Food and Agriculture Organization of the United Nations

Towards the institutionalization of forest data: The importance of data management and sharing

global environment facility
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1. Introduction

Context

A National Forest Monitoring System (NFMS) is essential for countries to track their forests, collect forest information, and support sustainable forest management and transparency. Institutionalizing an NFMS involves establishing robust governance structures, legal frameworks, and collaborative mechanisms to ensure the consistent generation and use of reliable forest data. This enables countries to produce high-quality data, vital for effective resource management, environmental conservation, and informed policy development. Integral to this process is effective data management and sharing, which enhances the accuracy and accessibility of forest data within the NFMS framework.

The increasing prevalence of **digitalization** offers unique opportunities to transform and accelerate solutions for pressing global needs, and to build a more resilient future for agrifood systems. Globally, digitalization is advancing rapidly, and data sharing is crucial to realizing its full potential across various processes. In recent years, significant advances have been made in developing methods and approaches that facilitate data sharing, while also addressing the ethical considerations and promoting responsible use. The **advantages of digitalization** are faster access to information, increased productivity, lower operational costs and better decision-making and information security, as well as automation of business processes. However, it is important to address the challenges associated with this revolutionary innovation to enhance country ownership, produce reliable and transparent data, make better use of it and build capacities, particularly in developing nations (FAO, n.d.a.).

In effect, while monthly global data traffic is forecast to grow by more than 400 percent by 2026, activity is concentrated among a few global players (UN, 2023). Governments and research institutions, among others, are at risk of becoming mere providers of raw data while having to pay for the services that their data helps to produce.

Digital technologies have moved beyond the internet and mobile devices into autonomous intelligent systems and networks, generative artificial intelligence, virtual and mixed reality and distributed ledger technologies such as blockchain.

The wealth generated by these innovations is highly unequal, dominated by a handful of big platforms and states.

Better approaches to data production and management are encouraged to progressively deliver high-quality outcomes to all parties involved through effective data access and sharing, enhanced data governance and collaboration. These improvements may lead to informed decision-making, sound policy advice and robust data protection and privacy.

In the forest sector, the amount of data generated is considerable; data collection includes ***in situ* forest data**, through ground data acquisition, and ***ex situ* forest data**, through geospatial and remote sensing (FAO, 2024a).

Digitalization and **innovation** in the forest sector are both essential for securely storing forest data, monitoring forest trends in a timely manner, enhancing transparency, continuously informing policymaking, reducing disparities and improving the economic status of communities that depend on forests. However digital solutions in the forest sector often apply to isolated processes, while attempts to find general solutions for open data-sharing infrastructures are rare.

Overall, evidence of the transformative potential of digitalization for sustainable forest management emphasizes the need for further investment in digital infrastructures to boost productivity, inclusivity and environmental conservation (Barbarese *et al.*, 2024).

In this emerging context, data openness involving both data providers' and users' participation might also be part of the solution by promoting free access to publications, data, metadata, educational resources, software and source codes, accompanied by licensing that favours access, reuse and redistribution. Establishing clear roles and functions to access, use and manage data among data providers, users and relevant institutions is therefore paramount to promote trust, accountability and transparency related to data management and production.

Role of FAO in disseminating forest data worldwide

As the United Nations' specialized agency for food and agriculture, including forestry, the Food and Agriculture Organization of the United Nations (FAO) has a comprehensive mandate to address global food security and nutrition, poverty eradication and the sustainable management and use of natural resources.

As a leading international body dedicated to the sustainable management of the world's forests, FAO has long recognized the importance of accessible and reliable data in achieving its mission of halting deforestation and maintaining forests, restoring degraded lands and expanding agroforestry and sustainably using forests and building green value chains.

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Specifically, FAO's mandate includes (1) collecting, analysing and disseminating agrifood systems data from countries; (2) working with countries to develop national strategies, strengthening institutional and technical capacities and improving information systems; and (3) developing and promoting international food and agricultural standards, including methods and tools (FAO, n.d.b.).

Through publications and platforms, FAO disseminates data related to its area of work. Two notable examples in the forest sector are:

- The Global Forest Resources Assessment (FRA), which is the world's most comprehensive source of forest resource information. It provides insights into the extent, condition, management and uses of forest resources. The FRA offers a series of publications and an open platform available in six languages.
- The Food and Agriculture Microdata Catalogue (FAM), which publishes datasets from farm and household surveys covering agriculture, forests, food security and nutrition. The FAM catalogue disseminates metadata and relevant documentation in line with international standards. It serves as a one-stop shop for accessing forest-related microdata.

Purpose of this publication

This technical publication provides guidance for improving the accessibility and availability of high-quality forest-related data for private and public decision-making. It includes definitions and explains common challenges as well as factors for successful collaboration and integration to inform forest data management and data sharing.

Specifically, this publication offers government officials, researchers, members of non-governmental organizations, and community members ways to address different aspects of data sharing and data management in the forest sector, contributing to more informed and sustainable forest management worldwide. Case studies provide valuable country-specific examples that help navigate the complexities of global data sharing and data management.

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2. Definitions and common challenges related to data sharing and management

The development of technologies in the forest sector has transformed access to information for forest management by enhancing data collection. In many forest countries, these advances have allowed the development of a robust national forest monitoring system (NFMS). An **NFMS** comprises the people, institutions and resources that implement national forest monitoring at the country level in collaboration with other stakeholders (FAO, 2017). Historically, the general public has had limited access to this data, but the more recent trend is to make forest data available and accessible for multiple purposes.

An NFMS provides information on the status of forest resources, and this information can be used to inform the sustainable use and protection of forest resources. Thus, the NFMS has a key role in influencing policy- and decision-makers on forest-related matters. It also helps governments meet their national and international obligations related to forest monitoring. The NFMS relies on data collection, processing and sharing guided by the principles of FAO's *Voluntary guidelines on national forest monitoring* (FAO, 2017). **Open science** is a set of principles and practices that aim to make scientific research from all fields accessible to everyone for the benefit of scientists and society as a whole (UNESCO, n.d.). By fostering transparency, data sharing and collaboration, open science enhances the usability and credibility of NFMS data, ultimately supporting better-informed decision-making and international reporting. Open science is a key element of exploration, and it comprises a variety of elements, including **open access** and **open data**, among others. **Open data** refers to data that is available in a timely and user-friendly manner, in accordance with principles of good data governance and stewardship, known as FAIR principles: findable, accessible, interoperable and reusable (Wilkinson *et al.*, 2016).


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Forest data sharing can be defined as the process of making an organization's or institution's forest data available to multiple users, applications and other organizations or institutions for responding to private and public needs. Effective data sharing involves a combination of technologies, practices, and legal and institutional settings as well as organizational efforts to facilitate secure access to consistent data for multiple entities without compromising data integrity and ethical and responsible use considerations.

