



Food and Agriculture Organization
of the United Nations

First DRAFT SECTION III

**FAO Voluntary Guidelines on
National Forest Monitoring**

Comments are welcome !!

Sections I and II:

<http://www.fao.org/3/a-mk174e.pdf>

08.09.2015

PRESENTATION

Responding to the COFO's request⁽¹⁾, FAO has been working in close collaboration with member countries and relevant organizations on the preparation of the voluntary guidelines on national forest monitoring, taking into account the requirements for REDD+ reporting and the principles and goals of the Forest Instrument.

The preparation process started after the request, with the route map and the definition of the structure of the document. A two phase approach was defined to divide the process, Phase I comprised the development of section I and II with the definition of national forest monitoring, the scope and the principles, and phase II is then the compilation of good practices and technical recommendations on national forest monitoring.

COFO 22 endorsement of section I and II ⁽²⁾ prepared in Phase I was an important step and milestone in the preparation process and highly related with the final version of the document. These two first sections provide background, the definition of forest monitoring and the principles for a national forest monitoring system which are the key elements guiding the technical recommendations and further development of the document.

The first draft for the section III of the document has now been finalized, and is included in the present document for discussion and further comments. This last section is based on a thorough literature review as well as on inputs provided in international workshops and technical meetings, which have taken place in 2014 and 2015. Valuable contribution and advice has been received also from many institutional stakeholders.

In order to provide an opportunity for further comments and inputs, the document will be available in a virtual forum <http://www.Fao.Org/fsnforum/forum/discussions/forestry>, from the 1st to the 21st of October. We invite you to participate and provide your comments and inputs.

For more information

EMAIL: FAO-NFMA@fao.org, WEBSITE: www.fao.org/forestry/fma

Contact person:

David Morales Hidalgo (David.Morales@fao.org)

¹ FAO (Food And Agriculture Organization of The United Nations). 2012. Report on the Committee on Forestry, Twenty-First Session: COFO 2012/REP paragraf 50, page 7. Rome, Italy. Available at: <http://www.fao.org/docrep/meeting/026/me988e.pdf>

² <http://www.fao.org/3/a-mk174e.pdf>

DRAFT

SECTION III – FAO-NFMA Voluntary Guidelines for National Forest Monitoring

CONTENTS

1 INTRODUCTION 5

2 THE FOUNDATION ELEMENTS 6

 2.1 Institutionalization..... 7

 2.2 Developing national capacity 8

 2.3 Developing partnerships and collaboration..... 9

 2.4 Strengthening research and research institutions in forest monitoring..... 9

3 THE STRATEGIC ELEMENTS.....10

 3.1 Mandate:10

 3.2 Identification of information needs10

 3.3 Stakeholder engagement12

 3.4 Communication and dissemination.....13

 3.5 Integration of young experts13

 3.6 Data management.....13

 3.7 Impact assessment14

4 THE OPERATIONAL ELEMENTS15

 4.1 Preparation.....16

 4.1.1 Definition of the population of interest and sampling frame16

 4.1.2 Identification and specification of variables to be recorded17

 4.1.3 Definition of levels of precision for the expected products.....17

 4.1.4 Review of existing information19

 4.1.5 Available expertise and manpower19

 4.2 Statistical design20

 4.2.1 Integration of field and remote sensing data21

 4.2.2 Sampling design21

 4.2.3 Plot design25

 4.2.4 Estimation design.....27

 4.2.5 Model selection27

 4.2.6 Quality assurance: errors in forest inventory28

 4.2.7 Design of control measurements30

 4.3 Operational Design32

 4.3.1 Writing the field protocol (field manual)32

 4.3.2 Design of information management system34

4.3.3	Building the teams	34
4.3.4	Training	35
4.3.5	Field work planning	36
4.3.6	Field work implementation	37
4.3.7	Supervision of field work	38
4.4	Data management, data analyses and reporting	38
4.4.1	Data entry and management	39
4.4.2	Data quality control	39
4.4.3	Define the specific analysis steps in order to answer monitoring questions	40
4.4.4	Data analyses and estimation	40
4.4.5	Reporting	41
4.4.6	Communication and dissemination	42
4.4.7	Discourses on inventory approaches and results.....	43
4.4.8	Evaluation and impact analysis	44
5	CONCLUDING OBSERVATIONS	45

SECTION III: GUIDELINES

I INTRODUCTION

Establishing and running a National Forest Monitoring System (NFMS) is a complex scientific-technical exercise on the one hand but also an organizational challenge. It is at the same time an immediately policy related activity which is one of the pre-conditions for informed management and policy decisions regarding the sustainable use of the forest and tree resources and also regarding the efficient protection and conservation of forest ecosystems. In that, NFMSs support governments in fulfilling their obligations to continually develop, monitor, and report on the national asset “forests and trees resources”.

It is acknowledged from the outset that national circumstances are so variable in terms of biophysical conditions (e.g. forest types and forest utilization practices, road infrastructure), economic and financial challenges and possibilities, management and use (including the history of forest management and forest service, forest research and education, traditions in forest monitoring), among others, that there is definitively no “on-fits-all” optimal solution. It is rather so - as in so many other undertakings as well - that there are various suitable and good technical and organizational options that need to be combined such that an efficient implementation can be achieved. This implementation must be target-driven in that it is oriented towards the specified objectives and it must be realistically feasible within the available resources regarding time, budget and human resources.

In this section, technical issues of implementation are specifically addressed based on the principles introduced in the previous sections. A variety of planning issues are presented, some of which are technical while others are of organizational or strategic character. A detailed and comprehensive elaboration of guidance is given. However, it has to be highlighted that not all of the many points addressed here are equally relevant under all national circumstances. The specific goals or the framework conditions of specific NFMSs may require focusing more on some elements and lesser on others.

A schematic overview is given in Figure 1 on the components that constitute a full-blown NFMS.

This is followed by the formulation of guidelines on the following basic elements that constitute a NFMS:

- **The foundation elements** address fields of action that define the framework conditions within which a NFMS is implemented in organizational and technical terms. These foundation elements include activities like the institutionalization of the NFMS, developing national capacity and strengthening national forest research institutions in the field of forest monitoring, and also the establishing of national and international partnerships. These activities prepare the grounds for all subsequent technical implementation work and require sufficient time to be thoroughly addressed. They can hardly be tackled at short notice and if these elements are not carefully dealt with, it may become difficult to successfully run the planning and implementation of the subsequent organizational and technical steps. The foundation elements may be considered, therefore, a prerequisite to secure functioning and sustainability of the forest monitoring system.

Box 1.

This section III intends to offer guidance on technical and organizational issues in the context of setting up and further developing a NFMS.

It is important to note – and may possibly be surprising – that for various technical detail questions of forest inventory design there are no single optimal solutions - but many good solutions; for example for so central points like plot design and sampling design.

- **The strategic elements** address fields of action that are specific for data collection activities within a particular forest monitoring system but do not refer to specific scientific-technical issues. These organizational and planning actions refer to the definition of goals, products and variables based on inquiries about information needs, to project planning including assignation of responsibilities, networking, communication, provisions of computers, measurement devices and means of transport and communication, recruiting and contractual issues and other matters related to human resources.

Box 2.

This Section addresses many detail points that may be relevant for the establishment and implementation of a NFMS.

However, not all of these many points are equally important in all national contexts and circumstances.

For an efficient implementation, a step-by-step approach needs to be devised that covers the different points according to their priority in the national context.

- **The operational elements** address fields of action that refer to the optimization and definition of the technical design elements of field data collection and remote sensing analyses including approaches to quality control, the preparation and implementation of data acquisition, the data analysis, and eventually the focused reporting to specific target groups.

Figure 1 gives a schematic overview of the general structure of a NFMS, where cycles of activities like national forest inventories form the technical component of data collection and analyses. The subsequent chapters of this section follow this schematic representation.

2 THE FOUNDATION ELEMENTS

Establishing the foundation elements prepares the grounds for efficient planning and implementation of a forest monitoring system as a long term undertaking. They are grouped here into (1) Institutionalization, (2) Developing national capacity, (3) Developing partnerships and collaboration, and (4) Strengthening research and research institutions in forest monitoring.

These groups are thematic groups and are not completely independent of each other. Also they do not necessarily reflect a temporal development but may partially be pursued at the same time.

Preparing the foundation elements may take quite some time. However, that does not mean that the technical planning and implementation work of data collection activities in a first national forest assessment must be postponed and can only be started when all foundation elements are in place. Rather, if there is the possibility to immediately start with planning and implementation of a national level forest data collection, this work may indeed start right away and form an integrated component of the system while the foundation elements are being built simultaneously, in a step-by-step approach in order to eventually make it a permanent system.

