TNC), and the World Wide Fund for Nature (WWF). Oxford, UK. 172 pp. (also available at https://globalcanopy.org/sites/default/files/documents/resources/GCP_LSLB_English.pdf).

Di Gregorio, A. & Jansen, L. 2000. *Land Cover Classification System (LCCS). Classification concepts and user manual*. Environment and Natural Resources Service, Africover - East Africa Project and Soil Resources, Management and Conservation Service. 179 pp. Rome, FAO. (also available at http://www.fao.org/3/x0596e/X0596e00.htm).

Di Gregorio, A. y Leonardi, U. 2015. *Land Cover Classification System 3. Classification concepts*. Rome, FAO. (also available at http://www.fao.org/3/a-i5428e.pdf).

Domke, G., Woodal, C., McRoberts, R., Smith, J. & Hatfield, M. 2012. *Assessing estimation techniques for missing plot observations in the U.S. Forest Inventory*. Paper presented at the Conference "Moving from trends: Forest Inventory and Analysis Symposium": 177-181. (also available at https://www.nrs.fs.fed.us/pubs/42727).

Enderle, D. & Weih Jr., R.C. 2005. Integrating supervised and unsupervised classification methods to develop a more accurate land cover classification, *Journal of the Arkansas Academy of Science*, 59:65-73. (also available at https://scholarworks.uark.edu/cgi/viewcontent.cgi?article=1535&context=jaas).

Eswaran, H., Lal, R. & Reich, P. 2001. Land degradation: an overview. In: Bridges, E.M., I.D. Hannam, L.R. Oldeman, F.W.T. Pening de Vries, S.J. Scherr, and S. Sompatpanit (eds.). *Responses to Land Degradation*. Proc. 2nd. International Conference on Land Degradation and Desertification, Khon Kaen, Thailand. Oxford Press, New Delhi, India.

FAO. 2000. *Global Forest Resources Assessment 2000.* Working paper 140. (also available at http://www.fao.org/3/y1997e/y1997e00.htm#Contents).

FAO. 2002. *Second expert meeting on harmonization forest-related definitions for use by various stakeholders*. Proceedings. September 11-13, 2002. Rome. (also available at http://www.fao.org/3/Y4171E/y4171e00.htm#TopOfPage).

FAO. 2009. *High Level Expert Forum – How to Feed the World in 2050. Synthesis Report.* Office of the Director, Agricultural Development Economics Division. Rome. 4p. (also available at http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf).

FAO. 2011. *Assessing Forest Degradation. Towards the development of applicable guidelines.* Rome. 99 p. (also available at http://www.fao.org/3/i2479e/i2479e.pdf).

FAO. 2012a. *Manual for integrated field data collection. National Forest Monitoring and Assessment.* Working paper, NFMA 37/E. Rome. (also available at: http://www.fao.org/3/ap152e/ap152e.pdf/)

FAO. 2012b. *Enhancing FAO's practices for supporting capacity development of member countries.* Rome, FAO. (also available at http://www.fao.org/3/ i1998e/i1998e.pdf).

FAO. 2015. *World Programme for the census of agriculture 2020. Volume 1. Programme, concepts and definitions.* FAO Statistical Development Series 15. Rome, FAO. 203 pp. (also available at http://www.fao.org/3/i4913e/i4913e.pdf).

FAO. 2016. *The agriculture sectors in the Intended Nationally Determined Contributions: Analysis*, by Strohmaier, R., Rioux, J., Seggel, A., Meybeck, A., Bernoux, M., Salvatore, M., Miranda, J. & Agostini, A. Environment and Natural Resources Management Working Paper No. 62. Rome. (also available at http://www.fao.org/publications/card/en/c/7b020094-a986-4c93-8fa7-7e222b2cd649/).

FAO. 2017. *Voluntary guidelines on national forest monitoring.* Rome, FAO. 75 pp. (also available at http://www.fao.org/publications/card/es/c/3ba84dd8-5ba2-4905-8737-b1636915c988).

FAO. 2018a. *World Programme for the census of agriculture 2020. Volume 2. Operational guidelines.* FAO Statistical Development Series 16. Rome, FAO. 203pp. (also available at http://www.fao.org/3/CA1963EN/ca1963en.pdf).

FAO. 2018b. *Seventy years of FAO´s Global Resources Assessment.* 1948-2018. Rome, FAO. 65 pp. (also available at http://www.fao.org/3/I8227EN/i8227en.pdf).