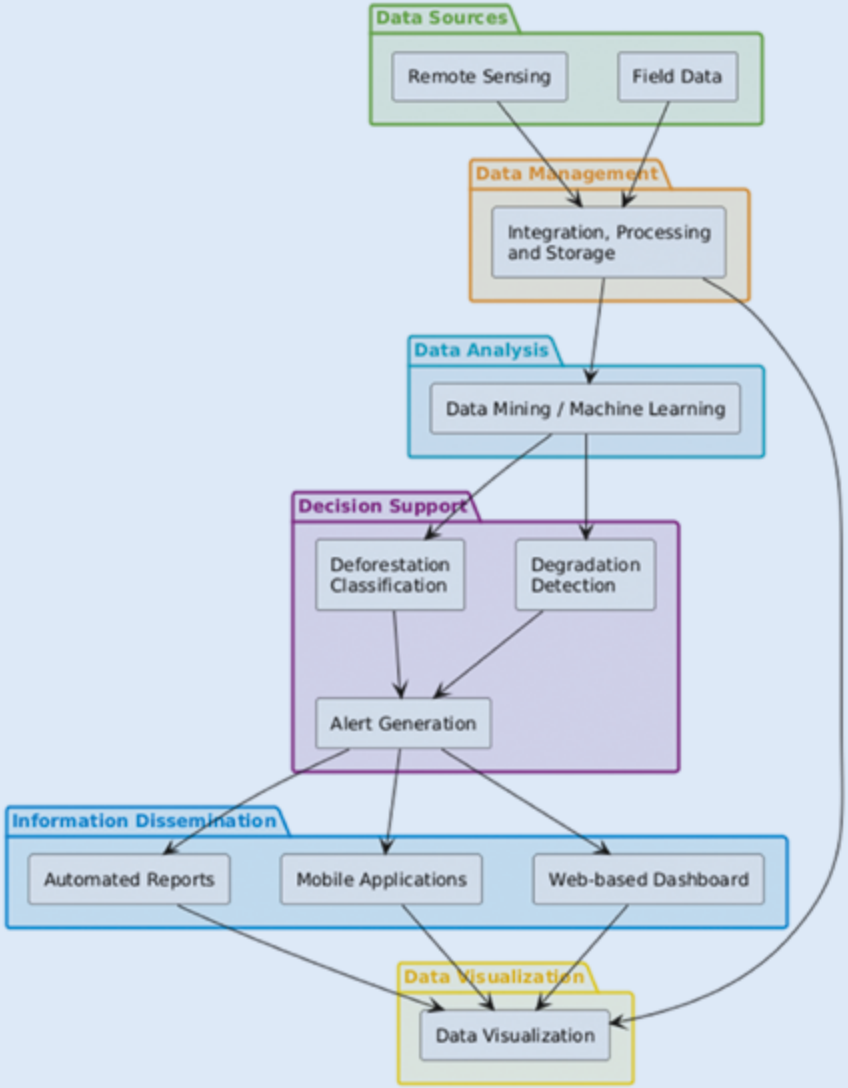
Forest data can be shared between forest-related institutions to facilitate informed decisions and policymaking and enhance transparency. Forest data can also be shared between forest institutions and public or private users to foster knowledge sharing for different needs (academia, research, knowledge generation, analytical, statistics, etc.). It also includes sharing data globally through dissemination platforms such as the FRA platform and the FAM catalogue.

Sharing data requires a commitment to preserving its integrity and reliability throughout its life cycle, ensuring it remains trustworthy, coherent and useful for accurate analysis. Effective data sharing enables stakeholders to gain valuable insights, develop policy, generate new services and technologies, and anticipate future trends (e.g. deforestation and degradation) by analysing extensive data from both inside and outside the institution and making it available under certain conditions.

Combining data from various sources, such as *ex situ* (e.g. satellite images, visual interpretation) and *in situ* forest data collection improves data quality and facilitates cross-check analysis.

As an example, **Figure 1** shows the key role of technology in informing the entire process outlining a deforestation monitoring system. It goes from data collection, data management and analysis, which are fundamental to informed decision-making, to the dissemination of forest information.

FIGURE 1. Example of the role of technology in informing a deforestation monitoring system



Source: Modified from Damaševičius, R., Mozgeris, G., Kurti, A. and Maskeliūnas, R. 2024. Digital transformation of the future of forestry: An exploration of key concepts in the principles behind Forest 4.0. Frontiers in Forests and Global Change, 7: article 1424327.

To allow effective forest data sharing, several challenges still need to be addressed (see Box 1):

- limited awareness of open science principles and methods and insufficient training to address this gap;
- limited human capacities within forest institutions to deal with forest data sharing;
- mistrust in data sharing both internally and externally and among colleagues within an institution;
- defensive culture of data sharing, characterized by a general reluctance to share data or willingness to share only the minimum amount because the data may be sensitive (e.g. spatial coordinates) or subject to commercial uses. Some tensions might emerge between the right to information and the right to privacy in relation to collection, storage methods, access and use of forest data (Rantala *et al.*, 2020);
- absence or weakness of internal organizational policies on data sharing, leading to fragmentation in the production of forest data;
- fragmented responsibilities among various institutions with specific mandates and differing inter- and intra-institutional functions at various scales which affects decision-making regarding the management, use and sharing of forest data;
- poor data management practices, including a lack of central repositories that allow for data tracking and inconsistency over time in ensuring analysis and quality assurance or quality control; and
- increased need for financial resources and infrastructure required for the implementation.

BOX 1. Case study: Uganda

Uganda overcame challenges related to lack of institutional coordination, informality and limited capacities nationally by establishing a protocol for sharing forest data, and globally by sharing data through the Food and Agriculture Microdata (FAM) catalogue.

Sharing data nationally

Coordination between various institutions involved in the national forest monitoring system remains a challenge, despite formal agreements such as the memorandum of understanding between the Climate Change Department and the National Forest Authority. To overcome this challenge, the country aims to develop a standardized framework to improve the collection, management and dissemination of forest-related data. In addition, a formal data-sharing protocol will be developed by means of:

- a detailed diagnosis of each institution or department involved;
- discussions among all data providers to establish a cohesive structure for managing data across its life cycle;
- agreements on data sharing and documentation of procedures to operationalize the data-sharing protocol; and
- institutions reviewing their operations and making necessary adjustments to ensure alignment with the newly established data-sharing framework.

Sharing data internationally (FAM catalogue)

Uganda was the first tropical country to openly share the metadata, microdata and relevant documentation of its national forest inventory (called the National Biomass Survey). Since 2021 its data has been accessible through the FAM catalogue, which features a dedicated section for forest inventory microdata. This milestone highlights Uganda's commitment to transparency in forestry data. The National Biomass Survey data is now available for anyone to use in monitoring and evaluation, tailoring programmes and interventions, and tracking important trends.

Notes: For more information, see National Biomass Study, 2016–2019.

3. Factors to strengthen data management and sharing

This section shares evolving and innovative approaches to foster successful data management and sharing, and to overcome challenges described in the previous section

Data quality

High-quality forest-related data is a cornerstone of effective decision-making, whether for public policy or private initiatives. To ensure such data is reliable and actionable, there must be consistency in how data is acquired. When data collection methods are consistent, there are fewer errors and datasets become more comparable across different sources and time periods.

A key step in fostering consistency is the development and adoption of **standard protocols** for data collection. These should provide clear, detailed guidance on measurement techniques, sampling strategies, and the use of specific tools or equipment. For instance, establishing uniform methods for measuring tree diameter or height, or identifying species taxonomies can help eliminate discrepancies that often arise when different organizations or individuals collect data independently.

To that effect, those responsible for data collection should be well trained and equipped to follow these protocols. Comprehensive **training programmes** can help field personnel understand not only the technical aspects of data collection but also the broader importance of accuracy and precision. When everyone involved in the process shares a common understanding of best practices, inconsistencies decrease significantly. Meanwhile, tools such as mobile data collection apps, GPS devices and remote sensing technologies can reduce human error and streamline data acquisition. By integrating these technical solutions into standardized workflows, organizations can ensure that data is collected uniformly regardless of who is conducting the fieldwork.

Implementing regular audits and quality checks maintain *consistency over time*. This helps identify and address any deviations from established protocols so that data collection remains aligned with best practices. Ideally, quality control measures should be applied at every stage, from fieldwork through data entry, management and processing, to safeguard data integrity.