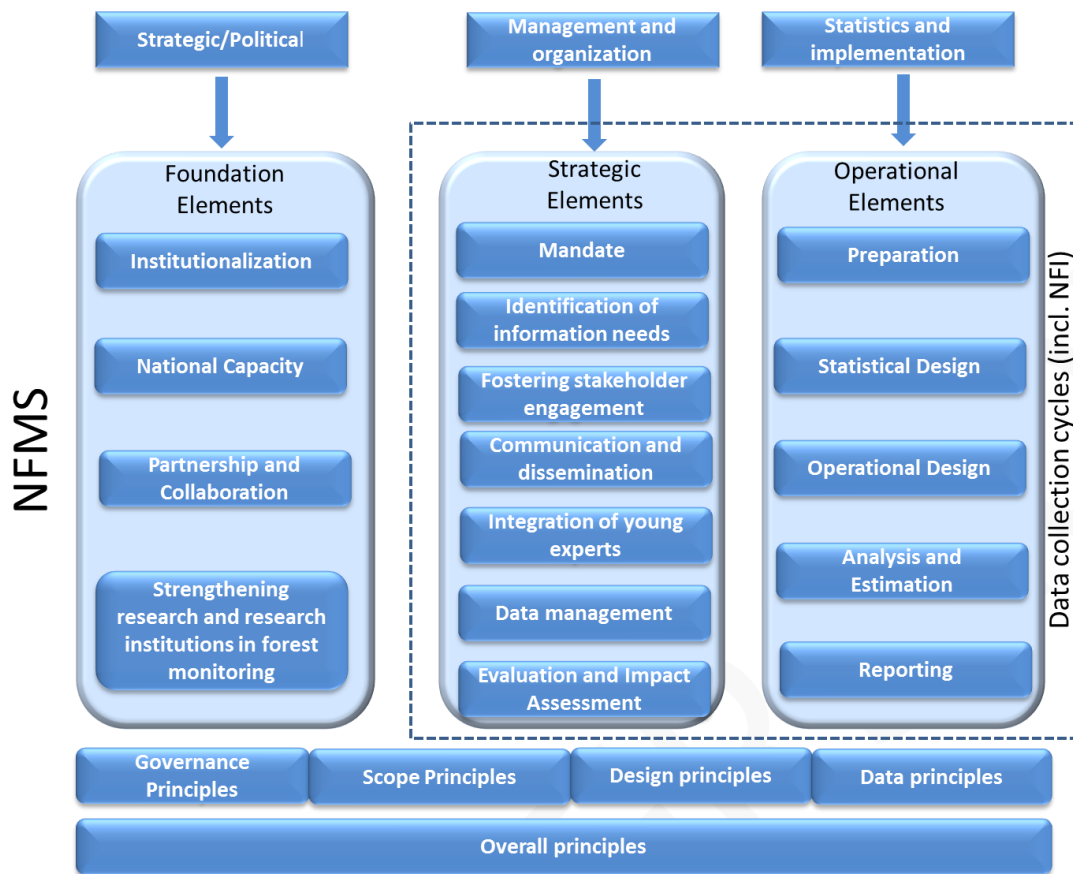


Figure 1. Illustration of the core elements in a NFMS planning and of the general relationship between NFMS and data collection cycles. The breakdown into the depicted fields of activities is further elaborated in the following chapters.

2.1 Institutionalization

Institutionalization means that the NFMS be formally, firmly and permanently embedded within the administration –usually the forest administration- of the country. Given the fact that a NFMS is a long-term endeavour makes clear that a legal basis and a permanent institution are required to efficiently implement it.

Only a permanently institutionalized NFMS can efficiently promote (1) that data and information are consistently managed and permanently available and that data can also be analysed over time (assessment of changes), (2) that national expertise can efficiently be accumulated and further developed which is a condition for the further development and improvement the system, (3) that there are clear professional perspectives for national experts in forest monitoring and (4) that the government has a clear contact point when analyses and specific forest information is needed.

Also, a formal institutionalization of the NFMS is a clear and obvious evidence that the government considers national level monitoring of forests an important government responsibility and that forest monitoring related knowledge is gradually accumulated. All that contributes to enhancing the credibility of national level forest related reporting.

Essentially, the institutionalization of a NFMS in a country shall address the following components:

- To efficiently integrate the NFMS and its activities (what will be done and produced, by whom, when, with what resources, etc.) into the existing national frameworks regarding policies and legislation and into government structures (organizations) and financing systems (e.g., national budget).

This integration creates the legal justification and the formal basis for the NFMS' long-term functioning. It is also a clearly visible expression of full national ownership.

- To formally assign, through legal instruments, clear mandates for the collection, management and analyses of data and for the delivery of specific products and services to an organization or network of organizations, such as a government agency, a research organization or academic institution).

The mandate assigned to such organizations should include a clear purpose as well as short and long-term goals of the NFMS.

It may be necessary and reasonable to create a new organizational unit or to create a new section within an existing organizational unit.

- To indicate (and ideally formally endorse) appropriate coordination mechanisms by which overall management, data collection, management and sharing among units and possibly the public, ministries and other organizations (private and public) will take place.

These activities of "institutionalization" address principles 1, 2, 4 and 11 (Country ownership & responsibility, Legal basis, Institutionalization and Cost Efficiency).

2.2 Developing national capacity

National ownership and sustainability of the NFMS depend on the institutional capacities and their continuous strengthening to meet the forest information needs of users. This calls for strengthening of human capacities in the technical fields of forest monitoring, but also regarding program management, administration and operation.

The NFMS shall ensure that person(s) responsible for it or working on its behalf are competent and have appropriate education, training and/or experience. In order to develop and sustain national capacity to maintain the NFMS, and in particular the technical capacity in remote sensing, field measurements and information management and communication techniques, an NFMS shall:

- Identify the existing capacities and assets of the staff performing the tasks, and then identify the gaps and training needs based on the institutional mandate.
- Prepare a capacity development strategy building upon the identified capacity development needs and gaps. The strategy should adopt a stepwise and continuous learning approach and should involve academic institutions, as appropriate.
- Cooperate with academic institutions by supporting the development or adjustment of curricula relevant for the NFMS.
- Promote student exchange programs, and student labs integrated into, for example, forest monitoring field work or remote sensing lab work, and promote short-term employment of young professionals through internships and early career positions (see also chapter 3.5).
- Promote use of NFMS data sets for research and innovation in all forest related fields.
- Strengthen linkages with other national, regional and global institutes partnership by sharing lessons learned through various mechanisms such as South-South Cooperation (see chapter 2.3).

These activities address principle 5 (Research infrastructure and capacity building).

2.3 Developing partnerships and collaboration

There is hardly any forested region that has not experienced some sort of examples of successful implementation of national level or subnational forest assessment. More and more countries are investing in the implementing of full-blown NFMSs so that international and regional collaboration offers excellent opportunities to share experiences regarding planning, implementation, analyses, capacity building, technical expertise, and lessons learned – both regarding success stories and failures.

Networks may be actively developed in all fields relevant to forest monitoring.

Based on the above, an NFMS shall:

- Promote and establish partnerships in fields relevant to the NFMS. These partnerships may extend to specialized national and international institutions and to international networks and programs and should be designed in a manner that ensures clear and agreed responsibilities and accountability by all partners.
- Promote agreements between partners with respect to intellectual property when specific activities are addressed that may generate material subject to copyright, patent or other intellectual property jurisdiction, such as publications.
- Promote inter-sectorial coordination within the country. It is likely that there are other “sectors” like agriculture, environmental protection, biodiversity conservation, ecotourism development or other forest-related fields that are interested in the results from national forest monitoring. The design of the NFMS is frequently such that additional variables or target resources can feasibly be integrated. This may not only lead to a great added value on national level – but also to a greater understanding, acceptance and support of the monitoring results and the NFMS program itself. The goal of a strategy to nationally embed a NFMS should be to work towards a collaborative working relationship with other national agencies rather than a competitive one.

Development of partnership and collaboration addresses principles 1, 9, 10 and 14 (Country ownership and responsibility, Flexible approach to integrate emerging issues, multipurpose approach, and International collaboration).

2.4 Strengthening research and research institutions in forest monitoring

Planning and successful long-term implementation of NFMSs requires accompanying research in all cases, even though to varying degree: optimization of technical design elements of forest inventories are generic research questions as is the development of locally specific models for the prediction of, for example, biomass or carbon stocks and for the development of optimal remote sensing analysis approaches.