FAO. 2018c. *Global Forest Resources Assessment 2020. Terms and definitions.* Rome, FAO. 33 pp. (also available at http://www.fao.org/3/I8661EN/i8661en.pdf).

FAO. 2018d. *Strengthening national forest monitoring systems for REDD+. National Forest Monitoring and Assessment Working Paper No.47.* Rome, FAO. 28 pp. (also available at http://www.fao.org/3/ca0525en/CA0525EN.pdf).

FAO. 2019. *Restoration of forests and landscapes. Note by the Secretariat.* Thirty-first session. Latin American and Caribbean Forestry Commission. Uruguay. (also available at http://www.fao.org/3/ca5677en/ca5677en.pdf.

FAO. 2020a. *Global Forest Resources Assessment 2020. Key findings.* Rome, FAO. 16 pp. (also available at http://www.fao.org/3/ca8753en/CA8753EN.pdf.

FAO. 2020b. *Position paper on "ecosystem restoration" of production ecosystems, in the context of the context of UN decade of ecosystem restoration 2021-2030.* Twenty-fifth session. Commitee on Forestry. 5-9 October 2020. (also available at http://www.fao.org/3/nd651en/nd651en.pdf).

FAO. 2020c. *National forest monitoring system assessment tool. Quick guidance.* Rome, FAO. 19 pp. (also available at http://www.fao.org/publications/card/en/c/CB0988EN).

FAO. 2020d. *From reference levels to results reporting: REDD+ under de United Nations Framework Convention on Climate Change. 2020 update.* Forestry Working Paper No. 19. Rome, FAO. (also available at https://doi.org/10.4060/cb1635en).

FAO. 2021. *Institutionalisation of forest data. Establishing legal frameworks for sustainable forest monitoring in REDD+ countries.* Rome. (also available at http://www.fao.org/3/cb3525en/cb3525en.pdf).

FAO. 2021b. *Enhancing FAO's practices for supporting capacity development of member countries*. Rome, FAO. (also available at http://www.fao.org/3/i1998e/i1998e.pdf).

FAO, CIFOR, IFRI & World Bank. 2016. *National socioeconomic surveys in forestry: guidance and survey modules for measuring the multiple roles of forests in household welfare and livelihoods*, by R.K. Bakkegaard, A. Agrawal, I. Animon, N. Hogarth,D. Miller, L. Persha, E. Rametsteiner, S. Wunder and A. Zezza.FAO Forestry Paper No. 179. FAO, CIFOR, IFRI and World Bank. Rome. 171 pp. (also available at http://www.fao.org/publications/card/fr/c/I6206E/).

FAO, MADS y IDEAM. 2018. *Propuesta de lineamientos para el monitoreo comunitario participativo en Colombia y su articulación con el Sistema Nacional de Monitoreo de Bosques*. Institute of Hydrology, Meteorology, and Environmental Studies (IDEAM), National Forest and Carbon System (SNByC), Ministry of Environment and Sustainable Development of Colombia (MADS), ONUREDD Programme Colombia. (also available at http://www.fao.org/3/I9584ES/i9584es.pdf).

FAO and WRI. 2019. *The road to restoration: a guide to identifying priorities and indicators for Monitoring Forest Landscape Restoration*. Rome, Washington, DC. (also available at http://www.fao.org/in-action/forest-landscape-restoration-mechanism/resources/detail/en/c/1253837/).

Forest and Landscape Restoration Board of Guatemala (MRPF). 2015. *Estrategia de Restauración del Paisaje Forestal: Mecanismo para el Desarrollo Rural Sostenible de Guatemala*. Guatemala. 58 pp. (also available at http://www.fao.org/forestry/43244-0d7675c1321e62fbaa45f9e3d339c77c8.pdf).

Geoenvironmental Information Centre of Costa Rica (CENIGA). 2020. Descripción del Sistema de Clasificación de Uso y Cobertura de la Tierra propuesto para el SIMOCUTE. *Revista Ambientico*. 273: 23-34. (also available at http://www.ambientico.una.ac.cr/pdfs/art/ambientico/273_23-34.pdf).

Global Forest Observations Initiative (**GFOI).** 2020. *Integration of remote-sensing and ground-based observations for estimations of emissions and removals for greenhouse gases in forestry. Methods and guidance for global observations initiative*. GFOI, 3rd edition. Rome, FAO. 331 pp. (also available at https://www.reddcompass.org/download-the-mgd).

