Course 2

Text-only version

Preparing for a national forest inventory

The interactive version of this lesson is available free of charge at https://elearning.fao.org/

In this course

This course describes the planning and preparation phase of a national forest inventory (NFI).

Who is this course for?

This course is primarily intended for people who are involved in NFIs but can be taken by anyone with an interest in the subject. Specifically, this course targets:

- Forest technicians responsible for implementing their country's NFIs
- National forest monitoring teams
- Students and researchers, as curriculum material in forestry schools and academic courses
- Youth and new generations of foresters

Course structure

There are four lessons in this course.

Lesson 1: Ensuring an enabling environment
This lesson elaborates on the preparatory work that is ideally done while setting up an efficient national forest inventory (NFI) or national forest monitoring system (NFMS), as they require more than just short- term project planning to be sustainable.
Lesson 2: NFI design principles
This lesson focuses on the design principles and related topics as these are closely linked to the design planning and preparatory work for an NFMS.
Lesson 3: Assessing information and capacity needs
This lesson elaborates on two assessments that are part of NFI preparatory work: the information needs assessment (INA) and the capacity needs assessment (CNA).
Lesson 4: NFI workflow
This lesson focuses on planning and preparing a standard workflow of NFI data collection, which is part of an NFMS.

About the series

This course is the second in a series of eight self-paced courses covering various aspects of an NFI.

Here’s a look at the complete series:

Course	You will learn about
Course 1: Why a national forest inventory?	Goals and purpose of an NFI and how NFIs inform policy- and decision-making in the forest sector.
🖙 **Course 2: Preparing for a national forest inventory**	**(You are currently studying this course)**
Course 3: Introduction to sampling	General aspects of sampling in forest inventories.
Course 4: Introduction to fieldwork	Considerations for fieldwork, plot-level variables and tree-level measurements.
Course 5: Data management in a national forest inventory	Information gathering and data management for NFIs.
Course 6: Quality assurance and quality control in a national forest inventory	QA and QC procedures in forest inventory data collection and management.
Course 7: Elements in data analysis	Typical approaches/calculations in data analyses and related topics.
Course 8: National forest inventory results: Reporting and dissemination	NFI reporting and the importance of reporting in the context of REDD+ actions.

Lesson 1: Ensuring an enabling environment

Lesson introduction

This lesson elaborates on the preparatory work that is ideally done while setting up an efficient national forest inventory (NFI) or a national forest monitoring system (NFMS), as they require more than just short-term project planning to be sustainable.

Various organizational, legal, administrative and technical foundations should ideally be prepared to justify smooth planning and implementation.

Objectives

At the end of the lesson, you will be able to:

1. Understand the main elements of the enabling environment necessary for the implementation of NFIs, in the context of an NFMS.
2. Describe the importance of national ownership in national forest monitoring (NFM).
3. Discuss NFMS institutionalization and its legal basis.
4. Understand the role of networking and collaboration.

An enabling environment for an NFMS

National ownership in an NFMS and NFI

The concept of country or national ownership is self-explanatory. Country ownership means that countries, based on their national circumstances and development priorities, need to exercise full control over the entire NFMS development process, assuming full responsibility for its implementation and effective operation. Without full country ownership, international partner organizations and foreign institutions are limited in their ability to provide support in technology transfer, technical capacity building, and the development of institutional capacities.

Did you know?

The relevance of country ownership

Many former NFIs conducted in the Global South around the 1980s were implemented as technical cooperation projects with external funding and external experts – and often with little consideration regarding capacity development and sustainability.

However, part of the truth is also that in many cases, the countries either did not show interest in these NFIs, or funds, technical expertise or capacity were not available. Often, even a functioning forest service was not in place where an NFI could have been institutionalized. Implementing an externally funded NFI was the only goal in these cases.

And after the NFI report was published, often everything vanished: the experts, the expertise – and in some cases – also the data. Of course, such a one-time exercise could neither serve as a basis for a longer-term NFMS nor feed into long-term plans for the development of the forest sector. As a consequence, if some years later there was an interest in updated national-level forest data (e.g. by a new technical cooperation project in the forest sector), a new NFI was planned – in many cases again – with donor money and external expertise.

Such a situation is exactly what can be avoided by emphasizing the relevance of country ownership.

The concept of country ownership is widely used in international cooperation and normally refers to how developing countries own development priorities, including their ability to define, lead and implement their preferred development model. The concept grew out of a consensus that in order for development policies and programs to be effective and aid in successfully supporting development efforts, they must be owned by national governments.

In the context of an NFMS and an NFI, the concept of country ownership becomes relevant primarily when the NFMS or the NFI is carried out with international cooperation.

To have country ownership, the government, and in particular the government agency leading the NFMS or NFI, has to demonstrate, at the very least:

Power and legitimacy	To exercise power over defining the development and decision-making processes, prioritizing interests and determining how initiatives will be implemented. Likewise, political legitimacy is considered a basic condition for governance , without which a government will suffer legislative deadlock(s) and collapse.
Commitment and responsibility	To have the right to insist on deciding its own development agenda without coercion, it is also obliged to take full responsibility for the outcomes resulting from policy and programme implementation.
Capacity	To have the institutional capacity to develop strategies and operational plans, coordinate and align the activities of key stakeholders, implement programmes or delegate their implementation to others, and provide oversight and hold implementers accountable.
Accountability	To have a power dynamic in which an agent reports to a principal on his or her activities and faces the consequences for noncompliance.

Eventually, country ownership is key for sustainability, not only with respect to an NFMS. Ideally, it also paves the way for a more comprehensive usage of the information generated from the NFMS. Of course, there are also good, early examples of developing national ownership, such as the Forest Survey of India, described below.

Example: FSI, the Forest Survey of India: from technical cooperation to full country ownership

The Forest Survey of India (FSI) is an institution that governs the National Forest Inventory in India plus various other forest- and tree related projects on national level. It is part of the Government of India´s Ministry of Environment, Forest and Climate Change. The FSI was established in 1981. Before, FAO and UNDP had sponsored the technical cooperation project "Preinvestment Survey of Forest Resources" (PISFR). That project was initiated in 1965 in collaboration with the Government of India. In its report in 1976, the National Commission on Agriculture (NCA) recommended the creation of a National Forest Survey Organization for a regular, periodic and comprehensive forest resources survey of the country. This has eventually lead to the creation of FSI in the year 1981.

This is an instructive (and at that time quite exceptional) example how the country ownership has gradually grown during the implementation of a longer-term national level forest monitoring project. Of course, establishing the FSI meant a considerable and long-term investment by the Indian Government, and the readiness to do so is a clear indication of a full country ownership of the NFMS idea. Nowadays, FSI is an internationally renown and powerful institution.

NFMS ownership by governments (and maybe also by other relevant stakeholders) is an important precondition when sustainability of the system is at stake. The ownership conditions must be considered from the beginning of the NFMS and NFI planning.

An important point here is that country ownership also means country responsibility. Country ownership does not come for free; it will only work when dedicated staff are at work in the country, equipped by the authorities with the required mandate and resources in terms of working time, personnel and expertise, possibilities for networking and capacity development, and financial resources. The FSI example above illustrates that country ownership works only in tandem with investments and long-term commitments.

Legal basis: defining the mandate of the NFMS and its institutionalization

Embedded in the concept of country ownership is having a legal basis established for the implementation of NFIs or an NFMS.

If a government wants to spend money, at least in a constitutional state, there needs to be a legal basis for that. Therefore, in many countries, where the NFMS is in firm country ownership, a clause has been integrated into the national forest act that authorizes the government to spend money for the NFI and NFMS, and their institutionalization. Such a law may also:

1. specify the mandate of the NFI in more detail;
2. provide reliable forest resource information covering a whole country to include computation of forestry statistics;
3. define at which intervals the reporting shall take place;
4. outline how the responsibilities are distributed among the responsible units; and
5. describe how the financing shall be carried out.

It may also contain an authorization for the field teams to enter private forests to carry out the requisite

NFI observations. The legal regulations may also extend to making the NFI data publicly available for all interested parties in the country.

When the NFI and its regular implementation in the framework of a longer-term NFMS is firmly founded in a national forest act, it is evident that sustainability and country ownership are taken very seriously, because the NFMS cannot simply be abolished when the government changes. This means that the explicit legal basis may also serve as a component of evidence of fulfilling the expectations formulated by **the United Nations Framework Convention on Climate Change (UNFCCC)**. The UNFCCC has stated in their COP decisions (from the **Conference of the Parties**) that countries should establish an NFMS when they expect results-based payments for their efforts in forest carbon emission reductions.

It is certainly one of the most powerful enabling conditions to have the NFI and NFMS explicitly detailed in a national forest act, as we see that it has far-reaching implications.

The institutionalization of an NFMS contributes to increased country ownership, which is key to sustainability and paving the way for a more streamlined use of information generated in the forest sector. Forest-related institutions with clear mandates can facilitate the task of ensuring the sustainability of an FMS and adequately informing decision-making processes to reduce deforestation and enhance the sustainable management of forests.

Did you know?

NFMS legal instruments: A checklist

FAO has developed a **checklist tool** to assist countries in identifying relevant features that should be included in an NFMS legal instrument. This checklist may facilitate the assessment of their inclusion in the legal text during the drafting process, and help to clarify if further consultations are needed to that end.

For more details on a stepwise approach to guide development and adoption of a legal instrument aimed at institutionalizing an NFMS, please see the publication **Institutionalisation of forest data.**

Networking and collaborating

Research infrastructure and academia: a win–win integration

While an NFMS is essentially a policy instrument, following a clearly-defined (and possibly legally-endorsed) mandate, many of its technical components benefit from or depend upon input from scientific research. In the end, an NFI is a large empirical study that should be firmly based on scientific principles. Then, it is as important to have academia accompanying the planning of the NFI and NFMS as to warrant that these scientific principles are being observed.