Also, the data generated by a NFMS offer manifold opportunities for research beyond the specific field of forest monitoring. There is a clear need to build capacity to identify priorities for forestry research based on stakeholder needs to strengthen existing institutions and create new ones where necessary. NFMS-related activities in the context of strengthening research and research institutions in forest monitoring shall:

- Ensure that the flow of information between the NFMS and researchers is reciprocal: the research objectives should be clearly defined by the NFMS, yet flexible enough to allow incorporation of new research results.
- Identify scientific research needs to fill existing information gaps. State its research priorities and provide certain basic facilities to enable progress, while on the other hand the researcher should be able to lead the NFMS into new areas of development.
- Promote the collaboration with different research units, where possible, with the goal to enhance implementation and foster sustainability of the NFMS. In this context, one may consider that research collaboration with universities does have

the side-effect the young scientists may become interested or even enthusiastic about forest monitoring. Strengthening research, therefore, has immediate links to “capacity development” (see also chapter 3.5).

- Promote networking and collaboration of national, regional and international research institutions and actors in order to ensure adequate channels for dissemination of research results.

The strengthening of forest monitoring related research addresses principles 5 and 9 (Research infrastructure and capacity building, Flexible approach).

3 THE STRATEGIC ELEMENTS

The strategic elements are to be considered during preparation and implementation of a national forest monitoring programme. These elements define the course of the NFMS and define the specific issues of the NFMS regarding the “how” and “who” without, however, addressing detail technical-scientific elements that are dealt with in chapter 4. Issues regarding the mandate of the NFMS, the assessment of information needs, the definition of the desired output, taking a participatory approach, the management of the information, the dissemination of findings and the planning for an impact assessment are among the topics covered here.

The strategic elements may ideally be reviewed periodically to ensure that they still apply to the current (and anticipated future) needs of the NFMS. If a need for adjustment is identified, they may be modified accordingly: the NFMS shall not be looked at as a static system but shall dynamically meet evolving issues and integrate new components wherever sensible and feasible, while maintaining consistency over time so as to not interrupt the possibility to estimate changes and establish time series for relevant variables and topics.

3.1 Mandate:

The implementation of a national forest monitoring system requires a clear political mandate which can only be issued from a government body. Mandating usually also means definition of vision, goals, targets and available resources: budget, personnel, and infrastructure among others. Sometimes, a legal regulation must be added along the way, for example to gain access to private land to conduct field inventory work.

The NFMS mandate shall include:

- The goals and targets of the NFMS which should be specific and measurable – covering both the short and long term.
- A clear designation of responsibilities and functions by agency for achieving objectives and targets of the NFMS.
- Specification of the means (including resources) of the NFMS.

The mandate responds to the “why” in an NFMS and addresses principles 2 and 4 (Legal basis and institutionalization).

3.2 Identification of information needs

The NFMS shall be demand-driven along a clearly stated and formally mandated mission. Its objective shall be to produce the best possible information within the given resource constraints. In order to visibly follow this path of being demand-driven, an information needs assessment is a key step to specify what information the NFMS should produce on a regular basis.

Based on these actual and perspective information needs as expressed by all identified interested parties, the design of the NFMS will be defined (or revised). The results of the

information needs assessment are used to determine and prioritize the data to be collected.

While this is an essential step, a balance needs to be found between a purely prescriptive, technically driven approach, and a fully participatory approach which involves all partners (those who have a vested interest in the NFMS) and other stakeholders (others who will use the data). If information needs are specified by technical experts without stakeholder participation, resulting monitoring systems tend to be technically solid, but often fail to meet stakeholders' needs. Information needs assessments with broad open participation tend to result in extensive and unspecific wish lists, given that the future as well as possibilities and limits of monitoring systems are often unclear.

Information needs assessments thus need to be managed in a way to ensure that its results are oriented towards strategic information needs of governments and other stakeholders but focus on essential information that is feasible to be covered by the monitoring system. Experience shows that stakeholders in many countries have similar basic information needs related to forests and trees; hence information needs assessments do not have to start from a blank sheet of paper, and experiences from other similar countries are useful to consider.

For the information needs assessment, the NFMS shall:

- Compile and take into consideration "key topics" derived from strategic goals and targets set by key forest and other natural resource, environment, land-use and development policies of the country and from forest-related international policy commitments and reporting requirements (e.g. UNFCCC, CBD and FRA).
- Identify the "target area of reference": information needs may refer to the national level, to the sub-national level or other areas of reference. Sometimes, the expectations of stakeholders are mistaken, believing that a NFMS may serve at the same time all forest management planning information needs for small areas.

An information needs assessment is a good opportunity to clarify the respective limitations of and technical challenges for NFMSs when it comes to try to make estimations for small areas (but also regarding estimations for rare events or complex variables like faunistic species diversity).

- Identify the "target objects" to which the information needs refer. Usually and traditionally, a NFMS focuses on lands that are falling under the definition of "forest".

However, more and more, the whole tree resource of a country is the "target object" and that has a great impact on the technical planning.

Also, when the field work shall be complemented by interviews with forest users about their activities and attitudes towards the forests, this has a great influence not only on the technical design planning but also on training and expert recruitment.

- Identify concrete forest monitoring-related questions for each of the key topics and define the concrete expected format and type of product that shall stand at the end of the analysis, by designing, for example, tables, graphs, relationships between variables.

The more concrete these information needs are formulated, the more straightforwardly can they be translated into measurable variables by the inventory planners.

- Provide the opportunity for stakeholders at different levels and sectors, including representatives of indigenous groups, to freely express their information needs - and also their potential concerns - in a participatory way so that strategic goals and targets can clearly be addressed.

- Specify the precision requirements (or expectations towards the precision of estimation) in quantitative terms for all expected results.
- Prioritize the needs of information to assist in addressing budget and precision constraints during the technical implementation process.
- Making a clear distinction between “must know” information needs and “would be nice to know” information needs – where the latter may be of interest for research or because they address expected upcoming information needs.
- Provide a compilation of information needs that are explicitly specified in a manner that they can be translated into variables that can be operationally observed in an accessible data source. This is then part of the technical design planning of the NFMS (see chapter 4).

The information needs assessment does essentially respond to the “*what*” in an NFMS and addresses principles 3, 6, 7, 8, 9 and 10 (Landscape view, Participatory process, and National level information needs, Integration with existing information, Flexible approach and multipurpose approach).

3.3 Stakeholder engagement

Involvement of stakeholders may extend far beyond the expression of their expectations within the information needs assessment. Depending on their interest and expectations, representatives of stakeholders’ groups may be invited to or integrated into the strategic or technical planning of the NFMS.

Such integration will support acceptance of the NFMS as a whole, helps in decision making on the various components of the system in line with identified information needs, avoids misinterpretations of information needs and eventually also reduces the posterior criticism that a NFMS may face when important data had not been gathered – but posteriorly identified as important, once the results are presented. While this is a common situation (that many good ideas around NFMSs come up only once the results are presented) one may wish to reduce this phenomenon to a minimum.

At the end, strong participation and engagement of stakeholders’ groups is key to the overall success of an NFMS and contributes considerably to creating national ownership. In some cases, the main constraint of genuine and proactive participation, however, is the weak political will to promote the process of an NFMS.

To ensure efficient participation of different stakeholders, an NFMS shall:

- Identify partners and other stakeholders through a stakeholder analysis. Consider who is willing to participate in the process including different national institutions (especially the ones involved in forest related policies and land management), private sector, academia, civil society, minority groups (including indigenous groups) and communities who utilize forests for their livelihoods.
- Encourage politicians, top decision-makers and planners, to incorporate the organizations’ participation in the NFMS process in their plans and programs. In particular when the information needs assessment has revealed that also lands shall be tree-inventoried that do not fall under the mandate of the forest administration, it is mandatory to integrate the respective other sectors, commonly agriculture or urban development.
- Stimulate cross-sectorial participation of the academia and research institutes.
- Reinforce capacities and knowledge of stakeholders on the benefits and use of an NFMS and resulting information.

Fostering stakeholder participation responds to the questions “with whom” and “for whom” in an NFMS strategy and addresses principles 1, 3, 6, 7, 9 and 14 (Country ownership, landscape view, participatory process, flexible approach, national level information needs and International collaboration).

3.4 Communication and dissemination

Pro-active communication and dissemination is the basis to ensure that all sorts of potentially interested stakeholders are adequately aware of the existence of the NFMS and its related activities so that access to the results produced and to the description of methodologies applied is possible whenever needed.

To guarantee a good communication and dissemination, an NFMS shall:

- Plan for efficient internal communication between the various actors and processes of the NFMS, important for a smooth functioning of the process and supports quality assurance;
- Make sure that all those who participate in different functions in the NFMS know why their contribution to the system is so important;
- Define a strategy to respond to relevant inquiries from external interested parties, including the interested public, NGOs and journalists.
- Secure availability of a communication officer who can deal with these inquiries professionally and who will at times support launching an information bulletin or a press release.