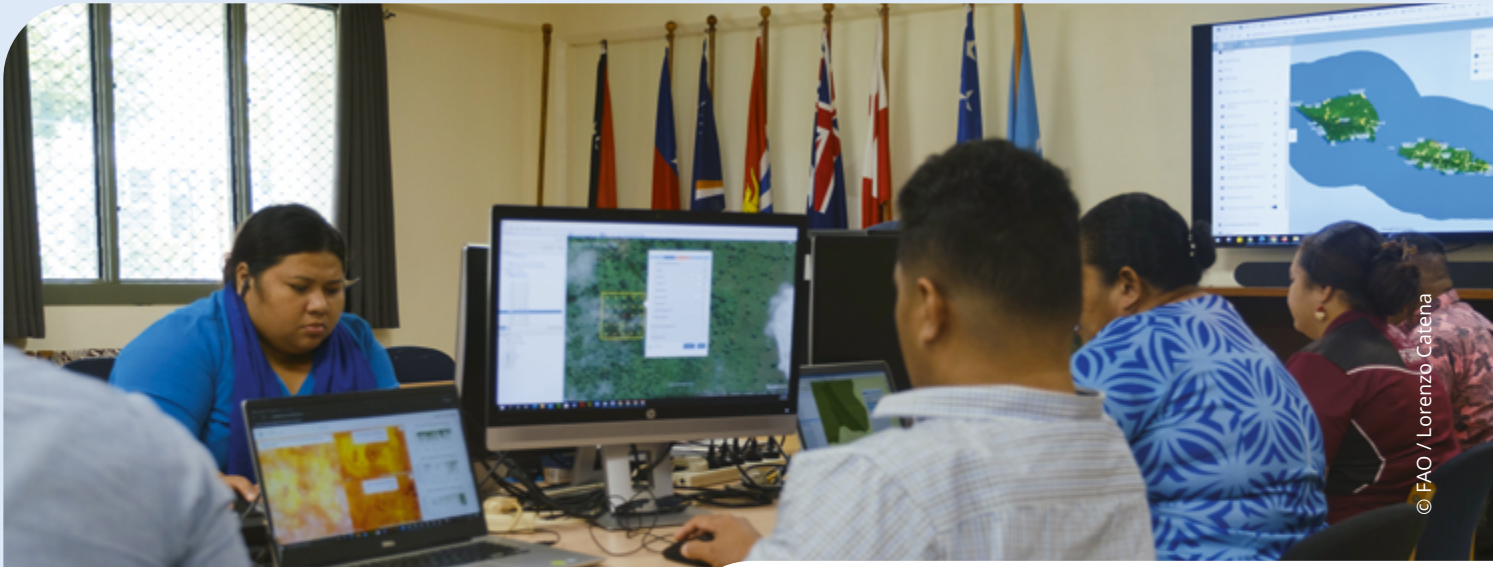
By prioritizing consistency in data acquisition, both data providers and users can significantly improve the quality of forest-related data. This in turn supports more accurate analyses, better-informed decisions and more effective forest management and conservation. Consistent, high-quality data is thus both a technical requirement and the foundation for achieving the broader goal of making forest data more accessible and available for decision-making.

Data management

Effective forest data management involves acquiring, validating, storing, protecting and processing data to ensure its reliability, accessibility, and timeliness. This process is essential for an NFMS to provide accurate and actionable information for decision-makers. Beyond raw data, management also applies to processed information, ensuring transparency and reproducibility in data analysis and reporting.

A key principle of forest data management is to **store all collected data in its original form**. This safeguards data integrity, allowing calculations to be reproduced from the raw database. Retaining original data also supports error detection during validation and analysis, ensuring that inconsistencies can be traced back to their source.

The use of **structured databases** enables efficient organization of diverse data types, including **inventory records** (e.g. field measurements, laboratory data), photos and videos, quality control data, **geospatial maps** (e.g. forest cover, deforestation trends), and **reference documents** (e.g. field manuals, reports). **Remote sensing imagery**, such as satellite images and drone and LiDAR data, may also be integrated into such databases where applicable. However, many countries and organizations may access and use remote sensing materials hosted in the cloud or provided by external service providers (e.g. Google, Planet Labs), which may not necessitate direct storage in the same database.



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Databases must be designed for **interoperability, scalability and adaptability**, ensuring they can integrate different data formats and remain functional as technology advances. NFMSs rely on structured data flows linking raw data to processing and final reporting. A standard NFMS management framework is presented in **Box 2**.

BOX 2. Data management framework for a national forest monitoring system

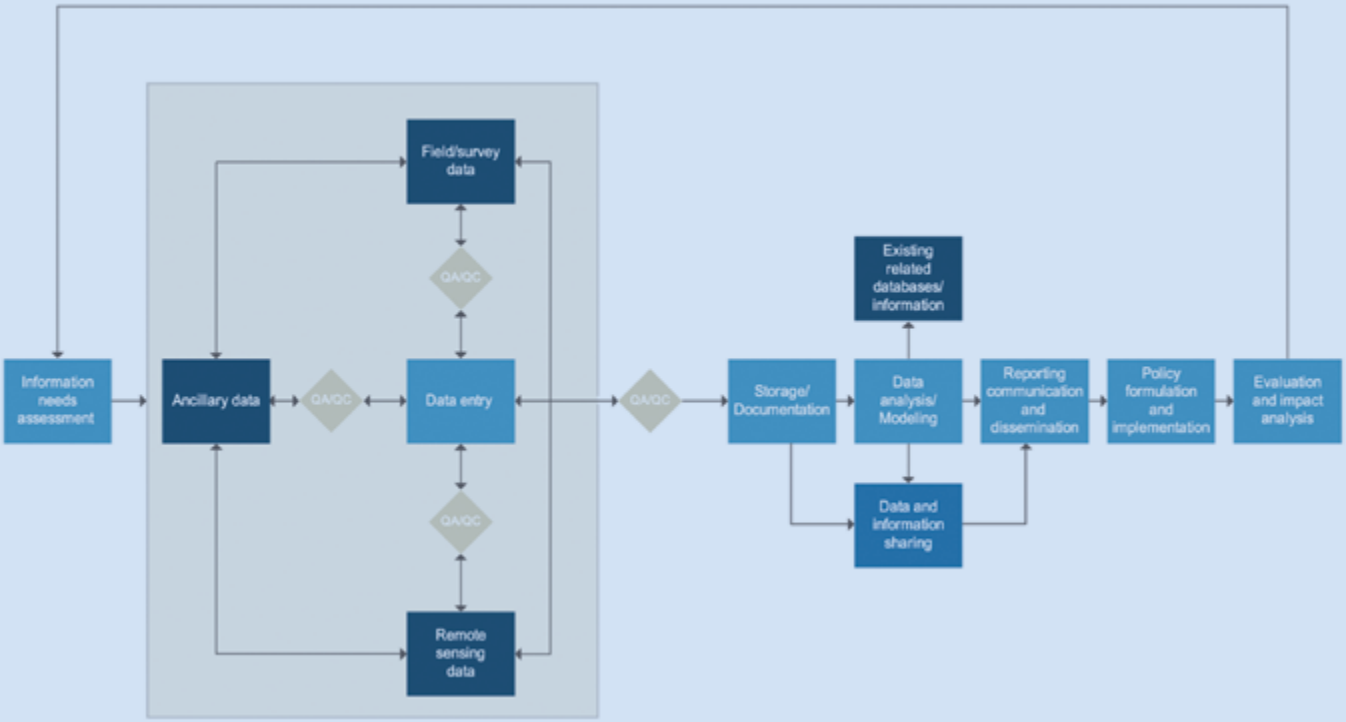
The Voluntary guidelines on national forest monitoring (FAO, 2017) highlight a typical flow of information from data collection to policy evaluation (see **Figure 2**). The process begins with an **information needs assessment**, which defines objectives and data requirements. This informs the collection of **field or survey data, remote sensing data** and **ancillary data**, which are essential inputs. These datasets undergo **quality assurance or quality control** to ensure accuracy before they are integrated into the system through **data entry**. This phase ensures that data from multiple sources is harmonized and structured for further use.

Once data is entered and validated, it moves to **storage and documentation**, where it is securely archived and made accessible for analysis. The **data analysis and modelling** phase processes this information, integrating insights from **existing related databases or information** to enhance its comprehensiveness. This step supports **data and information sharing**, ensuring that stakeholders can access and use the processed information for informed decision-making. The analysed data then progresses to **reporting, communication and dissemination**, where findings are shared with relevant authorities, organizations and policymakers.