Another important enabling condition for establishing NFIs and an NFMS, therefore, is to foster collaboration and coordination with academia on a national level. “Academia” may be either universities that have faculties with forestry courses or forest research institutes. Both are also candidates for hosting the NFI coordinating institute, as related to the institutionalization of the NFMS.

The presence and availability of powerful research units in forest sciences in national academia is an important enabling component for NFIs in several aspects; it is a win–win collaboration where the responsible NFI institutions should support and link to research institutions in activities that include the following:

1. recruiting qualified staff (possibly with a long-term perspective);
2. commissioning research tasks (e.g. the development of biomass functions or simulation of sampling alternatives, among many others);
3. support in data analysis of field data or of remote sensing data; and
4. making data available to work on research questions on a national level that are beyond the mandate of the NFI.

Note

Of course, academic collaboration may also efficiently extend to researchers in foreign countries; the topic of NFMS may be a good reason to establish or foster such collaborations. National forestry faculties may take the opportunity to include more aspects of the NFI into their curricula – a topic that appears to be slightly neglected in many curricula when compared to forest management inventories.

NFI networks and links to neighbouring countries

All NFI planning benefits from exchange with other NFI projects. There are many countries that have successfully installed their NFIs, and in practically all regions, there are neighboring countries that can share their experiences. In some regions, formalized NFI networks already exist.

Some examples of such initiatives include the European National Forest Inventory Network (ENFIN), the series of expert meetings leading to an NFI harmonization effort in **Latin America and the Caribbean (LAC)**, or the partnership of countries under the **Central African Forest Initiative (CAFI)** to collaborate in collating, analyzing and disseminating data from the region.

It is not necessary to re-invent the wheel – either regarding the technical NFI design or the institutional setting. Learning from the experiences of neighboring countries is extremely helpful and makes the planning process efficient.

Integration into the national forest service

If a national forest service is in place, close collaboration with this institution from the outset is encouraged. The NFI unit may even be installed there or at least have the NFI headquarters there. The national forest service has experiences from the forestry sector from which any NFI planning and installation of an NFMS will greatly benefit.

Summary

Before we conclude, here are the key learning points of this lesson.

- An ideal enabling environment for an NFMS has multiple dimensions - and even though no NFMS has all the conditions met from the outset, working on an enabling environment is a continuous process as an NFMS is being implemented.
- In the context of an NFMS and an NFI, the concept of country ownership becomes relevant primarily when the NFMS or the NFI is carried out with international cooperation.
- In many countries, where the NFMS is in firm country ownership, a clause has been integrated into the National Forest Act that authorizes the government to spend money for the NFI and NFMS and their institutionalization.
- The presence and availability of powerful research units in forest sciences in national academia is an important enabling component for NFIs in several aspects.

Lesson 2: NFI design principles

Lesson introduction

While there is no one-size-fits-all approach to an NFMS, there are a number of principles that are generally accepted to guide the planning process efficiently.

In this lesson, we focus on the design principles and related topics as these are closely linked to the design planning and preparatory work for an NFMS. These principles are elaborated in detail in FAO's **Voluntary Guidelines on National Forest Monitoring (VGNFM)**; they are divided into five groups.

Additional guidance: For a more complete understanding, it is recommended that you consult the VGNFM.

Objectives

At the end of the lesson, you will be able to:

1. Understand the role of NFIs in large-area forest-related decision-making.
2. Acknowledge the importance of the integration of and consistency with existing information sources.
3. Explain why an NFI should be flexible and have a multi-purpose approach.
4. Describe inventory costs and the basic tradeoff between statistical precision and implementation costs.
5. Elaborate on the link between an NFMS and the Sustainable Development Goals (SDGs).
6. Appreciate the role of goal-driven planning as compared to technology-driven planning.
7. Enumerate the design elements that are common to many NFIs

General principles of forest monitoring

FAO's VGNFM is probably the first publication in which the basic principles of national forest monitoring have systematically been identified and elaborated.

While there is no *single* optimal design and setting for national forest monitoring (due to the diverse natural and socio-economic conditions in every country), there are a number of principles upon which the planning of an NFMS is usually founded. These principles are elaborated below.

Governance principles	**Principle 1**: Country ownership and responsibility **Principle 2**: Legal and policy basis **Principle 3**: Landscape view **Principle 4**: Institutionalization of an NFM **Principle 5**: Research infrastructure and capacity building
Scope principles	**Principle 6:** Participatory discussion process **Principle 7:** Satisfaction of national information needs
Design principles	**Principle 8**: Integration of and consistency with existing information sources **Principle 9**: Flexible approach **Principle 10**: Multipurpose approach **Principle 11**: Feasibility including cost-efficiency
Data principles	**Principle 12**: A well-defined data and information sharing policy
Overall principles	**Principle 13**: Credibility through transparency and quality **Principle 14**: Collaboration at the international level

As this lesson focuses on the planning of an NFI and an NFMS, it is the design principles that are of particular interest and what we will learn about next.

How NFIs are elemental to forest-related decision- making

You already know that that an NFMS is (typically) a government-driven, long-term programme that exists to support forest-related policy formulation. As such, they are critical elements in national- or subnational- level forest-related decision-making processes, and should have clear goals. All preparatory work and design planning needs to have these goals in mind.

It is not easy to measure the direct impact of high-quality NFMS information on the "quality" of decision processes; however, NFMS results are welcomed support by decision-makers – otherwise, funding of such a long-term programme would not be endorsed by national parliaments.

The next lesson of this course elaborates on the information needs that an NFMS satisfies and their identification – these may evolve over time and new challenges and questions may emerge. That means that an NFMS should be flexible enough to accommodate new topics at a later point in time and the information provided needs to fit into the existing information frame. Also, the NFMS must be feasible in terms of resources needed, or else it will not be sustainable.

Of course, a further goal of an NFMS is to inform forest-related international conventions to which the country is a signatory state; however, most of the information needed for such international reporting is contained in the NFMS anyway, so that the international reporting often becomes a "by-product". However, the timing when the reporting is due may co-determine the timing of the inventories

Integration of and consistency with existing information sources

National forest monitoring should not be considered an isolated and stand-alone initiative, but an undertaking that—within the scope of its particular mandate—links with other initiatives that generate national-level information. This includes research projects or surveys at the national or sub-national level on land use, biodiversity, soils, wildlife habitat, etc., as well as sub-national forest inventories. Knowledge about such initiatives may help plan for an NFMS, mainly in terms of design, practical implementation and logistics. The evaluation of such initiatives does not usually relate to or interfere with the assessment of information needs.

In NFI planning – as well as any other forest inventory planning as well – the planners need to resort to all possible available information sources for economic and technical efficiency (including maps, remote sensing data, earlier inventory reports, results from research activities and surveying experiences and reports in the field of forestry, ecology, etc.). Of course, all information used in support of the NFMS planning needs to be thoroughly quality checked for compatibility, accuracy and completeness.

It is also important to check target variables that already have national data published in the national statistics institute. An NFMS should be compatible with these existing statistics; otherwise, it may cause confusion. However, sometimes it is not easy or even possible to generate this compatibility, such as where forest land is a "legal definition" of land and not a biophysical definition of where a forest stands. If the definitions cannot be made identical, one should at least strive to produce results from the NFMS that can be compared to or harmonized with the existing data as much as possible. In any case, when reporting the NFMS results, the differences in definitions need to be clarified so that possible numerical differences can be explained.

Example

The need to clarify definitions

In 2015, the Government of Ethiopia modified its forest definition by reducing the height threshold from 5 m to 2 m and increasing the minimum canopy cover from 10 percent to 20 percent. This forest definition differs from the definition used for international reporting to the Global Forest Resources Assessment (FRA) and from the forest definition used in the NFI which both applied the FAO forest definition with the thresholds of 10 percent canopy cover, a 0.5 ha area and a 5 m height.

The reason for changing the national forest definition was to better capture the natural primary state of Ethiopia's forest vegetation – notably natural forest vegetation types like the dryland forests, which consists of trees reaching a height of around 2 m – 3 m. The proposed change in forest definition resulted in the inclusion of what previously was classified as Ethiopia's dense woodlands that have a wider distribution throughout the country. Commercial agriculture is expanding mainly on dense woodlands and Ethiopia desires to enable REDD+ incentives for its conservation.

These changes require a monitoring approach that allows for reporting on both the old and new forest definitions in order to accurately compare forest area over time. This means creating an approach and forest classification system that allows for the disaggregation of results, in this case including or excluding the dense woodland class. When describing forest statistics, communication of this new forest definition is very important in order to be able to accurately track and report on forest status over time. NFIs: The need for flexibility and a multi-purpose approach.