Communication and dissemination is key for any NFMS since it promotes principle 6 and 13 included in these guidelines (Participatory discussion processes, Credibility through transparency).

3.5 Integration of young experts

National forest monitoring programs are complex multi- and transdisciplinary undertakings in which numerous professionals from different academic backgrounds and with different technical skills are closely collaborating and, where also many helpers are involved.

As such, NFMS offer excellent vocational training and educational opportunities for students and for young and early career experts. They can engage in various functions to further develop their knowledge and expertise. By that, they do not only have the chance to learn about NFMS from inside but they do also get direct insights into the forest resource of their country.

Integration of young experts is a component of its own within the planning and organizational aspects, but it is, of course, closely linked to capacity development and networking.

In terms of integration of young experts, an NFMS shall:

- Promote the participation of young experts wherever possible in the NFMS, for example involving national MSc and PhD students in data collection and analysis.
- Promote quality internships within education, training and employment schemes by way of the collaboration with research groups and universities.

The "Integration of young experts" component addresses the "who" in an NFMS and is related mainly to principle 5 (Research infrastructure and capacity building").

3.6 Data management

The immediate outcome of a NFMS is data, collected on scientific grounds at subsequent occasions, from which targeted information for decision-making is derived both regarding the current status and regarding changes. Provision need to be taken for a long-term data management so that analyses can be repeated and time series built from inventories at earlier points in time.

It is, therefore, recommendable to plan for a comprehensive data management from the very beginning of the design of a NFMS. Such a data management system is ideally located within the permanent institution responsible for the NFMS in order to guarantee long-term preservation and availability of the data both for standard analyses and for upcoming research questions.

Policies on sharing data must be developed. Special consideration must be given to sensitive data, such as Personally Identifiable Information (PII) such as plot locations that may be on private grounds; this may be viewed as a release of PII. Also, if actual coordinates are known, then data users could possibly query the data for valuable trees or invasive species and visit the plot to harvest the tree or remove the invasive species – which would be unwanted side-effects. Hence consideration should be given to making only approximate locations public, restrict the use of actual coordinates to those few analysts who need to know or to make publicly accessible only duly aggregated data.

In order to serve these goals, a good data management system within a NFMS shall take into account the following points, which are common for data management systems:

- Have a well-documented data set with associated metadata, a complete and well-defined protocol for data archiving and preservation, including storage and backup with a long-term vision so that data storage technologies remain up-to-date.
- Include a security protocol, with a description of technical and procedural protections for information, including confidential information, and how permissions, restrictions, and embargoes will be enforced.
- Define a data policy which describes how and which data may be shared, including access procedures, embargo periods (if any), and technical mechanisms for dissemination and exchange formats. In case some parts of the dataset cannot be shared, the reasons for this should be mentioned (e.g. ethical, rules of personal data, intellectual property, and commercial, privacy-related, security-related).
- It is dependent on national legislations, strategies and policies which data sets to make publicly accessible, and for which data sets to define a more restricted access.
- Define who, how and where data will be stored, indicating in particular the type of repository (institutional, standard repository for the discipline, etc.). Depending on the general national strategy to storing national statistics, there may be institutions prepared to integrate the NFMS data sets as standard national data sets generated in regular intervals. This would underline the general information character of the data generated by the NFMS.

The data management system is an important component of a NFMS and is related to various of the principles laid out in these guidelines' sections I and II: it relates to principle 12 "Data policy", to principle 13 "Credibility through transparency and quality" if open access to data and results can be granted, and also to principle 8, when integrated with existing available information.

3.7 Impact assessment

NFMS are dynamic systems which need to be continuously further developed according to new scientific findings on strategies of data collection, evolving information needs and new forest related policies. An important component of this further development is the learning from the implemented national forest monitoring systems during the process and after their conclusion.

Although it is not at all a standard component of NFMSs as of yet, it is recommended to plan for a systematic impact assessment and for a systematic evaluation of the process itself. That helps to streamline the improvement of the NFMS and to analyse its overall usefulness.

Regarding developing strategies to impact assessment an NFMS should:

- Analyse who is using which of the NFMS results and for which purpose. A logical expectation would be that the stakeholders who expressed information needs in the planning process can then demonstrate for which ends they are utilizing the results. This analysis may also reveal gaps and new information needs that may be taken into account in the next national forest inventory.
- Analyse the efficiency of the technical approaches chosen. These analyses shall take place in close communication with the staff and experts involved into the NFMS. Valuable observations are commonly also made by the supervision teams who carry out control measurements for quality control. This analysis of efficiency refers mainly to the revision of the protocols of the monitoring process both in terms of field sampling and remote sensing analyses.

The impact assessment relates to principles 7, 9, 10, 11 (Meeting national information needs, flexible approach, multi-purpose approach, cost-efficiency).

4 THE OPERATIONAL ELEMENTS

In order to meet the technical goals of a NFMS, complex strategies of data acquisition and analyses need to be defined that eventually will lead to the desired products. These operational elements refer mainly to the design of the measurements and observations in a NFMS, the efficient integration of different data sources and the up-to-date methodological analyses.

As in most complex projects, two major guiding criteria need to be constantly considered when planning for these operational elements:

- (1) That the approach is methodologically sound and allows producing scientifically defensible – and therefore overall credible – products along the defined objectives. This corresponds mainly to the Overall Principle 13 (Credibility through transparency and quality)
- (2) That the approach is operationally feasible in terms of available resources; and this refers to the time frame, the available financial resources available the expertise / human resources who can be contracted. This corresponds mainly to the Design Principle 11 (Feasibility including cost-efficiency).

There is, of course a trade-off between these two criteria. For all NFMS an efficient compromise between them need to be found.

In a hypothetical world, the optimal data acquisition design is sought for a specific well-identified individual objective (for example: finding an optimal sample size as a function of the demanded level of precision of estimation); thus following above criterion (1). However, the real life forest inventories are frequently determined by above criterion (2): that the available resources are given and fixed and that the best allocation of resources to the different methodological components needs to be found so that the defined set of objectives are met as well as possible.

Box 3.

It is emphasized here again that for various detail questions there is not the one optimal solution but various good solutions - and the decision in favor of one or the other approach is frequently based upon good experiences and successful implementations in other cases.

In this context, it is the goal to produce data and information of highest quality; that is: keeping errors of all kinds low. As in any empirical study, errors cannot entirely be avoided. It is, however, an important point in every planning step to do everything that helps keeping the errors as low as possible. This is not only a matter of statistical design (for example, sample size considerations), but very much also a matter of training (keeping measurement errors low and secure that the inventory protocol is followed), of regular and focused controls, and of focused accompanying research that produces, for example, specific biomass models that fit to the conditions in the country.

The operational elements of a NFMS mean all methodological details that refer to data acquisition, analyses and reporting, also including the respective institutional, organizational and logistical aspects.

At the end and in order to avoid confusions and repeated adjustments of the approaches, all methodological details and procedures shall be unambiguously defined and documented, ideally before the data gathering campaigns start.

The treatment of the operational elements is subdivided here into considerations on preparatory activities, the statistical design of field sampling and the corresponding remote sensing integration, the operational planning of implementing this design, and aspects on data management/analyses and reporting.

4.1 Preparation

A NFMS consists of an organizational structure under whose responsibility data gathering processes are carried in cycles, either organized at regular intervals or permanently.

The preparatory steps of the NFMS design focus on the operational and target-oriented definition of terms, the identification of the variables to be observed in order to meet the information needs and their prioritization, the definition of data sources useful to be accessed to observe these variables, including available information, and the assessment of the available expertise and other country resources.

The preparation process may also identify potential implementation uncertainties and problems and propose ways to address them. Among the most relevant points in the preparation phase is to realistically prepare the technical design planning that the data gathering campaign can technically and logistically be implemented such that all (or at least the priority) information needs can be fulfilled within the allocated budget.

Principles such as landscape view (3), participatory process (6), integration with existing information (8) and data sharing policy (12), govern this component.

4.1.1 Definition of the population of interest and sampling frame

Commonly, the definition of the population of interest in a NFMS is a matter of course and would not need further specifications: it is the forests in a country. However, it is recommended to define each and every aspect in a NFMS as clearly and as explicitly as possible.

This issue of defining the population of interest does not only refer to the manifold different options to define "forest" but also to the question whether other land uses shall be explicitly included - for example for the assessment of the complete tree resource of a country which would also include trees outside the forest, and to the question whether all forest types and ownerships shall be considered: while the term national level forest inventory refers linguistically to all lands where forest is found, for good reasons countries may decide to exclude from field assessments, for example, national parks or larger protected areas or commercial timber tree plantations, or to cover only forests that are in public ownership.