Goodbody, T., Coops, N. & White, J. 2019. *Digital Aerial Photogrammetry for Updating Area-Based Forest Inventories: A Review of Opportunities, Challenges, and Future Directions. Current Forestry Reports*: 5, 55-75. (also available at https://doi.org/10.1007/s40725-019-00087-2*)*.

Government of Chile. 2020. *Contribución determinada a nivel nacional de Chile.* (also available at https://mma.gob.cl/wp-content/uploads/2020/04/NDC_Chile_2020_espan%CC%83ol-1.pdf).

Government of Colombia. 2020. *Actualización de la contribución determinada a nivel nacional de Colombia*. (also available at https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Colombia%20First/NDC%20actualizada%20de%20Colombia.pdf).

Government of Guatemala. 2019. *Documento del Programa de Reducción de Emisiones*. Forest Carbon Partnership Facility. Carbon Fund. World Bank. (also available at https://www.forestcarbonpartnership.org/system/files/documents/Final%20ERPD%20280519V2clean%20b.pdf).

Government of Mexico. 2020. *Nivel de Referencia de Emisiones Forestales de México. 2007-2016*. (also available at https://redd.unfccc.int/files/nref_2007-2016_mexico.pdf).

Government of Nicaragua. 2020. *Niveles de Referencia de Emisiones Forestales*. Republic of Nicaragua. (also available at https://redd.unfccc.int/files/nref_nicaragua_vf_limpio_14072020.pdf).

Government of Panama. 2018. *Niveles de referencia de emisiones forestales de Panamá*. (also available at https://redd.unfccc.int/files/modificacion_frel_report_panama_vfinal_5_6_2018.pdf).

Hobbs, R. & Harris, J. 2001. Restoration ecology: Repairing Earth's ecosystem in the new millennium. *Restoration ecology*: Vol 9:2, 239-246. (also available at https://www.researchgate.net/publication/229790530_Restoration_Ecology_Repairing_the_Earth's_Ecosystems_in_the_New_Millennium).

Institute for Forest Conservation and Development, Protected Areas and Wildlife of Honduras (ICF). 2017. *Resultados de la Evaluación Nacional Forestal de Honduras. Instituto de Conservación y Desarrollo Forestal, Áreas Protegidas y Vida Silvestre (ICF). Proyecto de Modernización del Sector Forestal de Honduras*. EuroFor MOSEF. Tegucigalpa MDC, Honduras. 152 pp.

Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM). 2018. *Manual de Campo Inventario Nacional Forestal Colombia*. IDEAM. Bogota, Colombia. 160 pp. (also available at http://www.fao.org/3/i9619es/I9619ES.pdf).

Inter-Agency Forest and Land Use Monitoring Group (GIMBUT). 2019. *Mapa de Cobertura Forestal de Guatemala 2016 y Dinámica de la Cobertura Forestal 2010-2016*. 137 pp.

Intergovernmental Panel on Climate Change (IPCC). 2003. *Orientación sobre buenas prácticas para uso de la tierra, cambio de uso de la tierra y silvicultura*. IPCC. Greenhouse gas inventory programme. (also available at https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html).

Intergovernmental Panel on Climate Change (IPCC). 2006. *Guidelines for National Greenhouse Gas Inventories. Volumen 4. Agriculture, Forest and Other Land Use*. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds). IGES, Japan (also available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html).

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). 2018. *Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science-Policy Platform on Biodiversity and Environmental services*. By R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B. Erasmus, J. Fisher, T. Gardner, T G. Holland, F. Kohler, J.S. Kotiaho, G. Von Maltitz, G. Nangendo, R. Pandit, J. Parrotta, M.D. Potts, S. Prince, M. Sankaran & L. Willemen (eds.). IPBES Secretariat, Bonn, Germany. 44 pp.

International Tropical Timber Organization (ITTO) & International Union for Conservation of Nature (UICN). 2005. *Restoring Forest Landscapes. An introduction to the art and science of forest landscape restoration*. ITTO and UICN. OIMT Technical Serie No.23. 160 pp. (also available at https://portals.iucn.org/library/sites/library/files/documents/2005-127.pdf).

International Tropical Timber Organization (ITTO). 2002. *ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forest*. ITTO policy development series No. 13. Yokohama, Japan. 84 p.