NFIs: The need for flexibility and a multi-purpose approach

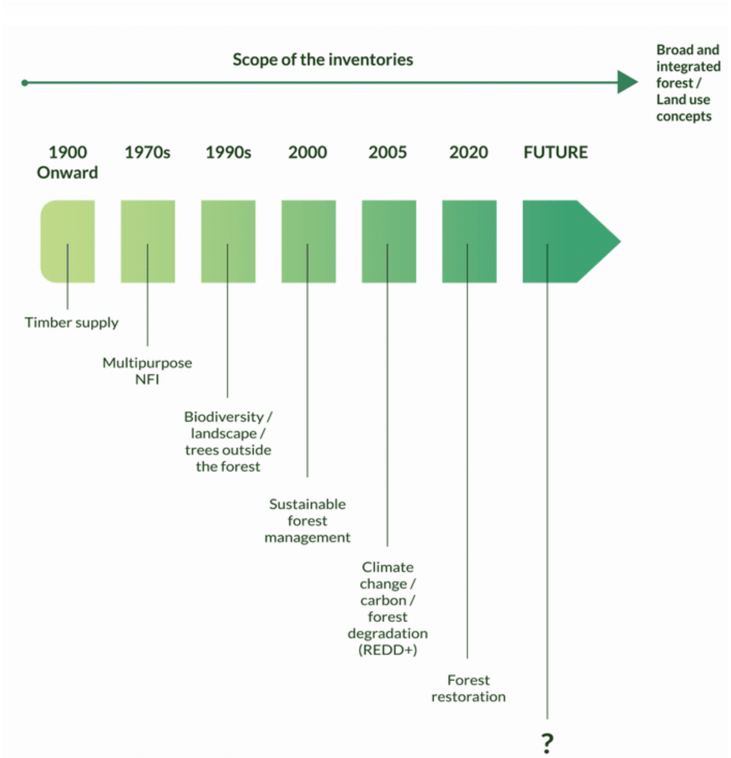
Because an NFMS is a long-term programme, forest-related issues emerge and need to be integrated in the course of periodic revisions of the NFIs. These issues may arise due to changes in national policies, new topics brought up by international processes, new scientific findings, and so on. Additionally, climate change- related events such as the increased number of forest fires, insect outbreaks, floods or storms may require an adaptation of the NFMS.

A flexible approach is an important element of the strategic and long-term character of an NFMS. Actually, any NFMS that has been in place for decades exhibits such flexibility and successful integration of emerging topics. Integration between the topics, however, requires technical and organizational expertise, as well as extensive communication between different interest groups.

Because emerging issues cannot be foreseen during planning, the technical design of an NFMS must be sufficiently flexible to allow for adjustments, and the organizational design must be able to adapt to changes as well; actually the standard designs of an NFMS are all sufficiently flexible to accommodate emerging issues. An important point here is that the consistency of the time interval should not be unnecessarily disrupted; design modifications or changes in definitions should be done in a way that existing time intervals are not compromised, and they should be clearly reported so as to facilitate the understanding and interpretation of time-series.

The evolution of NFMS also becomes clear when we look at the changing focus of the NFIs: early NFIs focused almost exclusively on the assessment of the state of wood resources; much later, the assessment of biomass, and nowadays carbon, have been integrated, which are, of course, closely related to the traditional assessment of the volume of the growing stock.

Biodiversity variables and the naturalness of forest, non-timber forest products and lately also information about the use of forests (socio-economic variables) were topics that came into the NFIs later. Some NFMS have also included trees outside the forest (TOF) into the inventory design, thus converting the forest inventories into tree inventories on a national level. It has been since the late 1970s that NFIs have also been called multi-purpose forest inventories, integrating additional objectives other than assessing the production of the raw material, wood.



The multipurpose orientation requires intersectoral communication and coordination, ideally through legally binding data sharing protocols. In the end, however, the multipurpose approach may support the feasibility and cost-efficiency of national forest monitoring efforts, when the development of the design not only succeeds in integrating new issues from other sectors - but also in raising the corresponding co-funding.

Cost considerations

An NFMS must be planned in such a way that it is able to deliver the target information and feasible in terms of the resources required.

In the end, an NFMS, like many other empirical undertakings, is a matter of cost-efficiency. This refers to components such as technical implementation, institutionalization, supporting research activities or capacity building.

Establishing an NFMS entails the same costs as any other government expense. As such, it needs to be technically justified and economically reasonable. Ideally, there is a legal basis for the expenditure, as well: that the national forest act contains a clause that demands establishing and running an NFMS.

In the past, the lack of priority assigned to national forest monitoring may have made governments reluctant to invest in long-term forest monitoring systems. However, current international processes – with the emphasis on reliable and transparent forest information - play an important role, also in monetary terms. Result-based payments, for which the NFMS provides the evidence-based reliable data for the application of funding as a successful implementation of REDD+ activities, will help to change this attitude.

There are several factors that influence the total cost of an NFMS.

One set of costs refers to the regular implementation of the NFIs and the data collection activities, be they periodic or annual. The other set of costs are the running costs of the permanently installed NFMS unit. Both sets of costs are largely determined by the inventory design and depend in particular on the size of the field sample, which has a significant effect on the precision of estimation.

The relationship between precision and cost is non-linear: for higher precision requirements, an over-proportionally higher amount of resources needs to be available. As you will see in **Course 3: Introduction to sampling**, for example, doubling precision means fourfold cost (simple random sampling assumed)—that is, defining the target precision of the major variable(s) is one of the most relevant factors when it comes to NFI cost.

There is, however, no general recommendation for a “good” target precision, such as for the core variable “basal area”, which is related to various other relevant NFI variables, including above-ground biomass and carbon. The common approach is to take experiences from other NFIs, adopt the respective sample sizes (often in terms of the sizes of the systematic grids used), and accept the resulting precision of estimation.

NFIs often work with relatively high sample sizes (i.e. hundreds if not thousands of plots), which means that usually standard errors of less than 5 to 10 percent are reached (normally accepted as sufficient).

In an NFMS that uses periodic NFIs, one organizational and administrative financial challenge is due to the sporadic nature of the work. For example, if there is an intensive data collection period lasting one to two years that only occurs every ten years, there is an issue concerning how to retain the necessary field teams and associated specialists over time. As a result, many NFIs use consulting companies and other external providers for data collection.

The other option is to collect data annually, where each year a fraction of 1/***m*** of the total sample size is recorded so t after ***m*** years, one NFI cycle is fully completed. For these so-called “panel surveys”, the funding requirements are quite uniform over time and the funding and staff “peaks” that occur with the periodic survey are not there. Also, field teams may be contracted permanently in an annual data collection system and accumulate experiences, so that training efforts may be reduced. Planning and analysis efforts may be slightly higher, though, with the panel system.

Calculation of overall funding requirements for an NFMS is not easy. It can eventually be done only after the NFI and the NFMS program have been designed. Experience from neighboring countries may help. For field data collection, one may calculate and/or estimate the average expected cost per field plot as a basis which needs to include all person-power, logistics, devices, plus a buffer for unforeseen events. Factoring in plot size and transportation costs (which are different for every country), some ballpark figures for these expected costs range between USD 700 and USD 5 000. For the NFI headquarters, staff cost and offices plus equipment (including computer hardware and software) also need to be considered.

Reality check

A full-blown “cost-benefit analysis” for an NFMS is not possible; while the costs are easily determined in terms of the expenses, the monetary benefits of improved information can hardly be calculated and there is hardly any research about this topic. The cost-efficiency of an NFMS will, therefore, commonly be evaluated by the success in achieving the defined objectives at minimum cost without compromising data precision, accuracy or quality.

NFMS planning: Objective-driven or technology- driven?

An NFI and NFMS usually have a well-defined political mandate: a government body invests in procuring relevant data and information that is required for targeted decision-making. In that sense, a forest inventory has a character that can be compared to a population census or to the work of intelligence services; it is a “production exercise” and not a research project. While accompanying research is definitively required so as to optimize the resource allocation in the NFMS, the implementation of the NFMS is not a research program that tests and compares approaches.

The mandate, ideally formulated in a national forest act, and the specific goals that derive from this mandate, govern the design planning of any NFMS. The planners will apply the techniques and approaches that most efficiently allow for the achievement of the defined objectives. "Most efficiently" means here simply that the defined goals are achieved at the lowest possible cost – while, of course, always maintaining the defined quality standards.

Sometimes we hear the ideas, "I wish to use drones in the NFI" or "I wish to employ terrestrial laser scanning in NFI field work", for the forest inventory. Then, one needs to check if such new technology will really help to achieve the defined goals in a more efficient manner. If so, their use should be straightforward and accompanying research projects may find out how to optimally seize that use.

It may be that these technologies (or others) will be good to assess other variables beyond the mandate of the NFI—but they may not make it more efficient to achieve the defined, mandated objectives. Then, one would refrain from integrating these technologies into the NFMS, even though interesting research findings may be generated as a side product. It is sometimes difficult to convince enthusiastic colleagues that the most hi-tech approaches are not always the most efficient in field forest inventories. In accompanying research projects, the suitability and operationality of all approaches may be tested with the goal to evaluate whether they may be integrated into a future inventory.

Technical design elements of a typical field inventory in an NFMS

While there are many options for field sampling and field plot design, there are some elements that are common to most NFIs. These elements are already well-proven, and would one deviate from them only in well-justified circumstances.

Regarding field sampling design, **practically all NFIs use systematic sampling**, and with good reason. Given a defined budget, systematic sampling will achieve the best precision of estimation under practically all conditions in forest monitoring.

While for theoretical reasons, a triangular or hexagonal grid would be preferred, square grids are used in most NFIs, probably because they align so well with geodetic grid systems. The orientation of the grid is usually North–South, which is to say there is no randomization of the grid orientation; the grid size is often an integer value in kilometers, sometimes with a distance that can be easily densified.

Some NFIs use **unaligned systematic sampling** where the inventory region is subdivided into squares (resulting in a square grid where the centre points of the squares are always taken as the sample position) or hexagons (resulting in a triangular grid when using aligned systematic sampling); within each cell a random position for a sampling point is determined.

While this unaligned systematic sampling does not immediately reveal the coordinates of all sampling points (because they are not easily predictable on a fixed systematic grid), the precision of estimation will be inferior to that of an aligned systematic sampling where the sample points are exactly at the grid points without further randomization.