In this context, a NFMS shall:

- Clearly spelled out what the population of interest is and – wherever possible – provide maps showing which sub-national areas are included and which not. It is eventually the population of interest to which the results of the forest monitoring refer
- Ensure that the population's definition is duly in line with the identified information needs.
- Try to keep that most of the population accessible for measurements so that the risk of non-response is small; in other words: that the sampling frame is as close as possible to the population of interest.

- Explicitly clarify those areas where data acquisition is not possible, meaning that the sampling frame is smaller than the population of interest. This limitation refers commonly to field observations where problems of access may be prohibitive like for security reasons, while remote sensing will usually extend over the whole national territory without excluding areas for political or security reasons, limited in fact only by shadows and clouds.

4.1.2 Identification and specification of variables to be recorded

The information needs assessment produces a ranked list of results that the key stakeholders would like to materialize. Usually, this list does contain variables that can be observed or estimated (like forest area or tree species) – but also characteristics that need to be broken down into measurable variables or indicators. For example, when information on characteristics like “forest biodiversity” or “forest structure” or “sustainability of forest utilization” shall be among the products of a NFMS, a clear definition needs to be set up and an indicator based model; then the required indicator variables are to be recorded. The translation of the information needs into sets of measurable variables is an extremely important preparatory step that may require the involvement of those who expressed these information needs who do then collaborate with experts to identify suitable indicators that can feasibly be integrated into a NFMS. This feasibility is, of course, also a function of priorities and cost.

For the identification and specification of variables an NFMS shall:

- Translate the information needs into measurable variables.
- Clearly and explicitly define all variables, both in terms of their subject matter meaning and in terms of their observation or measurement. For metric variables (such as “tree height”) also the measurement device(s) to be used need to be defined. If a variable is nominal (such as the variable “forest type”) all possible names need to be listed (including the “name”: unknown) and if a variable is categorical (such as the variable “tree vitality”), all categories shall unambiguously be defined.
- Document all definition elements and use them as the basis for the later composition of a comprehensive field manual (see also chapter 4.3.1).
- For some target variables that cannot be directly measured nor observed, include such central variables like stem volume, tree biomass or carbon. For these variables, proxy approaches need to be defined, usually via models. This topic of statistical models is dealt with in more detail in chapter 4.2.5.
- Determine which data sources are to be used based on the variables to be recorded, where commonly the main sources are sample based field observations and remote sensing. However, depending on the information needs, interviews with forest owners or forest users might be planned for, or interviews within the forest service or ministries.
- Be consistent with national and international standards to foster comparability.
- Use consistent methods over time to enable estimation of change: Changes in definitions, when data collections are repeated, shall only be done for very good reasons and without compromising the comparability of the methods nor the possibility to reliably estimate changes of the priority target variables.

4.1.3 Definition of levels of precision for the expected products

As a further outcome of the information needs assessment it may be possible to more specifically defined levels of expected precisions of estimations for sample derived results or accuracies for remote sensing based classifications. It is important to take into account these expectations. They have eventually a great influence on the design planning, for example for the sample based field inventory (sample size and plot design) and also for remote sensing analysis (classification and accuracy assessment).

Commonly, however, it is extremely difficult to define “suitable” or “acceptable” precision levels for the sample based estimates and accuracy levels for remote sensing classification products. This has to do with various factors, among them the following: firstly the identification of “minimum precision requirements” for national level forest inventories is scientifically not intensively treated yet and certainly not resolved. There is simply no general recommendation how precise, for example, forest area or biomass stocks or intensity of illegal logging need to be estimated in order to best serve the needs of policy decision makers or stakeholders. The common approach is then to work with general orders of magnitude like 5% or 10%. The second factor is probably that the concept and specific meaning of “statistical precision of estimation” might not be generally known among stakeholders; it is then difficult to make an informed statement about precision requirements.

Commonly, minimum precision requirements will not be formulated for all analysis results, but only for a limited set of priority target variables. These priority target variables need to be identified and justified. Optimization of the sampling and plot design is often guided by precision considerations on one or two variables, for example “basal area” (or related variables like volume stocks or biomass stocks) and “forest area” - which are typically among the core variables in forest monitoring.

Box 5 describes, for sampling studies like field inventories, the basic relationship between statistical precision and sample size - where “sample size” may directly be taken as proxy for “cost”. Sometimes, one finds recommendations on a minimum *sampling intensity* in order to achieve precision goals, like “the fixed area sample shall cover at least 5% of the forest area”. It is generally not recommended to use these types of prescriptions because there is not a clear relationship between precision and sampling intensity. It is recommended to focus on sample size (taking plot size also into consideration), instead. In fact, it is one of the great challenges in national forest monitoring to explain to non-statistics experts, that high precisions may be achieved even though the sampling intensity is low. A sample size of $n=5000$, for example, may allow estimates of forest area and growing stock on national level with confidence intervals of $\pm 1\%$ or less - although the sampling intensity may be in the order of just 0.001%!

When specifying target precision of estimation, the following points shall be taken into account:

- Have a direct correspondence with the information needs assessment (point 3.2).
- Clearly have defined the priority variables and their precision requirements.
- Not losing out of sight the relationship between costs and precision and make sure that this is clearly understood both by stakeholders who express precision requirements and by those who design the inventory - in order to avoid unrealistic expectations.

Box 4.

Uncertainty is an important concept in empirical studies, including forest inventories.

It is a good practice to accompany all estimates with a precision statement in order to give the reader an impression of the reliability of the estimates, for example “the carbon stocks per hectare are an estimated 150Mg/ha with an estimated 95% confidence interval of $\pm 5\%$ ”.

A “high” uncertainty of the presented results will compromise credibility; sufficiently high levels of certainty need to be aimed at.

However, as of yet, there is no scientifically founded statement possible so as to what is a minimum acceptable precision level for results in national level forest inventories.

Target precision levels are commonly defined along general precision levels like 5% or 10% and are based essentially on experiences and traditions.

- Integrate considerations of precision of estimation as a priority topic into training and capacity building of the technical staff – but also in communications with stakeholders and those parties who are interested in the results.

4.1.4 Review of existing information

Similarly to the planning in any other complex project, readily available existing information should be taken into consideration as long as their origin is transparently documented and as long as the information has the expected quality.

“Existing information” refers here to all types of information useful or required for forest monitoring, it and may include technical information sources like forest inventory data and results at national, subnational or local level, existing models for the prediction of non-measurable variables like volume, biomass, carbon, topographic and thematic maps and remote sensing imagery and classification. Also, information on road infrastructure is relevant, and about its accessibility also as a function of seasonality.

However, “existing information” does also refer to the availability of information about contact persons in the provincial or local forest offices who may inform about risks of access to certain regions and may facilitate field work planning, information about contacts to potential local helpers in different regions of the inventory area, and information about contacts to inventory staff who participated in different roles in prior inventory studies.

Of course, existing information is helpful only, when it is not outdated and can be quality-checked.

When compiling existing information to support the NMFS, the following points shall be considered:

- Identify which of the expressed information needs can be addressed by using existing information.
- Take in consideration national and international sources that may provide pieces of existing information including maps, local forest inventories, ...
- Identify and prioritize information gaps, such as missing, incomplete, out-of-date, or imprecise variables.
- Evaluate whether or not it is worth collecting additional data to fill the information gaps.
- Provide useful information to better plan the implementation of data collection (e.g. rainy season, land accessibility, social conflicts, conflicting activities, course to plot, etc.).

4.1.5 Available expertise and manpower

The implementation of an NFMS implies identification and contracting of experts from various disciplines which include – among possibly others - project managers, inventory statisticians, statistical modellers, botanists, taxonomists, dendrologists, biometricians, and specialists in remote sensing, GIS and data management. These specialists need to be assigned to teams that adequately address the necessary monitoring task.

Box 5.

In statistical sampling, precision is mainly a function of sample size and also of sampling design and plot design.

Of course, increasing precision has repercussions also on the resources that are required.

For example, in simple random sampling and similar for other sampling designs: an improvement of precision by the factor f (for example $f=2$ for a reduction from 10% to 5%) requires an f^2 -fold sample size (in our example: 4-fold) and, therefore also f^2 times as many resources!

Not all required expertise may be readily available within government institutions so that cooperation or requests for external collaboration and partnership is a good option to find expertise and support.

Knowledge exchange and collaboration between countries have been found an efficient means to enhance in-country capacities in specific technical fields. Creating networks of technical experts who transfer their knowledge and share their experiences could be beneficial to monitor the progress of available national and regional capacities. However, as mentioned above, these short-term measures of training should also be accompanied by a long-term strategy of capacity development that target national students and support them to specialize in disciplines relevant to forest monitoring; if this support comes to a greater numbers of students, there will be well educated forest monitoring experts in the future.