The final stage involves **policy formulation and implementation**, where the insights derived from the national forest monitoring system inform strategic decisions and forest management policies. The effectiveness of these policies is then assessed through **evaluation and impact analysis**, closing the loop by providing feedback to refine and improve future monitoring efforts. Throughout this framework, robust quality assurance or quality control procedures and data integration ensure that outputs remain reliable, transparent and actionable for sustainable forest management and climate action.

Sources: FAO. 2017. Voluntary guidelines on national forest monitoring. Rome.
https://openknowledge.fao.org/server/api/core/bitstreams/d020c63f-2e61-4b1c-a238-4b8c49d0833a/content

FIGURE 2. Typical flow of information from data collection to policy evaluation



Note: QA/QC = quality assurance or quality control

Source: FAO. 2017. Voluntary guidelines on national forest monitoring. Rome. https://doi.org/10.4060/i6767en

FAO launched Open Foris, a suite of free and open-source software platforms designed to help countries measure, monitor and report on forestry progress. Open Foris is founded on the principle that innovative, accurate and transparent forest monitoring is essential to unlocking the full potential of forests for climate action and the many other benefits that forests provide. It provides robust solutions for field data collection, data management, visual interpretation and geospatial analysis, empowering countries to make informed, data-driven decisions for sustainable forest management. **Open Foris Arena** is a powerful solution that supports effective forest monitoring, data collection, data management and analysis, strengthening NFMSs (see **Box 3**).

BOX 3. Open Foris Arena

Open Foris Arena focuses on streamlining data management processes, ensuring that data is collected consistently, stored securely and made accessible for analysis and decision-making by providing versatility through different user levels. The platform supports a wide range of activities, from field data collection using mobile devices to some basic integration of remote sensing data and the generation of comprehensive reports. The tool, together with other Open Foris companion tools, is aligned with the needs of a national forest monitoring system (NFMS), and enables countries to design and implement a robust NFMS that adheres to international guidelines.

Arena emphasizes collaboration and capacity building through training resources and ensures that stakeholders at all levels, from field technicians to policymakers, can effectively contribute to and benefit from the data management process.

Arena thus exemplifies how integrated data management solutions can enhance the quality and accessibility of forest data, supporting both national and global efforts to monitor and manage forest resources sustainably. By leveraging tools like Open Foris, countries can strengthen their NFMS and contribute to more informed decision-making for forest conservation and climate action.

Notes: For more information, see https://openforis.org/solutions/arena/

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Data access

Enhancing data access is crucial for advancing technological innovation, developing digital public goods and improving forest-related data. Equitable and inclusive access to data enables evidence-based analysis and decision-making and fosters transparency and accountability in forest management.

Effective data access involves managing permissions to ensure that only authorized individuals can access certain data, thereby maintaining data confidentiality, integrity and availability. Forest data should be categorized based on access levels to balance transparency and security: **open access** (freely available to promote public and scientific use), **restricted access** (accessible under specific conditions to protect sensitive information), and **closed access** (limited to authorized users to ensure confidentiality). Establishing **clear access policies** ensures that transparency does not compromise privacy or legal requirements. These policies should align with international best practices and address the specific needs of forest data management.

In recent years, significant progress had been made globally to enhance the openness and accessibility of data, information and knowledge while ensuring best practices for their management. FAO has been at the forefront of these efforts, implementing policies and initiatives to promote open access and robust data governance.

In 2018, FAO launched its Open Access Policy, which guarantees immediate, irrevocable, and free online access to all FAO publications, articles published in non-FAO publications, and statistical databases. Building on this, FAO expanded its open access and licensing policy in 2020 to include all statistical data disseminated through its corporate databases. Further advancing its commitment to data governance, FAO introduced a Data Protection Policy in 2022 (FAO, 2022a). This policy establishes principles for managing and protecting data throughout its life cycle – from collection and processing to deletion.

These efforts by FAO not only strengthen global data access but also serve as a model for national and regional initiatives aiming to improve forest data sharing and management. By aligning with FAO's principles and practices, countries can enhance their data access frameworks, ensuring that forest data is both accessible and secure.

For an example of a platform facilitating data access, see **Box 4** on FAO's FAM catalogue.

BOX 4. FAO's Food and Agriculture Microdata catalogue

As of February 2025, the Food and Agriculture Microdata (FAM) catalogue had published **1 441 surveys across 187 countries** and over **564 000 variables**, covering agriculture, forests, food security, and nutrition. It enables researchers, policymakers, and stakeholders to access high-quality microdata with ease, enhancing both credibility and accessibility.

Since 2020, the FAO Forestry Division, through the FAO and Global Environment Facility project "Building global capacity to increase transparency in the forest sector (CBIT-Forest)" has worked closely with countries to populate the Forest Inventory Data collection in the FAM catalogue (FAO, 2022b).


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See this collection for data, metadata and microdata from Bangladesh, Brazil, Guatemala, Lao People's Democratic Republic, Mexico, Mongolia, Nepal, Peru and Uganda.

Among some of the benefits and suggestions to maximize the use of forest microdata are:

- transparent and accessible forest data for informed decision-making
- project development support and funding opportunities
- maximize visibility of forest data to ensure return on investment
- enhanced sustainability and reduced risk of data loss
- identification of data gaps and scope for development
- resource optimization and cost reduction
- collaboration among different entities
- national and international reporting needs and data credibility.

Notes: Learn more here: Transparency in agriculture and forest microdata

Source: FAO. 2022b. Towards open and transparent forest data for climate action: Experiences and lessons learned. Rome. https://doi.org/10.4060/cb8908en

Data platforms

The creation of data platforms has become a prevalent method for data sharing and demonstrates collaborative governance. Data platforms are technology solutions that enable the collection, storage, cleaning, transformation, analysis and governance of data (Holdsworth and Kosinski, 2024). These **web-based** infrastructures provide a wide range of data to various stakeholders, fostering collaboration and informed decision-making. Some examples of data platforms are provided in **Box 5**.

BOX 5. Case study: Lao People's Democratic Republic

Lao People's Democratic Republics data platform is hosted by the Forestry Inventory and Planning Division and managed by its Remote Sensing/ Geographic Information System Unit. It stores the necessary data for NFMS measurement, reporting and verification and monitoring functions, including:

- satellite imagery
- forest type maps
- national forest inventory data
- ground truthing and other survey data
- forest categories and concession boundaries.

The platform offers access to information on forest cover changes, emissions, removals and projects and is available at https://nfms.maf.gov.la/

Ensuring financial and human capacities to manage those platforms, along with instituting clear coordination mechanisms based on well-established arrangements, is essential to their success.