Note

Systematic sampling is sometimes combined with stratification, when the country can be subdivided in subnational units with considerably different stocking densities / forest types / target precisions. In the different strata, the systematic samples then have different grid sizes, often such that the less dense grids (e.g. 8 km square grid) are a subset of the denser grids (e.g. 4 km square grid). The resulting sampling design would be called a stratified systematic sample.

Regarding field plot design, most NFIs employ cluster plots (i.e. clusters of sub-plots) for obvious practical reasons: the sample plots have a large distance from each other and it takes the field teams a considerable time to reach the sample plot location. Then, field plots shall be established that are as large as possible and capture a maximum of variability; the field teams simply must seize the opportunity to register data once they are at the plot location. Instead of installing one single large sample plot, it is more efficient (though also more time consuming) to split the large plot into several smaller sub-plots that are arranged along a fixed geometric pattern (often squares, crosses or half-squares [L-shape]). The design of the sub-plots is commonly nested fixed area plots, sometimes circular and other times as strip plots, and often having combined elements of typical plot designs. The cluster plots also allow line intersect sampling on the lines connecting the sub-plots.

There is no general standard for remote sensing integration into an NFMS, but remote sensing data are increasingly integrated into NFIs in planning, modelling and analysis, and regionalization (map production). Publicly available image products and above all, analysis platforms such as FAO's System for Earth Observation Data Access, Processing, and Analysis for Land Monitoring (SEPAL) [https://sepal.io/], have fostered and facilitated the use of remote sensing for forest monitoring and will likely develop towards a standard in NFMS planning and implementation.

SEPAL "helps countries monitor and report on forests and land use", offering "users unparalleled access to satellite data" and "an easy-to-use interface"; the platform is "powered by cloud-based supercomputers, paving the way for improved climate change mitigation plans and data-driven land-use policies" (FAO, 2021). Other platforms such as **Collect Earth** allow for data collection through Google Earth. In conjunction with Google Earth, Bing Maps and Google Earth Engine, users can analyze satellite imagery (commonly of very high resolution) for a number of purposes, including supporting multiphase NFIs. For more information on this, please check **Course 3: Introduction to sampling**, Lesson 3, Double sampling (Two phase sampling).

Similarly for data management, there is no general standard; however, more recent developments by FAO may contribute to generating such a standard: they allow for efficiently configuring mobile data loggers, data management, data analyses and remote sensing data management.

FAO´s **Open Foris** initiative offers a range of open-source tools and it is a great step towards digitalization and standardization of forest monitoring programs in various respects. **Open Foris Collect** allows an easy and well accessible configuration of mobile data collection, and is also smart-phone based. Collect Earth and **Collect Earth Online** facilitate remote sensing data analyses and the smooth generation of remote sensing-based time series. **Open Foris Calc**, and the newly integrated **Open Foris Arena** platform support data analyses. Over time, SEPAL can evolve to provide a big-data platform for forest and land management.

While some general standards for NFMS design and implementation have evolved, a specific and good command of the underlying theoretical concepts is still required to efficiently plan for a sustainable and target-oriented NFMS.

Summary

Before we conclude, here are the key learning points of this lesson.

- National forest monitoring should not be considered an isolated and stand- alone initiative, but an undertaking that links with other initiatives that generate national level information.
- Because an NFMS is a long-term programme, forest-related issues emerge and need to be integrated in the course of periodic revisions of the NFIs. A flexible approach is an important element of the strategic and long-term orientation of NFMS.
- An NFMS needs to deliver the target information and should be feasible in terms of the resources required. Like other empirical undertakings, an NFMS is a matter of cost-efficiency.
- It is necessary to ensure that the use of new technologies will help achieve the goals of an NFI more efficiently; if yes, their use should be straightforward and accompanying research projects may find out how to optimally seize that use.

Lesson 3: Assessing information and capacity needs

Lesson introduction

This lesson elaborates on two assessments that are part of NFI preparatory work:

- the information needs assessment (INA) that determines the specific scope and range of an NFI and has implications for the NFI design; and
- the capacity needs assessment (CNA), which serves to contribute to enabling environment.

While both assessments need to be carried out before implementation, they should be continuous processes through implementation as well.

Learning objectives

At the end of this lesson, you will be able to:

1. Understand the importance of INAs and CNAs to NFIs.
2. Describe the typical process and considerations involved in determining needs in INAs and CNAs.
3. Explain the process of carrying out an INA or CNA and the errors to avoid.

Generic information required from an NFMS

The major purpose of an NFMS is to generate meaningful national-level forest-related information to support decisions at a country level and inform international processes.

Therefore, one of the most important preparatory tasks is to clearly define the data that should be recorded. This means that the expected outcome of the NFI and NFMS needs to be specified in the form of tables, graphs, relationships between variables, or map-like representations, which should be part of the NFMS reports.

Because the planning of an NFI and NFMS is guided by the information needs of stakeholders who use the information in decision-making, it can be said that the efficient planning of an NFMS is user-oriented.

An instructive article on **user-oriented national forest monitoring planning** identifies the basic principles for such planning.

While each NFI has its particularities because of each country's natural and socioeconomic conditions, there is a relatively large core set of variables that will form part of the dataset in any NFI. There is no formal research on that, but one may estimate that about three quarters of the variables recorded in an NFI belong to this generic core set of variables. This dataset includes:

1. **forest area and forest type areas**, **tree variables** (including, for example, tree species and dbh [diameter at breast height]);
2. **topographic variables** (including, for example, slope, elevation, and exposition);
3. **regeneration variables** (including number of seedlings and saplings); and
4. deadwood variables.

Note

For an NFMS, many variables are core variables. In addition to these, there are also the changes in these variables that constitute the core information to be generated. Part of this core set of variables are also those that need to be observed to generate results required for international reporting (e.g. in case the country is a signatory state to the **United Nations Framework Convention on Climate Change (UNFCCC)** or the **Convention on Biological Diversity (CBD)**. Regarding this core set of variables, the question is not whether to record them, but how to integrate them into the inventory design, or the plot design.

A list of examples of such generic information needs for national-level forest-related policies has been outlined in the table below (Arnold et al., 2014). What this table does illustrate, however, is that information needs alone do not provide clear guidance as to which variables to observe in an NFI, and requires the identification of corresponding indicator variables that allow inferring the target information.

Examples of knowledge and information needs related to forest policy issues

Forest policy issues	Examples of information and knowledge needs	Concerned sectors and/or stakeholders
Deforestation caused by expansion of industrial agriculture, tree crops, large scale cattle ranching and/or subsistence farming	• land use types in conflict with forests and their dynamics in time and space • availability of updated information adapted to temporal and spatial dynamics of land use change • historic and recent direct causes and trends of forest cover change • rates of deforestation and forest regrowth • opportunity costs of forest competing land uses	International bodies Government agencies Subnational governments Non-governmental organizations (NGOs) Local communities
Forest degradation caused by overcutting timber, fuelwood and charcoal, often followed by livestock introduction in open stands	• biomass density and volume by forest type, land ownership category, etc. • changes in time • and space of biomass density • quality and floristic composition of forest regeneration • growth potential of main tree species • biomass, volume and qualities of trees in non-forest areas (e.g. agroforestry systems) • opportunity costs for reduced impact logging • spatial extension of areas available for complementary afforestation or enrichment planting	International bodies Government agencies Subnational governments Forest owners Private companies Cattle ranchers Private investment companies Local communities
Forest degradation caused by	• spatial-explicit information on	Government agencies

uncontrolled intentional fires	hotspots of fire susceptibility and actual fire sites • fuel loading as a function of forest type and management • updated land ownership register	Subnational governments Forest owners Insurance companies Cattle ranchers Crop producers
Illegality of forest use as a result of unclear land ownership land ownership overlapping management responsibilities	• land ownership distribution in legal and in real terms including areas with customary rights (e.g. Indigenous Peoples) • geographical location and extension of areas in conflict (e.g. illegal occupation and encroachment)	Government agencies Subnational governments Forest owners Police Military Local communities
Bad harvesting practices and inefficient timber production	• inventory of harvesting practices and technological standards • capacity building needs for logging and sawmill companies; • investment needs for improved practices and technology	Government agencies Subnational governments Forest owners Harvesting companies Saw mills Trade unions Lending banks
Shortage of timber supply	• supply-demand gaps for roundwood and main forest products; • growth pattern of future wood demand • timber import trends • general socioeconomic trends (e.g. population and GDP growth) • potential for productivity improvement in natural forests • potential and availability of soils for plantation establishment • stock, growth potential and exploitability of non-wood	Government agencies Subnational governments Forest owners Forest industry industry Trade unions NGOs International investors Local communities

	alternatives (e.g. bamboo) • volume, qualities and usability of trees outside forests	
Rural livelihood demands	• biology and markets for promising non- timber forest products (NTFPs) • systematization of local use and cultivation knowledge • stock, distribution and growth potential for major NTFPs • dynamics in supply and demand of major NTFPs • availability (stock and growth rates) of fire wood • extension and quality of trees outside forests	Government agencies Subnational governments Forest owners Neighbourhood organizations Private companies International investors NGOs Local communities
Endangered forest biodiversity through habitat loss and fragmentation	• extension and location of forests with special amenity and biodiversity values • distribution and abundance of relevant CITES and Red List species at the landscape level • minimum viable populations of priority species at landscape level • status and representativity of protected areas • extension of areas suitable for complementary forest plantation establishment	International bodies Government agencies Subnational governments Forest owners NGOs Local communities

Additional country-specific information needs

While there is a base set of variables that are part of all NFIs, it is a country-specific task to find out the additional information needs that can possibly be covered by an NFI or NFMS. Such needs may arise from country-specific interests that may include variables related to non-timber forest products, forest fires, illegal logging, trees outside the forest, etc.