Kangas, A. y Maltamo M. 2007. *Forest Inventory methodology and Applications*. Springer. Netherlands.

Kristen, E. & Guariguata, M. 2008. *Monitoreo participativo para el manejo forestal en el trópico: una revisión de herramientas conceptos y lecciones aprendidas*. Bogor, Indonesia: Center for International Forestry Research (CIFOR). 50 pp. (also available at https://www.cifor.org/publications/pdf_files/Books/BGuariguata0801S.pdf).

Lamb, D. & Gilmour, D. 2003. *Rehabilitation and Restoration of Degraded Forests*. Issues in Forest Conservation. IUCN, Gland, Switzerland and Cambridge, UK and WWF, Gland, Switzerland. 110 pp. (also available at https://portals.iucn.org/library/sites/library/files/documents/FR-IS-005.pdf).

Lillesand, T. & Kiefer, R. 1994. *Remote sensing and image interpretation*. John Willey & Sons. Third edition. USA. 750 pp.

Liu, D. Xia, F. 2010. *Assessing object-based classification: advantages and limitations*. Remote sensing letters, 1: 187-194. (also available at https://www.researchgate.net/publication/233188285_Assessing_object-based_classification_Advantages_and_limitations).

Lund, G. 2009. *What is a degraded forest*. Paper on forest degradation definition prepared for FAO. (also available at https://www.researchgate.net/publication/280921178_What_is_a_degraded_forest).

Marmillod, D. 2012. *La red de parcelas permanentes de medición forestal en plantaciones forestales, bosques natural latifoliado y de coníferas de Guatemala. Diagnóstico del estado actual.* Tropical Agricultural Research and Higher Education Centre - CATIE. Turrialba. Costa Rica. 46 pp. (also available at http://repositorio.bibliotecaorton.catie.ac.cr/handle/11554/8668).

McDonald, T., Gann, G.D., Jonson, J. & Dixon, K. 2016. *International standards for the practice of ecological restoration – including principles and key concepts.* Society for Ecological Restoration, Washington, D.C. (also available at http://seraustralasia.com/wheel/image/SER_International_Standards.pdf).

McRoberts, R.E., Tomppo, E. & Czaplewski, R. 2015. *Knowledge Reference for National Forest Assessments.* Rome, FAO. 152 pp. (also available at http://www.fao.org/3/a-i4822e.pdf).

Méndez-Toribio, M., Martínez-Garza, C., Ceccon, E. & Guariguata, M. 2018. *La restauración de ecosistemas terrestres en México: Estado actual, necesidades y oportunidades.* Occasional papers. 185. Bogor, Indonesia, CIFOR.

Milla, F., Diaz, R. & Emanueli, P. 2014. *Inventario Forestal Multipropósito de la República Dominicana. 2014-2015. Elementos de planificación y protocolo para las operaciones de medición.* REDD/CCAD-GIZ Regional programme. Dominican Republic. 67 pp. (also available at https://www.researchgate.net/publication/312072381_Inventario_Nacional_Forestal_Multiproposito_de_Republica_Dominicana_2014-2015_Elementos_de_Planificacion_y_Protocolo_para_las_Operaciones_de_Medicion).

Millennium Ecosystem Assessment. 2003. *Ecosystem and Human Well-Being. A framework for assessmen*t. Island press. Washington DC. 245 pp. (also available at https://pdf.wri.org/ecosystems_human_wellbeing.pdf).

Ministry of Environment and Sustainable Development of Colombia (MADS). 2015. *Plan Nacional de Restauración: restauración ecológica, rehabilitación y recuperación de áreas disturbadas.* By: Ospina Arango, Olga Lucia; Vanegas Pinzón, Silvia; Escobar Niño, Gonzalo Alberto; Ramírez, Wilson; Sánchez, **&** John Jairo Bogotá. Colombia. 92 pp.(also available at https://www.minambiente.gov.co/images/BosquesBiodiversidadyServiciosEcosistemicos/pdf/plan_nacional_restauracion/PLAN_NACIONAL_DE_RESTAURACI%C3%93N_2.pdf).

Ministry of Environment and Sustainable Development of the Nation of Argentina. 2019. *Segundo Inventario Nacional de Bosques Nativos: Manual de campo.* Buenos Aires, Argentina. 76 p.