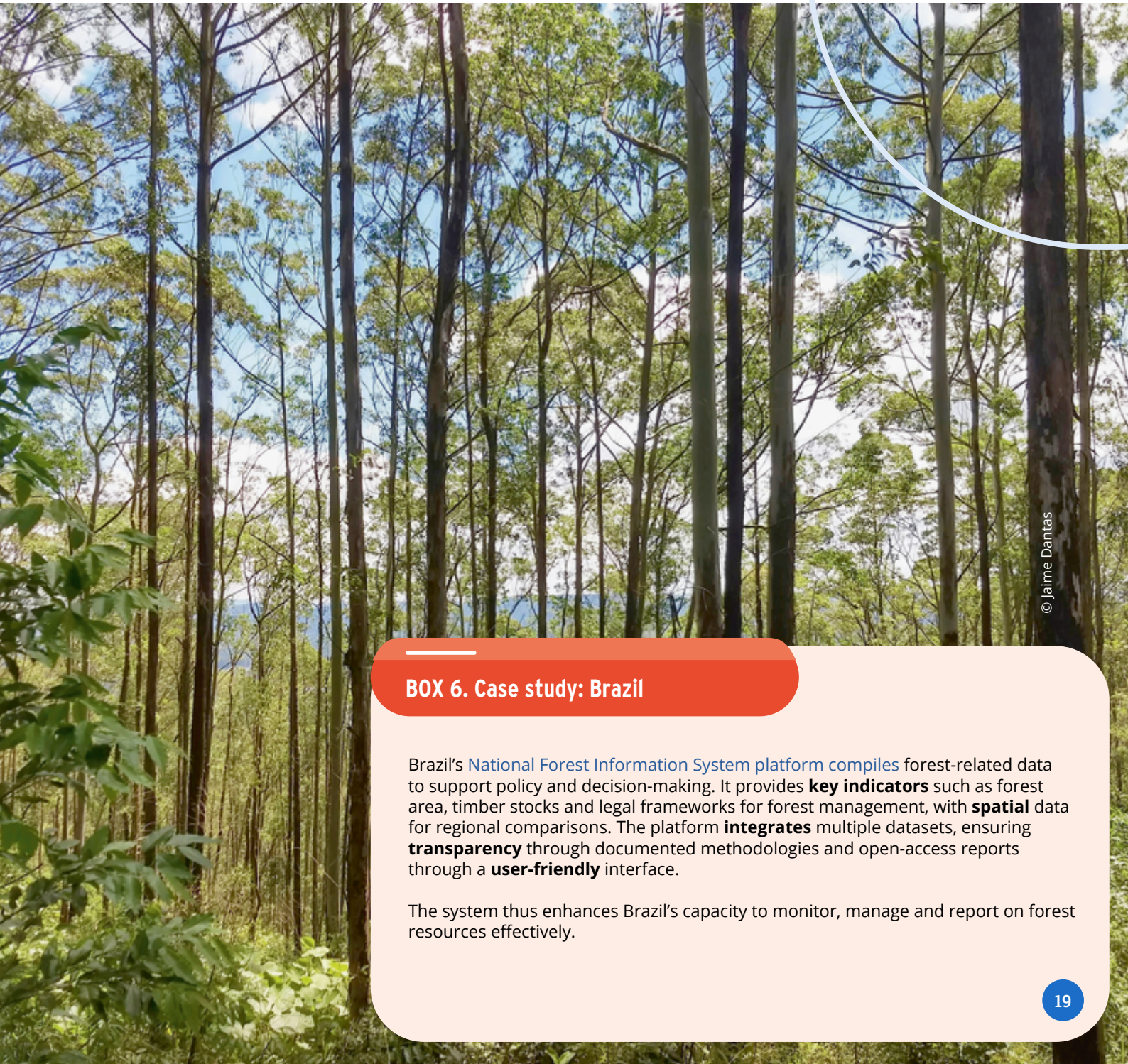
Effective data platforms for the public dissemination of forest data and results should meet several key criteria to ensure that the data is accessible, understandable and actionable for diverse users, including policymakers, researchers, local communities and the general public.

Below are some essential criteria for such platforms:

- **Data clarity and accuracy.** Present up-to-date data clearly and accurately, using intuitive visualizations and search tools. Tailor data presentation to the audience, ensuring accessibility for non-experts and detailed metadata for advanced users.
- **Key metrics and indicators.** Include critical forest-related metrics (e.g. forest cover, carbon stocks, biodiversity), standardized to international frameworks when needed for comparability.
- **Spatial and temporal resolution.** Provide data with appropriate resolution, enabling analysis of trends over time and across regions through maps, time series and comparison tools.
- **User friendliness.** Offer an intuitive interface, customizable options and accessibility features to accommodate users with varying technical expertise.
- **Data integration.** Support integration of diverse datasets (tabular and spatial) to enable comprehensive analysis, linking forest data with socioeconomic or climate data.
- **Transparency and accountability.** Adhere to FAIR principles and provide detailed documentation on data provenance, methodologies and quality assurance.
- **Policy relevance.** Ensure data outputs align with policy needs, supporting monitoring, evaluation and reporting processes at local, national and global levels.
- **Security and privacy.** Implement secure data storage and access protocols, anonymizing sensitive information (e.g. Indigenous communities, private landowners) to protect privacy.
- **Clear terms of use and licensing.** Provide transparent terms of use and distribution licences to clarify data access, sharing and reuse.
- **Financial and institutional sustainability.** Establish a sustainable business model or funding source to ensure long-term maintenance, updates and user support.

By meeting these criteria, data platforms can enhance forest data sharing, foster collaboration, and support evidence-based decision-making globally.

As an example, **Box 6** shows how the criteria have been applied in Brazil.



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BOX 6. Case study: Brazil

Brazil's National Forest Information System platform compiles forest-related data to support policy and decision-making. It provides **key indicators** such as forest area, timber stocks and legal frameworks for forest management, with **spatial** data for regional comparisons. The platform **integrates** multiple datasets, ensuring **transparency** through documented methodologies and open-access reports through a **user-friendly** interface.

The system thus enhances Brazil's capacity to monitor, manage and report on forest resources effectively.

Building trust and accountability

Trusted data is valuable data. To address data trust issues, it is crucial to consider the entire *data value chain*, from identifying data needs to data release, use and impact. Trust is essential at every stage, and building it requires adherence to ethical and quality principles.

For data to be trusted, it must be:

- **Free from political interference.** Data should be collected, processed and shared without bias or manipulation, ensuring independence and objectivity.
- **Representative of all individuals in society.** Data should reflect the diversity of populations and ecosystems, avoiding exclusion or misrepresentation of marginalized groups.
- **Relevant and responsive to users' needs.** Data should address the priorities and requirements of diverse stakeholders, including policymakers, researchers and local communities.
- **Freely accessible, usable and reusable.** Data should be accompanied by adequate metadata and documentation, ensuring transparency and enabling users to understand, interpret and reuse the data effectively. This aligns with the FAIR principles, which are critical for building trust.
- **Effectively use for maximum value and impact.** Data should be applied to inform decisions, policies and actions, demonstrating its practical relevance and societal benefits.

Data producers (e.g. institutions, local communities, non-governmental organizations) play a key role in building trust by making data easy to find, providing clear guidance for its use and ensuring robust metadata and documentation. Equally, citizens contribute significantly to improving data accessibility, usability and even production through initiatives like citizen science, which enhance data quality and inclusivity while fostering public engagement.

By adhering to these principles and involving diverse stakeholders, trust in forest data can be strengthened, ensuring its credibility and impact for sustainable forest management.

While misuse of data is often cited as a reason to restrict access, it is important to distinguish between regulations that protect privacy, address ethical and responsible use considerations, and ensure transparency, and those that unnecessarily limit access.

Special consideration must be given to sensitive data, such as personally identifiable information, locations of sensitive species, or plots located on private grounds. For example, if exact coordinates of commercially valuable or threatened species are disclosed, data users could exploit this information for overharvesting or other harmful activities. Therefore, it is essential to provide only approximate locations or restrict the dissemination of precise coordinates. In some cases, making only aggregated data publicly accessible may be the most appropriate approach to balance transparency and protection (FAO, 2017). As well, it is advisable to make use of different anonymization techniques (Hunter et al., 2021; Jenkins *et al.*, 2023; Schinke *et al.*, 2023) to ensure that sensitive information is hidden at levels that do not interfere with the widespread usability of the data shared. For example, FAO's Corporate Standard on Microdata (FAO, 2021b) highlights the appropriate procedures for statistical disclosure control – microdata quality checks to document anonymization processes where the risk levels of disclosure are evaluated and minimal procedures for anonymization to prevent losing valuable information – before data providers conduct a final validation of the anonymized dataset.

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4. Steps to fostering institutional coordination

Setting up and operating an NFMS is a complex scientific and organizational task. A key step is identifying the relevant units or divisions responsible for collecting, storing and coordinating forest data, tools and portals across different scales.