In order to assess the available expertise in the country, the NFMS should:

- Identify expertise needed and compare to the available expertise for the NFMS; this is best done by public announcements of positions in the NFMS and by consulting with national forest monitoring experts making use of their networks.
- Develop networks of expertise within the country across agencies, academia, NGOs, and industry.
- Develop networks with other countries, such as developing countries to share technology and innovation through South-South collaboration.
- Push short-term-training measures to rapidly fill capacity gaps, while not ignoring the commonly urgent need to also care for a long-term strategy to national capacity development by means of supporting students.

4.2 Statistical design

Based on the preparatory works and their assessments the detail planning and definition of the scientific design and its implementation can be done. The identified information needs, the set of variables that need to be observed as derived from the expected products, the available resources in terms of prior information, expertise and budget define the framework within which the detail planning of the statistical design takes place.

The planning of the statistical design goes along the three major guiding criteria of (1) meeting the information and precision goals, (2) staying efficiently within the allocated / available resources and (3) adhering to methodological-scientific soundness.

It is the latter that is the major foundation of subject matter credibility and that makes the NFMS results defensible. It is a common situation that NFMS results are unexpected or even not welcome. Methodological-scientific soundness is the only means to defend the results. Methodological flaws and inconsistencies and even just lack of transparency or completeness in documenting the methods applied may put the NFMS credibility at risk. Therefore, defining a sound statistical inventory design that follows scientific principles and complies with state-of-the-art research is one of the most relevant - and most demanding - tasks in NFMS planning.

Definition of the statistical design is a complex process that consists of various components. In forest inventory for example, the two most prominent data sources are sample based field observations and remotely sensed imagery. There are numerous options for their integration and combination. It is typical for forest inventory that a series of variables cannot directly be observed, either in the field or in remote sensing imagery, and that models are needed that help to "convert" the directly observable variables into the variables of interest. These models are either available from prior studies or need to be established as a part of the accompanying research to the forest monitoring system.

In the planning for the statistical design, principles such as research and capacity building (5), flexibility (9), cost efficiency (11), transparency (13), and international collaboration need to be considered.

4.2.1 Integration of field and remote sensing data

Sample based field observations and remote sensing imagery are commonly the most important data sources in forest monitoring. Both data sources have their specific characteristics in terms of the variables that can directly be observed, their “availability and accessibility”, their cost, the expertise required, but also in terms of analysis options and reporting options.

Field observations are the core of any forest assessment and relatively large sets of variables are recorded during national forest assessments., including biomass, species composition, diameter distribution and regeneration, illegal logging – although remote sensing approaches are making rapid advances. Remote sensing is useful in the sampling designing phase, and is indispensable when spatially explicit analyses and reporting (maps) are required or when retrospective analyses are at stake as is the case for the assessment of the historical deforestation trends in REDD programs. Forest fragmentation and the improving of the precision of the estimation are another forest features that can best be assessed and evaluated by remote sensing.

The considerations on integration of field observations and remote sensing shall include the following points:

- Both field sampling and remote sensing shall strictly be objective- and target-oriented, contributing to meet the information needs – or to satisfy broader research goals.
- The same definitions shall be used for variables that are both field and remotely observed. This refers, for example, to the definition of “forest”, where it is all but a trivial task to apply exactly the same definition to both data sources.
- Statistical rigor and methodological strictness shall guide data acquisition from all data sources: a clear protocol needs to be developed for both types of data acquisition and analyses.
- When planning for the field sampling design one shall take into account that field observations may be useful for validation of remote sensing image analysis.
- Try to include as much as possible geographical coordinates of the collected information, such as plot centres (or corners) and tree centres.
- The semantic interoperability between the descriptors, used to describe the ground and remote sensing measurements, should be well understood and described.
- Remotely-sensed data with on-the-ground information should be calibrated and validated, allowing field data to be spatially extended and to obtain accurate estimates across large areas.

Box 6.

It is an important decision regarding sampling design whether every x years a complete inventory shall be carried out (periodic approach) or whether a so-called panel system is implemented where every year a set (panel) of samples is worked on (panel approach).

4.2.2 Sampling design

Statistical sampling in the context of forest assessment refers to the strategy how sample points are selected within the target area as defined along the considerations made in chapter 4.1.1 (e.g. country’s area or the forest area of the country); around

these sample points the sample observations are carried out along a defined approach which is then called “plot design” and dealt with in chapter 4.2.3.

“Sampling design” is the strategy how these samples are selected.

This “how” refers mainly to the selection of “spatial positions” of sample points – but in particular in the context of national forest monitoring it does also refer to the “temporal positions”: national forest inventories are covering large areas and have frequently a relatively large sample size so that it may well take several years until the sampling is completed and the analysis can begin. An unambiguous reference point in time needs then to be defined. Frequently however, results – and be it only intermediate results – are demanded much earlier. One solution is that the sampling is temporally organized in several campaigns that are carried out annually or bi-annually and cover a certain percentage of the total sample each. This is also called a panel-based approach because sample panels are observed every year. If, for example, the inventory cycle is planned for 10 years, then a fraction of 1/10th of the systematic grid may be observed every year; this would be a fairly coarse grid but then, already after the first year an up-to-date estimate may be produced – even though at relatively low precision.

Sampling is relevant in at least two important statistical contexts in forest monitoring: firstly, field observations are sample based and serve to produce estimates for a number of forest inventory core variables. Because field observations are commonly a very time consuming and costly component of a forest inventory, it pays to put sufficient efforts in optimizing the sampling design such that the defined precision goals can be reached with the least efforts / cost. Secondly, samples of field observations are required in accuracy assessments of remote sensing map products. In both cases, a methodologically sound analysis and interpretation of the results is possible only if the sampling studies are rigorously following the rules of statistical sampling.

This is probably the most relevant criterion in choosing a sampling design: that a methodologically sound analysis must be possible. That means: an estimator framework must be available (formulae) that allows statistically sound estimation. It is not a good idea to select the sampling positions in a non-statistical manner – that is: arbitrarily or in some way subjectively – because this excludes the possibility to do methodologically sound estimations and it may altogether compromise the credibility of the NFMS.

Almost all national forest inventories employ so-called design-based sampling where the unbiased estimation depends exclusively on the statistically sound selection of the sample points – and not on population characteristics. A straightforward and methodologically correct selection procedure for the sample points is therefore imperative. In statistical sampling, randomization is the strategy to select sample points; other general – and not well clearly defined concepts – like “objectivity” or “fairness” or “representativity” of selected sample locations are not acceptable.

In forest inventory, systematic sampling is then combined with sampling design options like stratification and with plot design options (see chapter 4.2.3) like cluster plots or with estimation design options like the integration of ancillary variables (see chapter 4.4.4).

Once a sample position has been selected, for example with grid coordinates in a defined system, this position is fixed and must not be modified. The sometimes-practiced approach of plot-shifting, when a sample point position does not appear to be suitable, is by no means permitted. Even if a sample point falls into an entirely open area within the forest and not one sample tree will be recorded there: this point must be taken as sample point and recorded: at the end, this open area around this particular sample point is part of the defined population just as any other tree-covered sample position as well. However, non-response may occur as described in .

One of the most relevant question when defining the sampling design is to find an appropriate sample size, that is: the number of sample points that need to be sought in the field in order to establish the observation units (sample plots). Sample size is one of the most important factors influencing precision of estimation: given all other conditions constant, a large sample size leads to a higher precision – but also to higher cost. The relationship between precision (in terms of simple standard error or width of the confidence interval) and cost is important (see also Box 5): in simple random sampling (and similarly for other sampling designs) improving precision by the factor f requires an increase of the sample size by the factor f^2 . To illustrate this with an example: to bring down the precision of estimation from a 95%-confidence interval of 20% to a 95%-

Box 7.

There are essentially two basic sampling strategies that are used as elements in all sampling designs: simple random sampling and systematic sampling.

Simple random sampling can straightforwardly be analysed; and unbiased estimators are available for all statistics to be estimated. It is dealt with in much detail in classrooms, because it is so instructive and because much of inferential statistics (tests, for example) require it.

However, in practical applications of forest inventories, simple random sampling is highly inefficient and systematic sampling is the most frequently used basic sampling strategy. There are many approaches to systematic sampling and most frequently, square grids are placed over the area of interest and all points that fall into the population of interest (for example, forest land) are taken as sample points.

An issue in statistical estimation with systematic sampling is that there is very “limited” randomization. When using a regular square grid, for example, there is only one randomization step that defines the location and orientation of the grid. Consequently, there is no statistically unbiased estimator for the error variance (and therefore: precision) – while there are unbiased estimators for the mean.