Part of the country-specific information needs assessment is also to systematically assess what information is accessible and available, upon which the assessment of additional information needs may be built.

Additional information requirements may also come from outside the forest sector, which indicates that NFI planning also needs to be communicated to other forest-related interest groups and that these groups have the chance to participate in planning discussions.

Note

Remember that an NFI is the only large area assessment of data on a renewable natural resource (the forests) covering the whole country. Identifying additional information needs may therefore also encompass not only the trees within forests but all trees in the country – and this would possibly lead to the idea to also include trees outside the forest (TOF) – which has considerable implications on the NFI design because it requires the inclusion of non-forest lands in the inventory work.

If TOF is a relevant resource in a country, there may be an interest in information about TOF and its development and contribution to rural livelihoods that warrants the expansion of the NFI to all lands. That leads to widening the scope of the NFI towards a “landscape inventory” or “national-level land-use inventory”. Then, the potential interest groups that should be invited to contribute to the inventory planning become much more diverse and much larger; planning and defining design elements will be an even greater task.

Example

Example: Integrated Land Use Assessment (ILUA) programme in Zambia

An instructive example in this context is the Integrated Land Use Assessment (ILUA) programme in Zambia that, in collaboration with FAO, went into its second cycle in 2011-2016. Read the **flnal report** of the programme second cycle.

A formalized information needs assessment (INA)

A formalized information needs assessment (INA) is a very basic preparatory task in the course of NFI design planning and is frequently listed as a standard element of planning. Such assessment mainly refers to the additional information needs beyond the standard set of NFI variables. The table below presents an overview of a formalized information needs assessment.

Goal: Assessing information needs		
HOW	**WITH WHOM**	**WHEN**
• Questionnaires (online or on- paper) • In-person meetings	• Direct users of NFI and NFMS results (e.g. forestry, wood sector, etc.) • Potential users of NFI and NFMS results (e.g. agriculture, energy, tourism, etc.) • National and international forestry experts (e.g. individual persons or organizations)	• Planning stage • Reporting and feedback stage after implementation stage (if needed to revise the information needs list for the next data collection period)

Let's look at the goals, format and participant profiles of an INA.

Goals - The major goal of an INA is to complete a list of information needs that support guiding the NFI and NFMS planning process. However, by launching such an information needs assessment—in whatever format— important secondary goals may also be achieved: the NFI planning process is made widely known, and potentially interested users become aware of it and can get their clarifications addressed.

Format - INAs may be organized in different formats, as questionnaires (online or analogue), or as discussions in smaller focus groups or larger plenary type of meetings. Identifying needs based on discussions or meetings is probably a much more efficient way than just written or anonymous questionnaires – meetings help clarify doubts and set the right expectations from an NFI. Also, in meetings, information needs may emerge that need first to be discussed and jointly developed to be eventually formulated. Of course, meetings are more difficult to organize and it may be a challenge to gather the potential NFI users at the same time and place.

Questionnaires may deliver faster answers but lack the possibility of jointly elaborating and specifying information needs. For example, when there is a list of topics in a questionnaire that may be ticked as information needs, such a list is likely to be incomplete and people might tick more supplementary “nice-to- know” topics than absolutely necessary “need-to-know” ones.

Participants - Participants of such INAs are all users and potential users of NFI and NFMS results. Sometimes, therefore, these assessments are also called “user needs assessments”.

The assessment should be made as inclusive as possible, inviting representatives of all potentially interested groups, including not only government officials, but also representatives from NGOs, research institutes, technical cooperation projects, land owners´ associations, the general public, etc. The invitations should not only address representatives from the forest and wood sector but also 'neighbouring' sectors like nature conservation, agriculture, tourism and energy.

Quick tips!

It is a challenging task to have such a complete list of potentially interested parties, and one may encourage the invited ones to also identify further potentially interested stakeholders in their “surroundings”. The assessment of the user groups, including the potential user groups, is an important component of an information needs assessment.

If the assessment is organized as a meeting, that also gives a platform for discussions, the NFI planners and experts have an important role and need to be present; they must explain about the role, possibilities and limitations of an NFI, and ask details about information needs that later on allow a smooth translation into indicator variables.

Organizing an INA

It is important to have the information needs assessment early in the planning process as there might be information needs that require reconsidering some standard elements in NFI and NFMS planning. However, it may also be that there are no surprises and that the standard information generated by an NFI fulfills all expressed information needs.

If the assessment is organized as a meeting, it is always helpful to have a submission of written statements on information needs prior to plan appropriately. Ideally, such a meeting is facilitated by a professional moderator, possibly with some background in forestry and forest monitoring.

At the beginning of such a meeting on INA, there must be a clearly and easily accessible formulated introduction about the reason why the government wishes to implement an NFI or NFMS. Enough time should be reserved for such a presentation and for subsequent questions. One cannot assume that the concept of an NFI is well-known among the interested parties—or that an NFI is acknowledged as a worthwhile investment in the first place.

Quick tips!

Frequently, even academic foresters think automatically of 'forest management inventories' when hearing the term 'forest inventory'. The idea behind an NFI often needs to be explained patiently because it is so different from a forest management inventory, where the economic usefulness appears to be more obvious from the outset. It is often a difficult task to make clear that an NFI is not meant to immediately support stand-wise forest management but that it has a more strategic and political character. Specific information needs that arise from questions on small-area forest management should, therefore, be discussed and checked whether they really relate to the mandate of an NFI and merit further consideration in NFI planning.

When explaining the background of an NFI in such discussion groups of potential users, it is helpful to present examples of NFI results from other countries as this best illustrates what one may expect from an NFI—and what possibly not. It is also a fact that the best discussions on specific information needs in a country will be done once the specific country report of the NFI is there. This means that the discussion about information needs should not stop with the implementation of the NFI but should be considered a continuous process that is also part of the results´ discussion after having published the NFI reports.

The dynamics of such information needs discussions may be such that unrealistic expectations are being expressed. Therefore, the moderator should insist that one tries to translate information needs directly into indicators viz. variables that can be observed and measured. The next discussion point may be whether such observation and measurement of indicator variables can realistically be integrated into an NFI, considering implications on logistics, capacity and cost.

Reality check

If, for example, the assessment of biodiversity is addressed and samples on insect abundance or presence are to be taken on each plot, one may discuss questions on what the field protocol may look like, how such an idea depends on the season of the year and the time of the day, how samples need to be preserved and transported, and how the lab analyses can be organized. Of course, further practical questions may be addressed, including: what would be the additional time/cost per plot and how to cover that; whether a normal field crew can be trained to do such measurements or is an (expensive) expert needed to accompany the field teams—if so, whether experts will be available at all (or whether they can be paid) to do the identification of insect species.

Role of the moderator

The moderator(s) should try to channel the expectations such that the discussion does not turn into formulating general wish lists—but that a realistic focus is being maintained—without, however, leaving behind interested parties. It must be made clear that an NFI has a core mandate and core funding, and that the design allows to accommodate additional variables—but not all; and that feasibility and funding is a relevant planning point.

In order to keep the discussions and expectations focused, the moderator may encourage participants to be specific regarding what a particular information need would be for, by asking questions such as: how will or might the corresponding NFI results be used and by whom; how will the corresponding results make a difference? Such arguments of a specific expected use will give more weight to an expressed information requirement.

Did you know?

It may turn out that an immediate use of such results cannot be formulated—but that one would expect it to gain relevance in the future. This is a valid argument, of course, because an NFMS generates a time series that becomes more and more valuable with time.

For example, several decades ago, the inclusion of deadwood variables was not a topic in NFIs— and nobody would have been able to release funds for the integration of measurements of deadwood into an NFI. Today, we would be happy to have deadwood information from the permanent plots from long ago. Of course, it is impossible to predict the relevance of specific variables, but a convincing perspective may be a reason to seriously consider integrating such variables.

An additional question is about the necessary precision of estimation that is expected for specifically required information. The higher the expectations towards reducing uncertainties, the higher the inventory cost. This question is, in fact, a very difficult one; one may orient oneself at the precision levels achieved in neighboring NFIs rather than defining one´s own expectations towards precision. Part of the process will also involve establishing a prioritization of which information will be more relevant in terms of producing precise estimates.

As you will see in **Course 3: Introduction to sampling**, optimizing an inventory design needs to establish which variable or group of variables are going to be used for the optimization. The prioritization process during the INA will help determine what these variables are.

Assessing capacity needs: enabling planning and implementation

The presence and availability of corresponding capacity on all levels is among the most relevant elements in establishing an overall environment that enables a country to implement and fully manage an NFMS under their own ownership. This refers to both individual and institutional capacities.

An assessment of the existing capacity plus a comparison to the needed capacity is a relevant step not only for the successful implementation of an NFI project, but above all, to warrant sustainability (i.e. mainly longer-term functioning) of an NFMS program.

A capacity needs assessment aims to provide a baseline of existing national capacities in the disciplines and tasks that are required in setting up a forest monitoring program and shall identify strengths, gaps, and above all, the need for action related to a successful and sustainable NFI design and NFMS implementation.

While an INA can be considered a relatively short-term activity that needs to be completed before an NFI can reasonably start, the capacity assessment has both short-term and long-term elements.

Regarding the short-term elements, the assessment of capacity needs aims to get the NFMS on the way. If critical gaps in the current capacity are identified, they need to be filled rapidly, which may require contracting external advisors such as FAO or NFI experts from (preferably) neighboring countries.

Of course, in order to generate full country ownership and to warrant sustainability of the NFMS, also in the form of institutionalization, the identified capacity gaps should be filled in the long run with national experts. It may be necessary then to make a longer-term plan for such capacity development, which may include raising student interest on NFIs and encouraging academic studies in disciplines that relate to forest monitoring (i.e. sampling and modelling statistics, remote sensing, project planning, forest management, forest inventory, etc.).