To support countries in establishing a legal framework to regulate their NFMS and sharing data, the first step is to collect relevant laws and analyse the existing forest-related legal framework, focusing on aspects related to the functioning of the NFMS, including institutional mandates and financial commitments, access to information and forest data, and security and privacy protection, among other matters. In particular, the legal expert assigned to this task identifies and collects the norms and provisions (of law and regulations) that establish the institutional framework and define the roles and mandates of the institutions involved in NFMS activities, including forest data collection and management rules, at national and subnational levels. As an example, certain institutions will be mandated to establish a satellite monitoring or remote sensing system, while others may develop a national forest inventory or greenhouse gas inventory. The data released is public and freely accessible through the web portal but is restricted under certain conditions. Such activities may require the participation of key actors at local level to establish community forestry monitoring.

The second step entails organizing interviews with key actors of the different institutions involved in the NFMS activities, forest data collection and management, to provide a better understanding of the main challenges, the relevant tools and the major risks identified in sharing and managing forest data. At this point, the expert will identify the main platforms, instruments, technologies, fora and other existing dialogue mechanisms that can facilitate an exchange of data for an NFMS. Then, a legal or institutional analysis containing key recommendations will be conducted to identify the pertinent instruments and processes to establish forest data arrangements, validated by key stakeholders through national workshops.

Finally, legal instruments, such as decrees or ministerial resolutions, could be drafted and adopted to regulate NFMS or data-sharing and data-management aspects, according to the country's needs and circumstances. In **Box 7** a summary of steps to foster institutional coordination from Guatemala and Italy is provided.

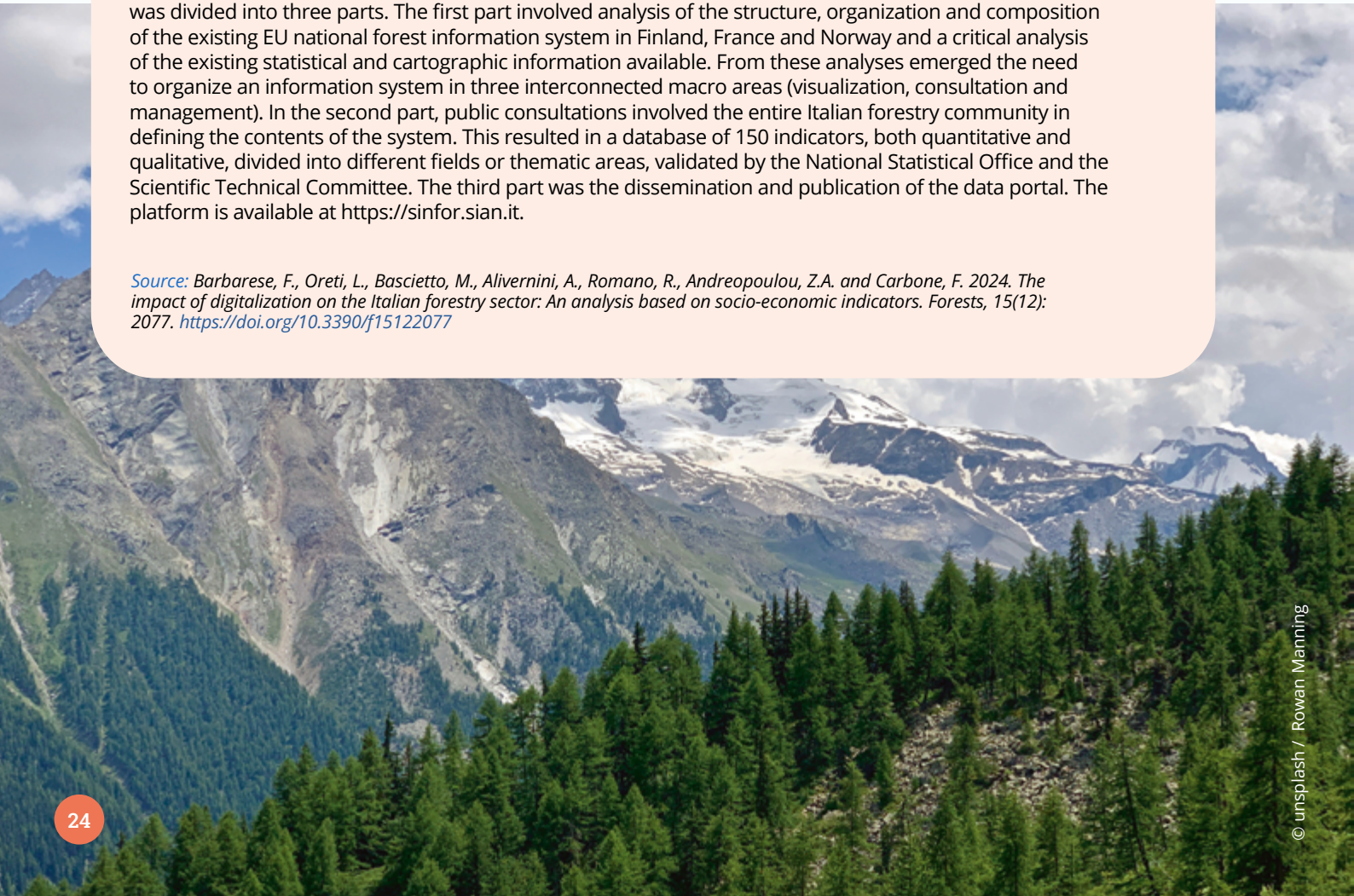
BOX 7. Case study: Institutional coordination in Guatemala and Italy

In 2024, Guatemala undertook a comprehensive review of its forest-related legal and institutional framework to operationalize the national forest monitoring system (NFMS), focusing on the use of forest data. Legal gaps and solutions were identified and discussed with key stakeholders, mainly centred on the need to update the technical cooperation agreement for the inter-institutional forest and land-use monitoring group. This agreement was signed by several institutions, including the ministry of environment and natural resources; the ministry of agriculture, livestock and food; the national forest institute; the national council of protected areas; and two universities. Its objectives are to (1) establish an inter-institutional and technical coordination framework for the monitoring, generation and harmonization of field geospatial and digital information on forest cover, land use and other related issues; and (2) contribute to the strengthening of public institutions in a coordinated effort with academia to monitor and evaluate public policies on forests and land use. Appropriate scientific technical support is necessary. A key recommendation highlights the need to include subnational staff, including organized local communities, in monitoring and using geospatial equipment to decentralize key NFMS functions. Overall, the NFMS should be structured according to the capacities and functions of each institution, so that both internal and external actors can participate, generate information and articulate actions. A sound financial commitment is also needed to ensure its sustainability and long-term operability.

BOX 7. Case study: Institutional coordination in Guatemala and Italy

Another example comes from Italy, as the country has decided to launch an important process of reorganization and harmonization of statistical and cartographic knowledge related to the forest sector, in line with the proposal for a Regulation of the European Parliament and of the Council on a European Forest Resilience Monitoring Framework To overcome policy and institutional fragmentation, the new National Forest and Forestry Information System addresses the current lack of accessible data on the forestry sector. It is the result of a participatory process and constitutes an important tool for disseminating knowledge on sustainable forest management while ensuring access to accurate and standardized information. The participatory process was divided into two stages. The first step was the creation of a Scientific Technical Committee. The second step was the operationalization of the data portal and its publication. This step was divided into three parts. The first part involved analysis of the structure, organization and composition of the existing EU national forest information system in Finland, France and Norway and a critical analysis of the existing statistical and cartographic information available. From these analyses emerged the need to organize an information system in three interconnected macro areas (visualization, consultation and management). In the second part, public consultations involved the entire Italian forestry community in defining the contents of the system. This resulted in a database of 150 indicators, both quantitative and qualitative, divided into different fields or thematic areas, validated by the National Statistical Office and the Scientific Technical Committee. The third part was the dissemination and publication of the data portal. The platform is available at https://sinfor.sian.it.