Ministry of Environment of Ecuador (MAE). 2013. *Metodología para determinar la relación gente - bosque.* MAE. Quito. 100 pp. (also available at https://www.ambiente.gob.ec/wp-content/uploads/downloads/2012/10/Metodologia-para-el-desarrollo-del-estudio-piloto-de-la-ENF.pdf).

Monge, R., Ramirez, C., Hamilton, R., Calvo, M., Soto, X., Acevedo, H. & Vargas, M. 2020. Desarrollo del Sistema Nacional de Monitoreo de Cobertura y Uso de la Tierra y Ecosistemas. SIMOCUTE. *Revista Ambientico.* 273: 6-15. (also available at http://www.ambientico.una.ac.cr/pdfs/art/ambientico/273_6-15.pdf).

Morales-Barquero, L., Skutsch, M., Jardel-Peláez, E., Ghilardi, A., Kleinn, C. & Haley, J. 2014. Operationalizing Forest Definition of Forest Degradation for REDD+, with application to Mexico. *Forest*, 2014. 15, 1653-1681. (also available at https://www.mdpi.com/1999-4907/5/7/1653).

National Committee for Ecological Restoration of Chile (CNRE). Undated. *Documento Marco para la Restauración Ecológica.* 39 pp. (also available at https://restauracionecologica.mma.gob.cl/wp-content/uploads/2018/01/Documento_Marco_Restauracion_Ecologica.pdf).

National Forest Institute of Guatemala (INAB) & National Council of Protected Areas of Guatemala (CONAP). 2015. *Mapa de cobertura forestal por tipo y subtipo de bosques para la República de Guatemala, 2012.* Guatemala. Technical report. 26 pp

National Forest Institute of Guatemala (INAB) & National Council of Protected Areas of Guatemala (CONAP). 2020. *Marco metodológico para el segundo ciclo del inventario forestal nacional de Guatemala*. Guatemala. 36 pp. (also available at http://www.sifgua.org.gt/Documentos/Cobertura%20Forestal/Cobertura%202012/Informe_de_Cobertura_Forestal_20_julio_15.pdf).

National Forest Institute of Guatemala (INAB). 2002. *Clasificación de Tierras por capacidad de uso. Aplicación de una metodología para tierras de la república de Guatemala*. 51 pp. (also available at http://portal.inab.gob.gt/images/centro_descargas/manuales/Clasificaci%C3%B3n%20de%20tierras%20por%20capacidad%20de%20uso.pdf).

National Forestry Commission of Mexico (CONAFOR). 2009. *Metodología del Inventario Nacional Forestal y de Suelos 2004-2009*. CONAFOR. Mexico. (also available at https://www.snieg.mx/DocumentacionPortal/iin/acuerdo_3_X/metodologia_del_INFyS_2.pdf).

National Forestry Institute of Nicaragua (INAFOR). 2009. *Resultados del Inventario Forestal Nacional. 2007-2008. 2ª edición*. FAO Technical Cooperation Project. INAFOR, Managua. 232 pp. (also available at https://cambioclimatico.ineter.gob.ni/bibliografia/Mitigacion%20del%20cambio%20climatico/Informe%20Final%20inventario%20forestal.pdf).

National System of Conservation Areas of Costa Rica (SINAC). 2015. *Inventario Nacional Forestal de Costa Rica 2014-2015: restuladados y caracterización de los recursos forestales*. SINAC, San José. 380 pp.

Olofsson, P., Arevalo, P., Espejo, P., Green, C., Lindquist, E., McRoberts, R. & Sanz, M. 2020. Mitigating the effects of omission errors on area and area change estimation. *Remote Sensing of Environment*. 236:1-9. (also available at https://www.mdpi.com/2072-4292/12/15/2438/html).

Olofsson, P., Foody, G., Herold, M., Stehman, S., Woodckok, C. & Wulder, M. 2014. Good practices for estimating area and assessing accuracy of land change. *Remote Sensing of Environment* 148(2014) 42-57. (also available at http://reddcr.go.cr/sites/default/files/centro-de-documentacion/olofsson_et_al._2014_-_good_practices_for_estimating_area_and_assessing_accuracy_of_land_change.pdf).

Paganini, M., Petiteville, I., Ward, S., Dyeke, G., Steventon, M., Harry, J. & Kerblat, F. 2018. *Satellite Earth Observations in support of the sustainable development goals*. European Space Agency. (also available at http://eohandbook.com/sdg/files/CEOS_EOHB_2018_SDG.pdf).