Regarding the formalization of capacity assessments for forest monitoring, FAO has taken action. In 2020, the Organization published an instructive information note, **Strengthening national forest monitoring systems through a comprehensive capacity needs assessment** on a formalized assessment tool. The elaboration that follows is based largely on this publication; reading this document is therefore highly recommended. The assessment tool that FAO developed is a useful guide of the capacity assessment process—the box below summarizes the significance of such assessment.

Note

FAO's new **NFMS assessment tool** facilitates the identification of needs and gaps in order to establish or strengthen a country's forest monitoring. The tool is based on FAO's VGNFM and reinforced with the **REDDcompass** resources of the **Global Forest Observations Initiative (GFOI)**. It also incorporates 50 years of FAO experience gained in the field, working together with countries around the globe. The assessment tool, which provides an easy way to use and implement the VGNFM, is free, Excel-based and available in English, French and Spanish.

The tool supports the strengthening of an existing NFMS, including capacity assessment of the system and facilitation of dialogue with key national stakeholders, helping to pool their flrst-hand knowledge of a problem or development challenge and identify possible solutions. It also helps to identify the institutional dynamics, strengths, weaknesses and opportunities for improvement of an NFMS. A useful complimentary series of guidance, good practices and practical tools based on local circumstances when running a capacity assessment, is available on FAO's **Capacity Development website.**

Elements of a country-level capacity assessment on NFM

The assessment of available capacities and gaps refers both to individual and institutional capacities, where the latter may be considered the basis upon which the former are founded. The field to which a national-level capacity assessment refers to is available in the table below. Capacities not only refer to technical-scientiflc knowledge, skills and experiences, but also institutional features and soft skills.

Measurement and estimation	Identification of information needs
	Data management and archiving
	Preparation
	Design for field data collection and remote sensing
	Operational design (remote and field sensing)
	Data management, data analyses and documentation
Reporting and verification	Communication and dissemination Preparation and submission of reports

Institutional arrangements	Institutionalization Developing national capacity Developing partnerships and collaboration Strengthening research and research institutions in forest monitoring Mandate Stakeholder identification and engagement Integration of young experts Impact assessment

It is obvious that the capacity required to implement an NFMS needs to be established in a team, and that parts of the capacities are knowledge-based and require good experience in the field. While the domains of measurement, estimation, and remote sensing require up-to-date technical-scientific capacities that are based on a solid academic background, communication and institutional arrangements may require some seniority, experiences and networks to the stakeholders and decision makers.

The relevance of institutionalization is founded on the fact that it gives the NFMS the necessary long-term character and sustainability and generates the basis for the staff to accumulate experiences and knowledge.

Summary

Before we conclude, here are the key learning points of this lesson.

- Although there is a base set of variables that are part of all NFIs, it is a country- specific task to find out the additional information needs that can possibly be covered by an NFI or NFMS.
- Additional information requirements may also come from outside the forest sector - making it necessary to communicate NFI planning to other forest- related interest groups and ensure their participation in discussions.
- A formalized information needs assessment (INA) is a very basic preparatory task in the course of NFI design planning and is frequently listed as a standard element of planning.
- A capacity needs assessment (CNA) is among the most relevant elements in establishing an

overall environment that enables a country to implement and fully manage an NFMS - under their own ownership.

Lesson 4: NFI workflow

This lesson focuses on planning and preparing the workf1ow of NFI data collection, which is part of an NFMS. While NFIs can be organized and designed very differently with many workf1ow variations, this lesson focuses on what may be considered a standard workflow. It also discusses and elaborates on how to plan an NFI data collection based on the national circumstances and the institutional and management structure.

Learning objectives

At the end of this lesson, you will be able to:

1. Identify the institutional needs to implement the data collection.
2. Acknowledge the relevance of a detailed protocol for the data collection.
3. Identify the common steps to implement an efficient and quality checked data collection.

Institutionalization: Administrative management and funding

Successful field data collection requires a mobilization of human resources, clear assignation of roles and responsibilities of the institutions and people in charge, as well as logistical capacities. In summary, it requires efficient management and organization.

The institutionalization of the NMFS has been addressed previously in Lesson 1 as one of the core elements when generating an enabling environment for establishing an NFMS and when aiming at country ownership and long-term functionality (sustainability).

Various models are possible for such institutionalization; most commonly the NFI/NFMS headquarters are integrated into the forest service or into a research institution such as a university or a forest research station (usually part of the forest service). A long-term perspective is crucial; therefore, NFI/NFMS headquarters should be integrated into a permanent institution that can count on core staff that is permanently dedicated to the subject.

This refers mainly to the upper management of the NFI/NFMS—more technical tasks can also be outsourced where close supervision is always recommended. Tasks may also be subdivided, where analytical tasks (e.g. design development, data management, data analyses) are given to a research institute and the overall coordination to the forest service (ideally, within the forest policy sector).

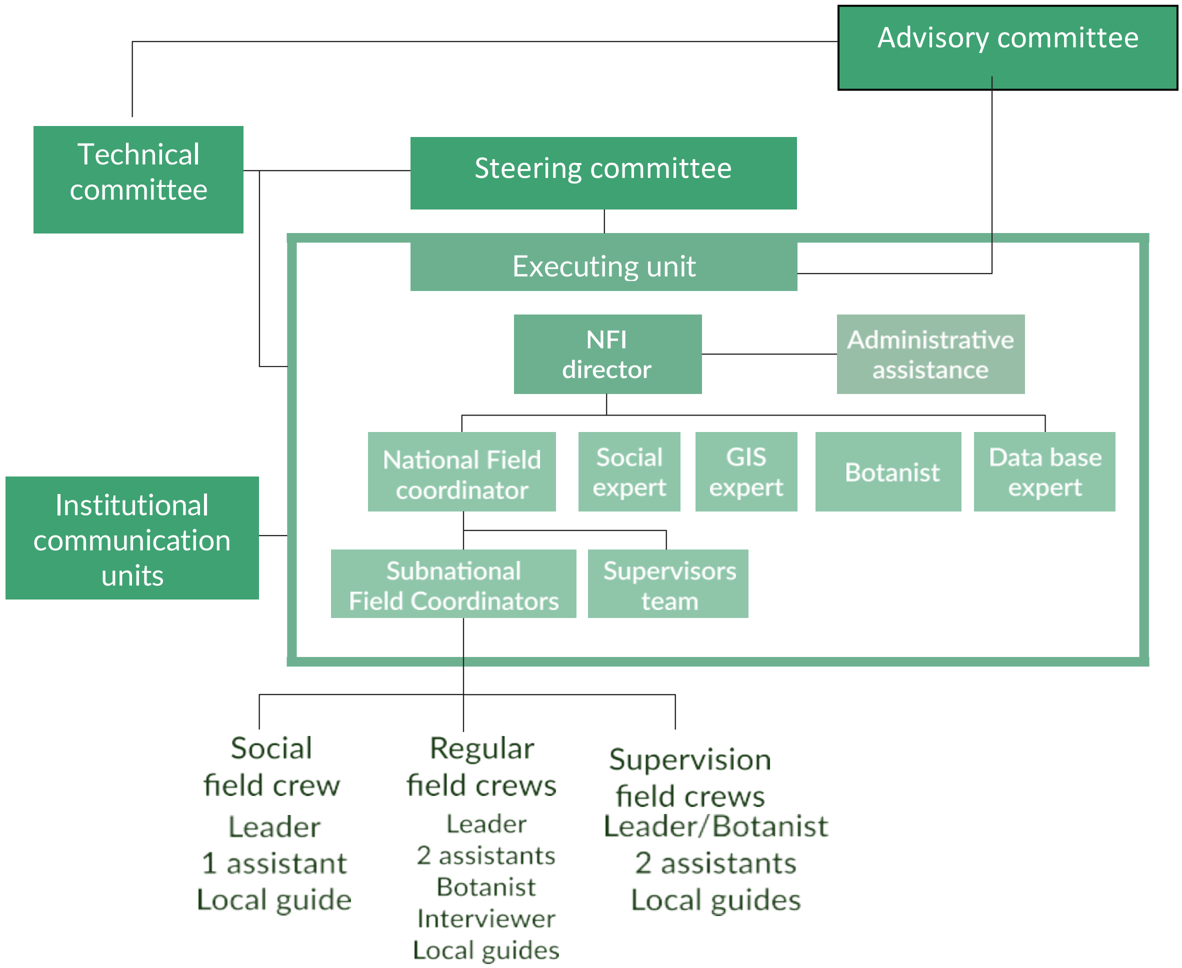
Did you know?

An important factor for institutionalization is the securing of sufficient funding for all NFMS-related activities, including data collection. Funding for NFIs frequently comes from international collaborations (either as donations or loans), but this is usually on a project basis and not long-term. For a long-term NFMS program, continual core funding is required, which often comes from the national budget and is sometimes topped up on a regular basis by international contributions.

Management structure: Responsibilities in NFI/NFMS implementation

While the collection of field data and remote sensing data is sometimes considered the major task to be organized when setting up an NFI/NFMS, there are various other tasks of comparable relevance. This includes coordinating the NFMS with stakeholders and other sectors, developing the technical design, and implementing measures of quality assurance, as well as data analysis, reporting, and communicating the results to the potential users and the general public. Finally, this also includes more general tasks such as managing the finance, human resources and logistics.