However, it is known from simple theoretical considerations and from numerous simulation studies that, applied to forest inventory, systematic sampling is always more precise – in many cases much more precise – than simple random sampling with the same number of observation points. This has to do – in general terms – with the facts that a systematic sample is always evenly covering the whole population, capturing much variability; and that there is always a defined distance between neighbouring sampling points, keeping autocorrelation between observations low.

Therefore, it is commonly accepted that precision estimates in systematic sampling are approximations only. In many cases, the variance estimators of simple random sampling are applied to systematic sampling and it is known that this will result in conservative estimates. That means: the true – but always unknown – error variance is lower (and often much lower) than the estimation that the application of the simple random sampling estimator yields.

confidence interval of 5% ($f=4$), one would need a 16-fold (f^2) sample size. This little example illustrates clearly that considerations of sample size and desired precision levels need always to be done jointly with cost considerations.

When determining sample size as a function of desired precision, it is important to focus on the one most relevant variable. It is not possible to optimize sample size simultaneously for several variables. Frequently, basal area is taken as the variable for sample size optimization, because basal area has shown to be well correlated with various other important forest inventory variables, and it is relatively easily measured.

Sampling has also its limitations in some regards. One limitation is regarding the estimation of rare events. It is impossible to produce highly precise estimations for rare elements from a forest inventory sampling study; the sample size would need to be prohibitively increased. That means: if rare events are among the priority target objects as identified in the information needs assessment, one would need to devise additional studies specifically for their estimation, possibly in a research-oriented context.

Regarding sampling design, the NFMS planning shall take into consideration:

- Follow statistically defensible and well documented approaches for which generally accepted estimation procedures are known.
- Refrain from inventing new selection mechanisms for which statistically sound estimation is not available.
- Desirable properties of the sampling design include being precise, cost-effective, straightforward to understand and implement, and adaptable for monitoring over time. Adaptations include technological and methodological improvements and adjustments for changes in policies and emerging information needs.
- In terms of precision and cost-effectiveness, sampling design considerations are

Box 8.

Once selected, sample points need to be located and found in the field to establish sample plot for observations.

However, of course, in some cases, the pre-selected sample points cannot be reached, for security or safety reasons or because the forest owner does not grant access.

In these cases, observations are not possible and these sample points are recorded as “non-response”. Non-response is a common feature in inventories and the term comes from interview-surveys where it is very frequent that selected interviewees deny answering questions.

Non-response becomes a challenge when its percentage becomes high, say, more than some few percent. Sampling statistics offers some methodological approaches how to deal with non-response. However, nothing can replace a direct observation and it is important to keep the percentage non-response as low as possible.

linked to considerations of plot design (see chapter 4.2.3).

- Devise and document clear instructions for the field teams how to search selected sample points. This includes also the unambiguous definition of the grid system in which the coordinates are given.

- Give clear indications how to deal with cases of non-response when the pre-selected sample locations cannot be reached.

- Consider building upon existing experiences of forest inventory sampling studies. Lessons learned from past efforts are very helpful in particular when

these efforts are well documented together with implementation experiences. If possible, the inventory planners should try to contact those who were responsible for the design planning of these earlier inventories. Usually such experiences are extremely instructive.

- Keep in mind the permanent character of the sample. Sample plots shall be visited again in the next inventory cycle in order to allow for precise change estimates. Sampling designs that restrict the future utility of the sample shall carefully be thought through.

For example, while stratification is a generally powerful and useful variance reduction tool, one should choose stratification criteria that are stable in time. When, after 10 years or so, the strata have changed, the estimation of changes becomes a challenge.

- Compute the sample size for the key variables based on the precision requirements or based on the budget available. This is often an iterative process where precision requirements or budgets are adjusted based on the information needs, national circumstances, and on technical, financial and human capacities.

4.2.3 Plot design

While the sampling design determines how to select sample points, “plot design” refers to the definition of the activities to be done when at the sample point: it defines how to include sample trees and other sample objects and how to do measurements and observations of their variables.

As with sampling design, there are many different plot design options and for a more comprehensive and detailed treatment, the reader is referred to forest inventory textbooks and the scientific literature. In this guide, some basic points and criteria are presented and discussed. Commonly, in national forest inventory it takes considerable time and effort to reach the sample points so that the goal is to make optimal use of the presence of the field team at the particular sample point. That leads eventually to commonly very complex plot designs that combine a number of basic elements like nested fixed area plots, relascope plots and linear observational units and others to record a number of sometimes more than 100 variables.

Sometimes individual plots or nested sub-plots are located only around the selected sample point; but more often, however, in large area forest inventories, a cluster of sub-plots is installed at some defined geometric pattern around that point. Commonly in use are square clusters with four or eight equidistant sub-plots, or cross shaped clusters with 4 or 5 sub-plots, or L-shaped clusters (also called “half-squares”) with an uneven number of subplots. This subdivision of the sample plot into several spatially disjoint subplots has the great advantage that a higher degree of independent information is collected per sub-plot and this will increase overall precision as compared to an approach where all sub-plots are jointly together or at very short distances. There are many factors that determine a cluster plot design (see also Box 10) and its optimization is one of the relevant research topics that accompany the planning of the plot design. If data from prior inventories exist where cluster plots were used, this data may offer excellent opportunities to simulate different cluster designs and to learn about the spatial autocorrelation in the forests to be inventoried. This requires, however, that the data sets be well documented.

Plot design options that can be combined at the same sample location, forming a set of sub-plots, include nested fixed-area plots in circular, rectangular or square shapes for trees of different dimension (e.g. small regeneration, established regeneration, small trees, large trees), relascope plots for the estimation of basal area, large plots for the assessment of terrain conditions, habitats and indicators of biodiversity, transects for down woody material, and possibly also soil cores.

All sample plots that are used in forest inventory have some spatial extension, except when simple points are used as sampling unit. Considering the spatial extension, all sample observations must eventually refer to the horizontal plane and to the population of interest. That means: if sample plots are laid out in sloped terrain (and many forest areas are indeed in hilly and mountainous areas), then they need to be duly corrected for slope. And sample plots whose (real or virtual) plot area overlaps outside the population domain need to be duly corrected for these boundary effects. Ignoring these corrections will lead to errors that cannot be corrected later and do impair analysis and estimation.

Box 9.

The overall guiding statistical principle in designing observation plots is that one wishes to capture a maximum of variability per plot.

This is contrary to establishing experimental plots where the goal is to have as homogeneous plots as possible in order to reduce confounding effects to a maximum.

However, in observational studies like inventories, one achieves the best overall precision of estimation when a maximum of variability is captured per plot.

That means, from a purely statistical point of view, and given the omnipresent autocorrelation structure of forests, the inventory plots shall best not be compact but spatially “extended”.

An important point in defining plot designs for field sampling is also the potential use of the field plots as input to remote sensing analyses. There is no clear and generally valid recommendation how field samples need to look like so that they can optimally be combined with remote sensing, if such joint analysis is planned for. Remote sensing derived observations may be used as auxiliary variables to improve forest inventory estimations. Also, remote sensing analysis may be used to produce regionalized maps of important forest inventory variables. In both cases, field and remote sensing observations need to be co-registered so that they can jointly be analysed: an exact determination of the field position of the plot is crucial, then.

For the joint analysis of field and remotely sensed data, fixed area plots with a defined reference area on the ground are more suitable than plots with variable or virtual plot areas or line sample. As of yet, there is no clear evidence that sample plot shapes and sizes that directly mimic the instantaneous field of view of satellite sensors - that is multiples of square pixel sizes - are superior in that regard to rectangular or circular plots; for example, laying out square fixed area field plots of 30m, 60m or 90m side length (that correspond to multiples of Landsat pixel sizes) in the forest is extremely tedious; and it is doubtful whether the coincidence with the satellite sensor's pixel size does justify these additional efforts. It is rather recommended to guide the field plot design along statistical criteria and along of criteria of operational feasibility in the field.

Just like with the definition of the sampling design, the planners should carefully make sure that sound estimation options exist for all plot design options chosen. It is easy and quick to devise a plot design by means of defining how to include which tree and how to take which measurements; it is another story to develop unbiased estimators for such plot design. There is, for example, not yet an operational unbiased design-based estimator available for point to tree distance plots (like, for example, 6-tree plots), so that its application cannot be recommended. In particular in the context of sampling rare events, adaptive plot designs have been developed. When using adaptive strategies, one needs to follow very clear pre-defined rules – and should use them only if estimators are available.