Source: Barbarese, F., Oreti, L., Bascietto, M., Alivernini, A., Romano, R., Andreopoulou, Z.A. and Carbone, F. 2024. The impact of digitalization on the Italian forestry sector: An analysis based on socio-economic indicators. Forests, 15(12): 2077. https://doi.org/10.3390/f15122077



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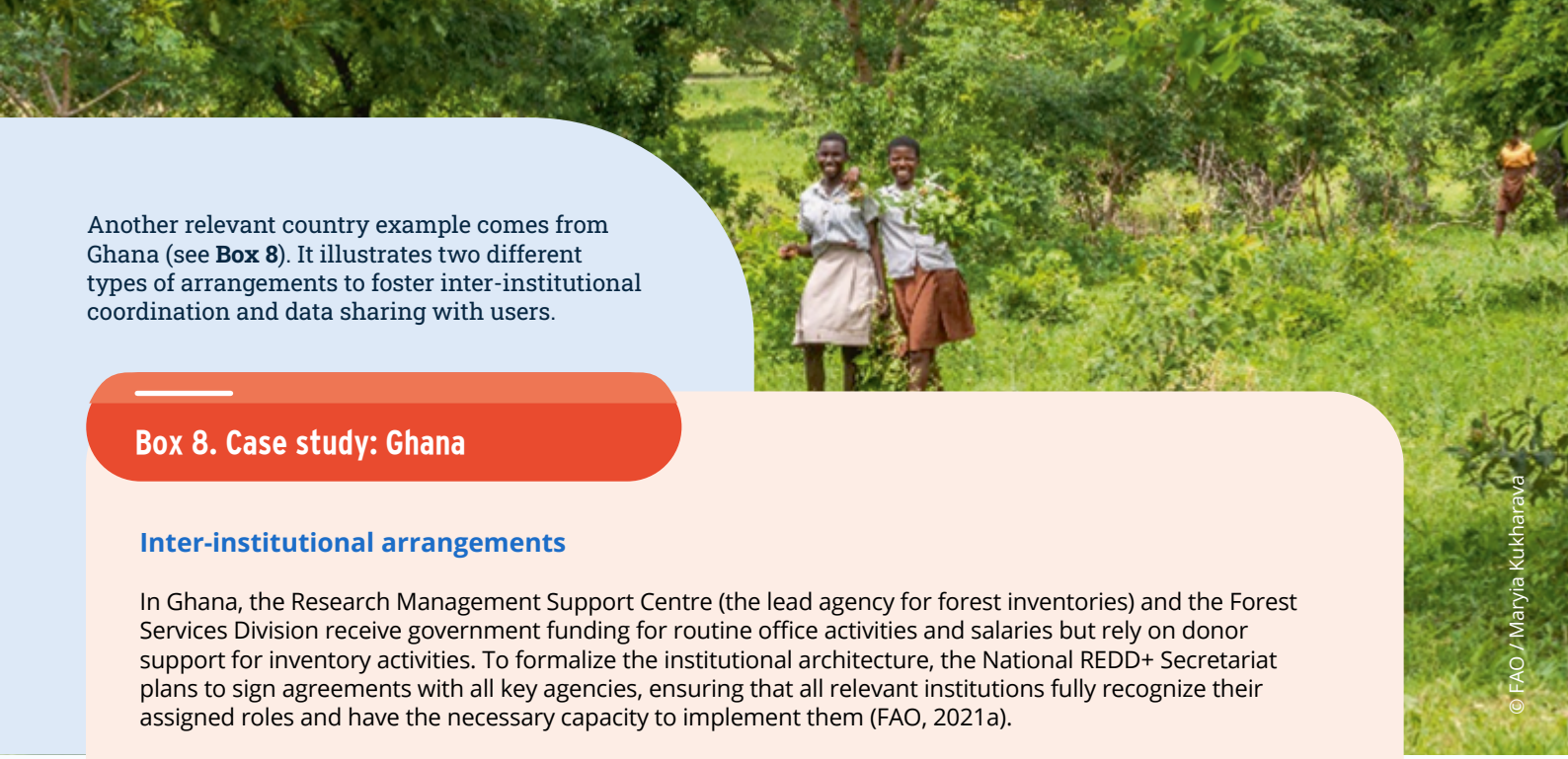

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Another relevant country example comes from Ghana (see **Box 8**). It illustrates two different types of arrangements to foster inter-institutional coordination and data sharing with users.

Box 8. Case study: Ghana

Inter-institutional arrangements

In Ghana, the Research Management Support Centre (the lead agency for forest inventories) and the Forest Services Division receive government funding for routine office activities and salaries but rely on donor support for inventory activities. To formalize the institutional architecture, the National REDD+ Secretariat plans to sign agreements with all key agencies, ensuring that all relevant institutions fully recognize their assigned roles and have the necessary capacity to implement them (FAO, 2021a).

National forest monitoring system data-sharing form

The data-sharing agreement serves as a binding document between the data supplier (the national forest monitoring system; NFMS) and the requesting organization, clarifying the terms of sharing, duration, access and usage of the data.

This draft agreement states that the data remains the exclusive property of the institution and the requesting organization will use it only for a specific purpose. The agreement is binding on any information shared and retained throughout its life cycle.

Data will only be processed and made available on a strict protocol request basis. After successful completion of all due processes required to obtain data from the NFMS, the requesting organization can access the data through a download link. That organization is completely responsible for the security and storage of the data once it has been supplied.

The agreement may be terminated prematurely if the data provider deems the use of the data by the requesting party is outside the agreed scope.

Ideally, the data supplied by the NFMS will be accessible at no charge. However, the data provider may charge for access to premium data at its discretion (Ghana Forestry Commission, 2022).

Sources: FAO. 2021a. Establishing a multi-purpose national forest monitoring system to improve land use monitoring capacities in Ghana. Rome. https://openknowledge.fao.org/handle/20.500.14283/cb4778en

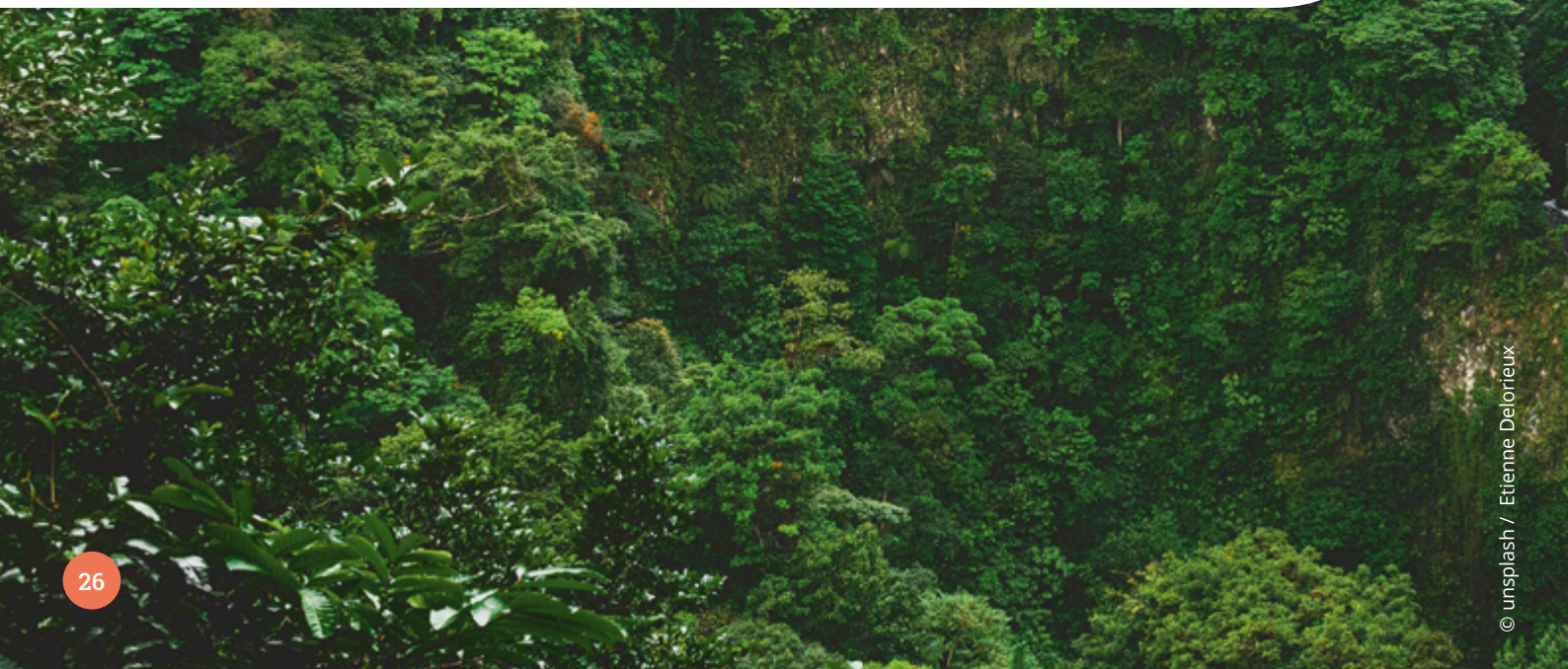
Ghana Forestry Commission. 2022. NFMS data agreement form.