When talking about the management structure, the two dimensions, technical and political/decision-making of national forest monitoring, must be kept in mind during all planning and implementation measures. The tasks occur at different times and require efficient management of teams of experts. An example of such a comprehensive management structure is given below:



A Steering Committee acts as the top entity for decision making about the political, inter-institutional, financial, and administrative issues. It should be chaired by the lead institution of the NFI/NFMS and integrate representatives from other relevant national partners. The steering committee accompanies and supervises the technical processes. The steering committee meets on a regular basis and its members are not on the payroll of the NFI/NFMS institution but steer the process from a perspective "external" to the government, the society and the potential users.

The Technical Committee is the technical body of the NFI/NFMS that advises the steering committee and the Executing Unit on NFI statistical design, methods and technology for data collection, analysis and reporting. It should consist of scientific professionals from government institutions, research institutions and national universities. Commonly, experts with backgrounds in fields that include forestry, statistics, data sciences, remote sensing, etc. are needed.

If the funding of the NFI/NFMS institution allows, it is good to have at least one technical expert permanently installed in the Executing Unit. More experts can then be invited to collaborate in a Technical Advisory Committee that consists of external experts and meets on a regular basis and when requested by the NFI/NFMS institution to discuss and advise on technical issues.

The Executing Unit is responsible for all technical-operative NFI/NFMS matters, including the technical planning and implementation of the NFI activities. Basically, it consists of the following staff:

1. The NFI director is the chief of the Executive Unit of the NFI/NFMS institution, and reports to the Steering Committee.
2. The Field Staff consists of a National Field work coordinator and the field teams. In larger programmes, one may establish sub-national executive units.
3. A Technical Expert who is familiar with the technical-scientific side of the NFI/NFMS planning, implementation and reporting, in the best case also including remote sensing. This technical expert may also be responsible for overseeing data management and analysis. Several technical experts can fill this role.

Quick tips!

If one person with overall knowledge is not available to fill the role of a Technical Expert, other expertise may be required but does not justify a permanent position in the NFI/NFMS institution. Such expertise may then be contracted from specialized service providers. This may refer to the design of the information system, to data analyses that can hardly be completely done by one technical expert only in the executing unit. Responsibilities may refer to remote sensing data analyses or to communication issues during reporting.

Collecting relevant data

The information that is expected from an NFI and an NFMS come from the analyses of the data collected. The efficient collection of relevant data is, therefore, a core "production" activity in any NFI and NFMS. All sorts of available data and information—including maps, earlier inventories´ reports, results of research studies—are used in the planning phase of an NFI. The NFI then gathers new and updated data on trees and forests at the national level. These new data come essentially from two sources:

1. **Field data**: collected by sampling approaches (that may include data from interviews with forest users and data on trees outside the forest).
2. **Remote sensing**: these data may refer to forest type mapping but also to modelling and regionalization of target variables. In any case remote sensing data analysis requires ground references (for modelling and for ground truthing) so that they will usually be linked to the sample-based field observations.

The field data collection is a lengthier and more staff-intensive endeavor that also requires significant logistical planning. The focus of this lesson is, therefore, on field work organization.

Who does the field data collection?

This section provides an overview of fieldwork.

The number of field teams depends on the **total number of field plots**, the **time period that is foreseen for field work**, and the **availability of suitable person-power**. Finances play a role as well—with more field teams, the inventory work can be concluded in a shorter time period—but the equipment required (including measurement devices and cars/means of transport) will be higher. Moreover, the higher the number of field teams, the more complex training, supervision and quality control becomes.

Besides the regular field teams, specialized field teams might be required for specific tasks (e.g. socio-economic interviews on use of the forest, measuring mangrove forests, etc.). The specific topics to be covered in field work determine whether such specialized field teams are needed or not. Let's spare some time to understand the types of expertise required in field teams.

Regular field teams - Regular field teams record the variables of the NFI. They should be led by a professional with good technical and coordination qualities, who knows well the country or region where the plots will be established. Other members are assistant(s) with good skills on field orientation and forest mensuration.

An expert for tree species identification is required. Specialized botanists are scarce in many regions—and often expensive given the available resources per field team. A specialized botanist is the optimal option but often, for tree species identification, one needs to rely on the knowledge of local wood workers/tree spotters. It may happen then, that field teams face the situation that some of the trees have different local names in different areas.

A consistent translation of local names into scientific names must be warranted. One may collect samples of non-identified and doubtful species and send them to an herbarium for identification. This, of course, increases the logistical efforts, and costs.

Local guides - Local guides are very important for a successful NFI because of their knowledge of the area and the local populations, customs and languages. Also, the integration of local communities in NFI field work increases the acceptance of the NFI work and contributes to general capacity development on forestry matters at local level.

Additional experts - If variables to be observed cannot easily be integrated into the general mensuration training, additional experts may need to be integrated into the regular field teams, such as experts in biodiversity of particular taxa or in socio-economic forest surveys if these are to be combined with the regular field work. However, each additional expert increases the cost per field team and per plot.

Interview field teams - In the case of interviews with forest users, these constraints have a significant weight in the NFI. Specialized interview field teams may then be deployed. These field teams usually work independently of the regular field teams.

It is convenient that these field teams visit the field plot (or its surroundings) before the regular field teams. Such visits may help to make the NFI work known and generate acceptance by local communities, as it might be considered suspicious when field teams with surveying devices are around doing measurements on lands where there are possibly no legally binding land ownerships assigned to the land tenants. Such pre-visits to the field plots may also be a good opportunity to identify and contract local helpers for the regular field teams.

Supervision field teams - Supervision field teams are responsible for quality checks. They are led by experienced forest inventory experts and report directly to the NFI director. The supervision field team is composed like the regular field team.

Models for assembling field teams

Depending on the NFI design, capacities and resources available, different models are common for assembling NFI field teams. These include:

Direct	Indirect	Mixed
Field teams are from the permanent institutional staff	Field teams come from service providers/consulting companies	Institutional staff and outsourcing

The direct model

Direct implies that all the field activities will be done directly by the national NFI/NFMS institution in charge and by staff with long-term contracts. This requires enough trained staff who are available full-time for the field work period and have other duties during the remaining time. This is difficult when organizing the NFI periodically (for example, every 10 years)—but a very suitable option exists under a panel system where a fraction of 1/m field plots is observed every year in a ***m*** years cycle.

Permanently employed field teams accumulate experiences and will likely contribute to reducing measurement errors. Also, training efforts will often be smaller in the panel system, because it ensures that field crews do not need retraining every time a brand new inventory is done. A logistical challenge with this direct model is that the coordinating institution is responsible for all devices and transport / cars. Any defect or loss would need to be dealt with by the institution.

The indirect model

Outsourcing is another option: it means that the institution contracts service providers/consulting companies. The advantage is that the contracts can be formulated exactly for the time period of the field work and may include all transport and measurement devices needed to be supplied by the company, including responsibilities for repairs, losses, etc.

Often, consulting companies deliver high quality field work as they see the NFI also as a future source of contracts. However, as consulting companies are profit-oriented and often tend to strive to minimize their efforts, clear contractual agreements need to be made in what refers to quality control—and consequences for non-compliance need to be stipulated. Supervision efforts may be higher than with the option of staff members doing the field work.

Training efforts will be higher or lower, as compared to staff member training, depending on the sustainability of hiring a reliable service provider versus that of government staff in between cycles.

Of course, the two field team options (direct vs. indirect) may also be combined, in situations where, for instance, there is not sufficient person-power in the institution for the direct option.

A typical workflow for field data collection

The workflow for field data collection may vary among NFIs, but the generic steps are essentially the same, and can be broadly divided into the phases **before**, **during** and **after** regular field work.

Before the fieldwork

➲ **Elaboration of the field manual (field protocol)**

A detailed guide for the fieldwork needs to be written down and tested before training and field work start. All variables need to be described there in terms of definitions, measurement approaches and how to deal with potentially challenging situations.

In case mobile data collection technologies should be used, the field manually needs to be “translated” into a mobile application for data entry. Open Foris Collect Mobile(opens in a new tab) is a great support to that. If field data are to be co-registered with remote sensing data, the accuracy in determining the field plot position is paramount. In this situation, high quality Global Navigation Satellite System (GNSS) receivers should then be used.

The field manual should also contain a communications strategy between field teams and between field teams and the NFI headquarters.

If samples are to be taken (e.g. soil samples or botanical samples) it must clearly be described how to do that and how to preserve and transport the samples back to the headquarter or the laboratory directly.

Moreover, the field manual should explicitly address security and safety issues, including ensuring proper health insurance (e.g., snake bites, malaria or small accidents maybe relatively common in certain areas), as this is paramount in all fieldwork. The field teams must know what to do in case of an emergency. Where possible, they may be equipped with satellite telephones.

➲ **Assembling the field teams**

The number of sample plots and the time period envisaged for the field data collection determine jointly the number of required field teams. These teams need to be assembled and 'secured' well ahead of training and field work. Experienced team leaders need to be identified, as they have more responsibilities, including the detailed planning of the field work.

Gender policies should be considered, as should be the inclusion of young enthusiastic foresters or forestry students, who may become future forest monitoring experts.

A sturdy physical health condition is a must for field team members as forest fieldwork over weeks and months is a physically demanding job.

➲ **Planning for transport and general logistics**

Accessibility has an enormous influence in the fieldwork cost. An overall accessibility analysis needs to be conducted per field plot in order to estimate travel times. Maps and recent remote sensing imagery might be purchased for this purpose. The detailed planning per field plot is then done by the field teams.

Planning for general logistics such as board and lodging during field work is the responsibility of the field teams. Other matters of general logistics that need to be organized include the transport and delivery of samples, if, for example, soil or botanical samples are taken.

➲ **Equipment**

The coordination team needs to make sure that all teams are equipped with the same necessary measurement devices, as defined in the field protocol. The coordination team should also have a set of replacement devices in case that there are losses or defects.