Peruvian Forest Service (SERFOR). 2016. *Marco metodológico del Inventario Nacional Forestal y de Fauna Silvestre del Perú*. SERFOR, Peru. 61 pp. (also available at http://www.serfor.gob.pe/portal/wp-content/uploads/2017/02/MARCO%20METODOLOGICO%20DEL%20INFFS.pdf).

Planet Labs Inc. 2021. *Welcome to Norway's International Climate and Forest Initiative Imagery Program!* [online]. [Cited on 16 March 2021]. https://www.planet.com/nicfi/

Ramírez, C. & Rodas, R. 2004. *Evaluación Nacional Forestal: Inventario Nacional Forestal de Guatemala 2002-2003*. FAO Technical Cooperation programme. Guatemala. 131 pp. (also available at http://www.fao.org/forestry/23224-015b0b120eb03aa8b646ce6e3095c7a6a.pdf).

Ramirez, C. & Salgado, J. 2006. *Evaluación Nacional Forestal: Resultados del inventario de bosques y árboles 2005-2006, Honduras*. State Forestry Administration – Honduran Forestry Development Corporation, Honduras. 85 pp.

Reytar, K., Martin, O., Landsberg, F., Ray, S., Granizo, C., Zamora, R., Duraisami, M., CB, K., Woldemariam, T., Stolle, F., Arakwiye, B., Curtois, A.M., d'Annunzio, R. & Finegold, Y. 2021. *Mapping Together. A guide to Monitoring and Landscape Restoration Using Collect Earth Mapatons*. FAO and WRI. (also available at https://www.wri.org/publication/mapping-together-monitor-forest-landscape-restoration).

Ruiz-Jaen, M. & Aide, M. 2016. Restoration success: How is it being measured? *Restoration Ecology*. Vol 13, 3, 569-577.

Schepaschenko, D., See, L., Lesiv, M., Bastin, J.F., Mollicone, D., Tsenbazar, N.E., MacCallum, I., Laso, J. Baklanov, A., Perger, C., Dürauer, M. & Fritz, S. 2019. Recent advances in Forest Observation with Visual Interpretation of Very-High resolution imagery. *Surveys in Geography*. (also available at https://link.springer.com/content/pdf/10.1007/s10712-019-09533-z.pdf).

Schoene, D., Kilman, H., von Lupke, H. & Loyche-Wilkie, M. 2007. *Definitional issues related to reducing emissions from deforestation in developing countries*. Forest and Climate Change Working Paper No. 5. Rome, FAO. (also available at http://www.fao.org/3/j9345e/j9345e00.htm#TopOfPage).

Seghal, J. & Abrol, I. 1992. *Land Degradation Status. Desertification control bulletin*. United Nations Environment Programme. No. 21. 1992.

Sijapati Basnett, B., Elias, M., Ihalainen, M. & Paez Valencia, A.M. 2017. *Gender matters in Forest Landscape Restoration: A framework for design and evaluation*. Center for International Forestry Research (CIFOR), Bogor, Indonesia.(also available at https://www.cifor.org/library/6685/gender-matters-in-forest-landscape-restoration-a-framework-for-design-and-evaluation/).

Simula, M. 2009. *Towards defining forest degradation: comparative analysis of existing definitions*. Forest Resources Assessment Working Paper 154. Rome, FAO. (also available at http://www.fao.org/3/i2479e/i2479e.pd).

Sinchi Amazonic Institute of Scientific Research. Undated. *Red de parcelas permanentes*. Amazonic Institute of Scientific Research. Colombia. [online]. [Cited on 15 February 2021] https://sinchi.org.co/coah/red-de-parcelas-permanentes.

Society for Ecological Restoration (SER) Australasia. Undated. *Appendix 1 Relationship of ecological restoration to other environmental repair activities*. SER. (also available at http://www.seraustralasia.com/standards/appendix1.html).

Society for Ecological Restoration (SER). 2004. *The SER international primer on ecological restoration*. Science & Policy Working Group (Version 2: October 2004). SER, Washington, DC.

The Global Partnership on Forest Landscape Restoration (GPFLR). 2011. *A World of Opportunity*. World Resources Institute, South Dakota State University and IUCN. By S. Minnemeyer, L., Laestadius, N. Sizer, C. Saint-Laurent & P. Potapov. (also available at http://pdf.wri.org/world_of_opportunity_brochure_2011-09.pdf).