Designing a national forest monitoring system strategy

An NFMS strategy is a comprehensive plan that outlines a country's goals and objectives in forest monitoring. It is fundamental, as it provides direction and coherence to government actions, promotes accountability and transparency, and ensures the efficient use of resources. It is also key to managing risks. Designing and implementing an NFMS strategy requires careful planning, stakeholder engagement and effective communication. Activities that contribute to develop an NFMS strategy include careful mapping of key institutional stakeholders based on a detailed matrix, self-evaluation of institutional gaps through a specific assessment tool, and completion of a detailed predesigned outline.

In certain cases, a technical and operational review of existing NFMS might be needed before elaborating a strategy/policy guiding document to enhance its design and functionality and help to harmonize and integrate various components hosted in different institutions. A cohesive and functional NFMS linked to other land-use monitoring systems will help the country overcome deforestation trends and agroforestry nexuses.

See **Box 9** illustrating Costa Rica's approach.



BOX 9. Case study: Costa Rica

The National System for Monitoring Land Cover, Land Use and Ecosystems (SIMOCUTE)

Costa Rica has established an interinstitutional platform known as the National System for Monitoring Land Cover, Land Use and Ecosystems (SIMOCUTE). The system is led by the Ministry of Environment and Energy through the National Center for Geo-Environmental Information (CENIGA), in close collaboration with the Ministry of Agriculture and Livestock (MAG) and the National Geographic Institute (IGN). These institutions share geospatial and environmental data according to their respective mandates and roles, as well as in alignment with established standards and requirements.

In addition to data sharing, four specialized Technical Working Groups have developed innovative methodologies for collecting, analysing and processing data. These efforts support the generation of accurate and timely information on land use dynamics and ecosystem changes.

A harmonized methodology is currently being developed to consolidate existing approaches. This will help reduce costs, address inconsistencies in definitions and methodologies, and enhance the coherence and transparency of data produced across sectors – ultimately improving the quality of official national reports.

To ensure effective coordination and sustainability, SIMOCUTE operates under a formal governance structure, as established by Decree No. 42886-MINAE-2021. This structure includes an Executive Committee, a Coordinating Unit, four Technical Working Groups and a Consultative Group that supports technical deliberations. This institutional architecture reinforces collaboration, technical rigor and the long-term sustainability of the monitoring efforts.

For more information, see the text of the decree establishing the SIMOCUTE and the text of the internal regulation of the SIMOCUTE.

See Pathways to forest data transparency: Best practices from national forest monitoring to support climate action for more details (FAO, 2024b).

Source: FAO. 2024b. Pathways to forest data transparency: Best practices from national forest monitoring to support climate action. Rome. https://doi.org/10.4060/cd3208en

A data policy may be developed to outline what data can be shared and how (freely available, available upon request, or restricted), including details on access procedures, any embargo periods, methods for sharing and data formats. If some forest data cannot be shared, the reason should be explained (e.g. ethical concerns, personal data rules, intellectual property, commercial interests, privacy or security). The decision on data accessibility should be aligned with national laws, strategies and policies (FAO, 2017).

Fostering regional networks

National forest inventory regional networks play a crucial role in harmonizing data collection, enhancing comparability and fostering collaboration among countries. By bringing together government agencies, research institutions and other stakeholders, these networks help harmonize methodologies and improve the quality of forest monitoring. The European National Forest Inventory Network (ENFIN) is a pioneering example, demonstrating how regional collaboration can lead to more consistent and reliable forest data. Through shared experiences and coordinated efforts, ENFIN sets a precedent for other regions to follow.

In the Network of National Forest Inventories of Latin America and the Caribbean, a similar initiative addresses the region's harmonization of diverse forest ecosystems and use of data. Ramirez et al. (2022) highlights the importance of national forest inventories across 21 countries and the steps taken towards methodological alignment. This collaborative effort represents a significant milestone in promoting data transparency and enhancing regional expertise. Moreover, workshops, webinars, and online fora have played a key role in facilitating knowledge exchange, allowing stakeholders to learn from one another and adopt best practices in forest monitoring.

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Building on these experiences, FAO is now facilitating another such network in the Asia-Pacific region. Given the ecological and institutional diversity in this region, this initiative aims to improve coordination, promote methodological consistency and facilitate data sharing across countries. By leveraging lessons from ENFIN and the experience in Latin America and the Caribbean, the Asia-Pacific national forest inventory network seeks to strengthen national capacities, support evidence-based decision-making and enhance the region's contribution to global forest assessments. Structured collaboration, combined with effective knowledge-sharing platforms, will be key to ensuring the success and sustainability of this network.

5. Conclusions

Data quality, management and access are foundational to advancing forest monitoring and sustainable management. Open science and open data principles are essential to facilitate better data access, enhance data relevance to policy needs and increase the impact and value of data. These principles ultimately contribute to building trust in data and supporting informed decision-making (Perucci and Swanson, 2024).

To enhance the management, use and sharing of forest data, it is crucial to build robust institutional capacities and create frameworks that enable efficient data handling and collaboration across public and private sectors. Promoting harmonized methods for data collection and fostering innovation through interoperable systems and digital platforms will ensure smoother data exchanges and greater consistency.

Clear mandates for entities responsible for collecting, managing and sharing forest data are fundamental to promoting transparency, improving accessibility and informing sound policymaking. Recognizing and establishing clear ownership of forest data is equally vital. This not only protects the rights of data owners but also promotes fairness and accountability. Adopting relevant legal instruments to govern data-sharing processes will provide the necessary guidelines and protections, fostering a culture of trust and cooperation among stakeholders.

The benefits of open, accessible and reliable forest data are far-reaching. When data is shared and used effectively, it empowers governments, academia, non-governmental organizations, the private sector, local communities and international organizations, ensuring their meaningful participation in decision-making. For example, the opening of NASA's Landsat dataset revolutionized remote sensing and created numerous business opportunities in the private sector, while global initiatives like the Global Forest Biodiversity Initiative and ForestPlots.net have advanced scientific understanding of forests through the collaborative use of both national forest inventory data and research plots.

Accessibility of forest data attracts sustainable investors, stimulating economic growth in forest-dependent regions. It fosters scientific innovation in ecology and biodiversity conservation, enabling breakthroughs in areas such as carbon stock estimation, species distribution modelling and forest health monitoring. Transparent and open data also enhances policymaking by ensuring decisions are evidence based and supports global cooperation on critical issues like forest management, climate action and biodiversity conservation.

In conclusion, overcoming the challenges of data sharing and management will unlock the full potential of forest data. By embracing openness, fostering collaboration and investing in capacity building, we can create a future where forest data drives sustainable development, scientific discovery, and equitable decision-making for the benefit of people and the planet.

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