Additionally, transport needs to be organized and vehicles assigned to the field teams. Field teams commonly have a size such that they can fit into one vehicle. In case of outsourcing, it facilitates the workload for the coordination team if the service provider uses its own equipment and cars. Of course, their measurement devices need to conform with the field protocol—and the cars need to be suitable for demanding fieldwork.

➲ **Training**

Training is a core component in planning for fieldwork. The better the field crews are trained, the better the results that may be expected. Details on training are in **Course 4: Introduction to fieldwork**, and also in section 5.3.4 of *FAOs Voluntary Guidelines on National Forest Monitoring (VGNFM)*.

Depending on the experiences of the field teams, an initial training may take between 3 and 8 work days. After having gone through the individual training steps listed in Course 4, one may have a field testing or pilot phase, where real sample plots are visited and measured, jointly by several field teams. This allows for intensive communication between field teams, generates confidence in managing the procedures and may also give indications as to how to divide labor between the field team members. As a result of such piloting, the field manual may need updating.

An important component of training is to insist that each field team carries responsibility for the whole inventory (at the end, it is the quality of their data that co-determines the quality of the final results) – and that they should be proud to be part of the NFI project. Motivation is the issue here! And motivation is often linked to aspects such as daily payment rates that adequately compensate for the difficulty of fieldwork, humane working conditions as well as having secure health insurance in the case of illness or injury.

➲ **Socialization and access**

Socialization and access permission means that local authorities, communities, landowners, farmers have been contacted (possibly through previous trips to field work locations) with the objective to communicate the upcoming NFI field work.

Distributing a handout with a brief description and contact addresses/phone numbers may be helpful here. Wider access to the population through information campaigns including radio or newspapers may ensure a larger fraction of the population is aware of the upcoming work.

➲ **Preparing for data analyses**

Preparing for data analyses is a good idea even before starting the field data collection. That implies setting up a pilot data set to test the data entry and data management system and to test-run the data analysis system. Such pre-analysis may also help identify potential gaps in the field protocol or problematic data structure for the analysis.

Also, when integrating the collection of soil samples or taking botanical samples for later identification, the corresponding labs need to be contacted and the lab analyses coordinated – and planned for budget-wise.

During fieldwork

➲ **Field data collection**

The FAO VGNFM elaborate in section 5.3.6 (Fieldwork) on suitable procedures for field data collection. A nice hands-on example from an NFI is in ***chapter 3.1. of the report of the FAO-supported NFI in Liberia.***

All steps for measurements and observations are described in detail in the field manual and need to be followed. It will take some sample plots until the field team has found the optimal division of labour. It may also be an idea to change roles now and then in order to avoid a detrimental routine, provided that the quality of the data obtained does not suffer from such changes.

Before leaving the plot, the team leader should check that plot measurements are complete and entered into the data logger, that all devices are there, and that all members of the field crew are ready to return. A checklist is useful for this task and may be a part of the field protocol. When tablets or data collectors are used, validation rules are included in the application to support the *in-situ* check, for example in **Open Foris Collect Mobile** and **Open Foris Arena mobile.**

➲ **Field control measurements**

Control measurements are a standard component in all good forest inventories and serve as an efficient measure of QA/QC. It is said that between 5 and 15 percent of the field sample plots should be visited by a control team to confirm compliance of the measurements with the stipulated quality standards.

More information about this check cruising / control measurements is available in **Course 6: Quality assurance and quality control in an NFI**.

After fieldwork

➲ **Field forms and report revisions**

In case paper forms were used, the data should be entered into the data management system as early as possible after data collection so that potential issues may be immediately tackled. If mobile data loggers were used, plausibility checks are usually part of the software. It is important to be sure that the taxonomic names are correct, that the plot information is complete for each variable, and that observations on inaccessibility or other issues are duly reported.

The NFI coordination unit should review the information as soon as possible after the fieldwork for asking questions for clarification to the field crews.

➲ **Blind checks**

Blind checks may be carried out by the control teams, visiting measured plots again and checking for quality and completeness. This is described in detail in Course 6: Quality assurance and quality control in an NFI.

Integrating remote sensing data

The focus of this lesson is on data collection from field sampling—but remote sensing has evolved rapidly (and continues to evolve) as a relevant data source in forest monitoring. Remote sensing in its generic meaning refers to doing observations remotely, that is: without direct contact to the object of interest. For large area forest monitoring it is mainly remote sensing from above (satellite imagery, aerial photographs) that is being applied, but normal terrestrial photography also counts as remote sensing when we use the photographs for photogrammetric measurements.

Remote sensing imagery is often available "wall to wall"—that means: for the entire inventory region; as opposed to the sample-based field observations which do not facilitate higher resolution spatial representations of the results. Through satellite remote sensing, forest or forest-type maps can be produced and these can support data analysis and provide a convincing element in reporting.

Also, remote sensing data can be linked to field observations and models established that predict field variables (e.g. plot biomass) from the remote sensing data. These models may then either be used to:

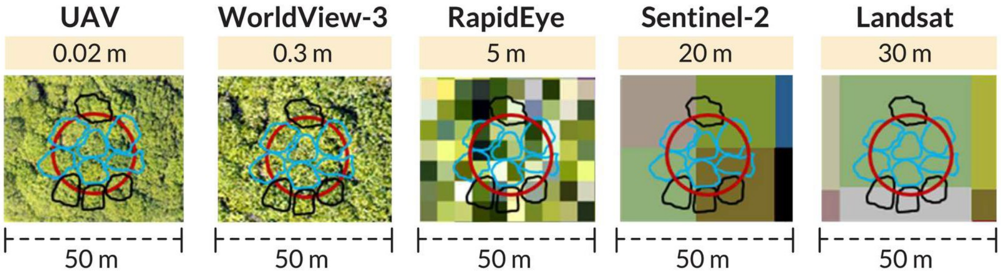
1. improve the precision of estimation of the field observations (remote sensing data are then used as so-called ancillary variables); or
2. produce continuous maps of target variables, such as a biomass map. The models generated are used to predict the plot volume everywhere outside the field plots, which is the basis for mapping. When using remote sensing-based models for map generation, it is called "regionalization" of a variable.

When such models are to be established, one needs to make sure that the field plot and the remote sensing data are geometrically co-registered as accurately as possible. This means making sure that the spatial coordinates assigned to the field plot and the corresponding signal from the imagery matched as closely as possible. Of course, one will never succeed to make a perfect match of a field plot to a remote-sensing pixel, but one should strive to minimize these mis-registration effects by using high-accuracy GNSS receivers to determine the geographic position of the field plots, and one should work with geometrically corrected remote sensing maps.

When using remote sensing imagery for modelling, not only the spatial co-registration should be accurate but also the temporal one. The used remote sensing image should correspond to about the same time as when fieldwork is done. The larger the temporal distance between the two, the larger the uncertainties that blur the models. If drones are used (e.g. to fly over the field plots) one can easily arrange for this temporal match (given that the weather is good and the flight licenses are there), but for satellite imagery that needs to be commissioned, one needs to be careful and selective because it is not guaranteed that appropriate imagery will be produced within a specifically defined time window. Satellite sensors and their imagery are categorized using four different kinds of resolutions:

Spatial resolution	The “sharpness of the image” = pixel size = size of the smallest object that can still individually be distinguished. Spatial resolution is usually given in meters pixel size.
Spectral resolution	The number and width of the spectral bands (“colours”) for which the reflected sunlight is separately recorded. Spectral resolution is usually given as the number of different spectral bands.
Radiometric resolution	The number of different colour intensities that can be distinguished per spectral band. While the human eye can, for example, only distinguish about 20 intensities of red, remote sensing sensors may distinguish thousands. Radiometric resolution is given in the number of bits that is available to record the reflection intensity per pixel. A 10-bit resolution means that 210 different intensities will be distinguished.
Temporal resolution	The time between two image acquisitions at the same location on earth. Temporal resolution is given in days of re-visit time.

The figure below illustrates different spatial resolutions. The resolution to be chosen depends entirely on the purpose of the remote sensing integration. For larger area forest type mapping, Sentinel or Landsat imagery will be the choice. If one is interested in more details—possibly tree/crown wise analyses—one would need to go for much higher resolutions.



According to the above definition, terrestrial approaches are also part of remote sensing, like terrestrial photography or terrestrial laser scanning (TLS). The latter is quite popular currently and in rapid development. A TLS device scans the surroundings and records the 3D coordinates where the laser beams have been reflected. The resulting point cloud data allows for modeling of features of interest, e.g. the tree trunk or the whole tree.

Currently (2023), there is a lot of research being done to further develop the use of TLS devices in forest inventory fieldwork. Maybe it will open up new options to make fieldwork more efficient in the future, but this field is still in development in regards to cost-effectiveness for national forest inventories.

Note

All remote sensing data analyses require specialist knowledge—and this implies that specialists should also be integrated in the planning phase so as to make sure that the suitable imagery and software are chosen.

Open-source software such as QGIS can facilitate practically all analyses tasks required for NFIs, in particular in combination with the open source statistical package R, Python or Google Earth Engine. Of course, sufficient knowledge and training is needed for both.

Summary

Before we conclude, here are the key learning points of this lesson.

- The institutionalization of an NMFS is one of the core elements when generating an enabling environment for establishing an NFMS and when aiming at country ownership and long-term functionality and sustainability.
- The efficient collection of relevant data is a core “production” activity in any NFI and NFMS.
- Depending on the NFI design, capacities and resources available, different models are common for assembling NFI field teams, these include direct, outsourcing, and mixed models.
- The workflow for field data collection may vary among NFIs, but the generic steps are essentially the same, subdivided into the phases “before”, “during” and “after” regular field work.