Tomppo, E. Gschwantner, T. Lauwrence, M. & MacRoberts, R.E. eds. 2010. *National Forest Inventories: pathways for common reporting*. Springer. London. 609 pp.

Thompson, I.D., Guariguata, M.R., Okabe, K., Bahamondez, C., Nasi, R., Heymell, V. & Sabogal, C. 2012. An operational framework for defining and monitoring forest degradation. *Ecology and Society* 18 (2): 20. (also available at http://dx.doi.org/10.5751/ES-05443-180220).

UN Women, Global mechanism of the UNCCD & UICN. 2019. *A manual for gender-responsive land degradation neutrality transformative projects and programmes*. (also available at https://www.unwomen.org/-/media/headquarters/attachments/sections/library/publications/2019/manual-for-gender-responsive-land-degradation-neutrality-transformative-projects-en.pdf?la=en&vs=2328).

United Nations Educational, Scientific and Cultural Organization (UNESCO). 2017. *A guide for ensuring inclusion and equity in education*. UNESCO. Paris, France. 46 pp. (also available at https://unesdoc.unesco.org/ark:/48223/pf0000248254).

United Nations Framework Convention on Climate Change (UNFCCC). 2016a. *Conference of the Parties serving as the meeting of the Parties to the Paris Agreement*. (also available at https://unfccc.int/sites/default/files/resource/cma2021_02E.pdf).

United Nations Framework Convention on Climate Change (UNFCCC). 2016b. *Key decisions relevant for reducing emissions from deforestation and forest degradation in developing countries (REDD+). Decision booklet.* (also available at https://unfccc.int/files/land_use_and_climate_change/redd/application/pdf/compilation_redd_decision_booklet_v1.1.pdf).

United Nations Framework Convention on Climate Change (UNFCCC). 2021. *Conference of the Parties of the Twenty-second session, health in Marrakech*, 7-18 November 2016. (also available at https://unfccc.int/resource/docs/2016/cop22/eng/02.pdf).

United Nations Framework Convention on Climate Change (UNFCCC). Undated. *Introduction to gender to climate change.* [online]. [Cited on 15 February 2021]. https://unfccc.int/genderr

United Nations General Assembly (UNGA). 2012. *The future we want.* Resolution A/RES/66/288. (also available at https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_66_288.pdf).

United Nations. 2017. *New York Declaration on Forest. Declaration and Action.* Climate Summit, 214. List of endorsers updated in July, 2017. [online]. [Cited on 10 February 2021] https://forestdeclaration.org/

United Nations. 2019. General Assembly. United Nations Decade on Ecosystem Restoration (2021-2030). Seventy-third session. Resolution 73/284. 6 March 2019. (also available at https://undocs.org/pdf?symbol=en/A/RES/73/284).

Veljanovski, T., Kanjir, U. & Ostir, K. 2011. Object-based image analysis of remote sensing data. *Geodesnik vestnik*, 55: 665-687. (also available at https://www.researchgate.net/publication/275607328_Object-based_image_analysis_of_remote_sensing_data).

Vibrans, A., Sevegnani, L., de Gasper, A., Lingner D. & Sabbagh, S. 2010. *Inventario Floristico Florestal de Santa Catarina (IFFSC): Aspectos metodológicos e operacionais.* Pesquisa Florestal Brasileira. 30:291-302. (also available at https://www.florestal.gov.br/publicacoes-ifn/1767-folder-the-national-forest-inventory-in-santa-catarina).

Webb, J., Brewer, K., Daniels, N., Madeira, C., Hamilton, R., Finco, M., Megown, A. & Lister, A. 2012. *Image-based estimation for land cover and land use monitoring.* In: R.S. Morin and G.C. Liknes (comps.), *Moving from status to trends: Forest Inventory and Analysis (FIA) Symposium.* December 4-6, 2012. Baltimore, USA. Department of Agriculture, Forest Service, Northern Research Station. (also available at https://www.fia.fs.fed.us/sciencestakeholder/proceedings/pubs/2012_FIA_Proceedings-opt.pdf).

Westfal, J., Lister, A., Scott, C. & Weber, T. 2019. Double sampling for post-stratification in forest inventory. *European Journal of Forest Research.* (also available at https://link.springer.com/article/10.1007/s10342-019-01171-9?shared-article-renderer).

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Rome, Italy

ISBN 978-92-5-134820-8

CB6021EN/1/08.21