When defining the plot design, the following points should be taken into account:

- Employ plot design elements such that all variables can be observed that were identified from the information needs assessment.
- Various different plot design options can be combined to sets of nested sub-plots.
- Use only those plot designs for which straightforward statistical analyses are possible and refrain from inventing new approaches to data collection without having developed suitable estimators.
- Duly apply slope and boundary corrections.
- Measurements per plot shall be operationally feasible in terms of time and equipment.
- Commonly, field sample plots for national forest inventory are installed as permanent plots to be visited again a certain time period like 5 or 10 years. The planned plot design and measurement procedures shall take that into account, by, for example, recording not only GPS coordinates in a well-specified grid system, but also by recording landmarks.
- When preparing for co-registration with remote sensing imagery: adjust the plot design accordingly – if operationally feasible.
- The work load of doing the measurements and observations per plot is co-determining the optimal size of the field teams – and working time.
- If possible, field plot size and workload shall be defined such that it can be worked by the field team at one day, including travel time.

Where this is not possible because of difficulties of access, the field teams need to stay in the field, which is causing additional logistical and cost challenges.

- Define all steps of plot establishment including measurements so that it can be transparently documented in the field manual (see also chapter 4.3.1).

4.2.4 Estimation design

In the context of sampling design (see chapter 4.2.2) and plot design (see chapter 4.2.3) considerations, it has yet been mentioned that it is absolutely crucial to choose techniques that allow straightforward statistical estimation. This is what is also called “estimation design”: to specifically identify and define the analyses algorithms, the estimators (formulae) to be applied once the data are readily collected and quality checked. This point is deliberately listed here as an extra point to emphasize its importance. It is recommended to develop yet in the planning phase as far as possible all details of the statistical estimation process. This helps preventing employing elements of sampling or plot design for which statistical estimation is unclear or impossible. It also helps to identify potential gaps in the variable list. Careful consideration in this step facilitates implementation of data analyses and estimation once all data are there (see chapter 4.4.4). A well prepared, transparent and consistent estimation approach is a pre-requisite for the overall credibility of the whole NFMS process and contributes, therefore, substantially to the overall principle of credibility.

This step requires a very good command of sampling statistics in forest assessment and requires the services of experienced forest survey statisticians.

In defining the estimation design during the planning phase, one shall consider the following:

- Specify all analyses steps and specify the corresponding estimators that must be consistent with the definitions of sampling and plot design.
- Prepare all analyses that are required to produce the outcomes that are expected according to the information needs assessment.
- Thoroughly discuss the approach in the team of analysts and document it step by step, including the software implementation used. This step-by-step analysis strategy may then be used as the starting point and basis for the methods’ volume during reporting (see also chapter 4.4.5)
- Consider estimators that integrate with maps or remotely sensed data to improve the precision and to provide spatially explicit information.

4.2.5 Model selection

Statistical models are an integral part of any NFMS, simply because many variables of interest cannot directly be measured but need to be modelled from variables that can more easily be observed. A typical example is individual tree biomass, from which stand and forest biomass is estimated. Individual tree biomass cannot be measured (unless the tree is cut and weighed) so that models must be used. It is absolutely clear that the models will never yield the true biomass of a particular tree, but it is the best possible approximation in the inventory context.

When the models are suitable and do not have a bias, we may assume that over the large numbers of sample trees that are modelled for biomass, the overall estimated biomass per hectare will be approximately unbiased. Of

Box 10.

It is sometimes observed that much effort is put into specifying the way how many and diverse data are collected (that is: defining sampling and plot design, but much less into the early planning of data analysis = estimation design.

It is strongly recommended, though, to consider estimation as a core element of the NFMS from the outset.

course, each application of a model introduces variability (statistical error) into the estimation because it is not a measured value but a modelled (sort of mean) value.

The most frequently used models are allometric volume functions that predict volume from *dbh* alone or from *dbh* and *total height* and possibly further variables (like diameters at upper places on the stem); and allometric biomass (and carbon) models that predict individual tree biomass (or carbon) from predictor variables like *dbh*, *total height* and wood specific gravity. The most simple models for biomass are so-called biomass expansion factors (BEF) that -depending on the definition- "expand" the tree volume as predicted from a volume model to the tree total (or above-ground) biomass.

Volume, biomass and carbon are among variables of commonly high interest in national forest monitoring so that corresponding models must be there. A huge number of models is out there and there are global initiatives like FAO/CIRADs GlobAllomeTree making them available on a systematic basis. In the best case, biomass models are available that are based on measurements from the inventory region and that are specific for the major tree species present. If one resorts to general global models or models from other regions, one must be aware that considerable uncertainties may be introduced.

It is a methodologically challenging task to judge whether a model at hand is suitable and applicable to a particular situation; an assessment of the quality of all models used in an inventory is important. Here, the quality is not so much referring to the question how well the particular model fitted to the sample data upon which it was built – but how well the model fits to the specific population of interest where it is to be applied. In other words: a model may have a very low standard error of estimation and a very high coefficient of determination, but it may nevertheless be heavily biased and not suitable for the population at hand.

When selecting suitable models, one shall consider the following:

- Find out whether locally specific models had been developed; this is frequently ground in gray literature.
- If local models are not available, there are two options: either to resort to global models which implies the risk to introduce considerable – but unknown – uncertainty; or to develop own models which is a generic research task and quite laborious, too.
- If possible, models shall be quality checked for their suitability before applying them to a specific project.

4.2.6 [Quality assurance: errors in forest inventory](#)

Forest inventories are complex, involving numerous methodological steps and involving many experts and staff from different fields of expertise. It is obvious that such a system is prone to errors and uncertainties. Box 11 does briefly explain the meaning of the term

Box 11.

In empirical statistical studies, the term "error" describes the residual variability – and not mistakes or failures.

In that sense, errors are omnipresent and cannot be entirely avoided.

The goal of NFMS survey planners is to identify the sources of errors, to address them as good as possible and to reduce the errors to the extent possible and economically feasible.

Of course, also "real errors" occur in forest inventory studies, for example by wrongly using measurement devices or by wrongly writing down observations. Also, cases are known where the inventory teams did not even go to the sample locations in the forest but faked the field forms altogether.

Causes of such "real errors", of course, need to be addressed very seriously and this is mainly an issue of training and treating all staff with due respect making clear that each one has an important and responsible function.

“error” in the given context. While errors cannot be eliminated, it is the goal of NFMS assessment planners to reduce the errors to the extent that is economically and logistically feasible. These measures are part of the quality assurance/quality control (QA/QC) plans, another component of the technical design of a national forest inventory.

Quality assurance/quality control (QA/QC) is critical for any empirical study including forest inventory. Generally, a QA/QC plan consists of three basic components: (1) prevention (2) assessment and appraisal, and (3) correction. “Prevention” attempts to ensure that high quality data is collected by providing clear and complete definitions and descriptions of the measurement procedures: reducing measurement and observation errors is an important element of QA/QC (see also chapter 4.3.1). “Assessment and appraisal” refer to the procedure to evaluate and document data quality. “Correction”, finally refers to the use of the findings from assessment and appraisal to apply corrections - where and if at all possible.

There are various sources of residual variability within a forest inventory system and a number of possibilities to commit real errors (for the distinction between these terms, see Box 11.).

For the residual variability, there are three major sources, which are described in the following together with actions that may be taken to keep them small:

1. Measurement/observation error:

Measurement errors occur when measuring or observing a variable. Typical examples for measurement errors in forest inventory are: repeated measurement of *dbh* by different staff may lead to deviations in measurements; identification of tree species may be mistaken. Measurement errors cannot be corrected posteriorly, unless one goes out again and repeats the measurement. When measurement errors shall be explicitly taken into account, repeated measurements of the same objects need to be taken and this needs to be clearly described in the field manual (see also chapter 4.3.1).

The goal must be to keep measurement errors low and that is achieved by a good preparation and “calibration” of the field teams (see also 4.3.4), by the use of well calibrated measurement devices (for the measurement of metric variables) and complete lists and identification keys (for tree species identification, for example). Equally important for keeping high quality standards of measurements (and frequently ignored or underestimated) is it to explicitly appreciating the hard work of the field teams and keeping them actively motivated.

For the purpose of subsequent analyses and estimation, the measurements are commonly taken as true, unless a specific assessment of measurement errors is integrated into the NFMS.

2. Model error:

Whenever models are used in forest inventory, they introduce additional residual variability. This comes from the fact that the prediction from a model does not produce the true value of the observed tree but rather a mean value from a set of research sample trees.

The true model errors in terms of the distribution of deviations between predicted and true values cannot be quantified in a forest inventory without time consuming additional measurements.

Frequently, the values taken from the models are assumed to be true. However, when model errors are known, they shall be explicitly taken into account in analyses and estimation.

3. Standard error:

The standard error is the residual variability caused by the fact that only a set of sample observations is taken to calculate estimations – rather than observing everything, which would allow to calculate the true value. The estimations vary as a

function of which sample elements were selected in a particular sample. The standard error is a function of the sample size, the plot design and the variability that is present in the population. As plot design (4.2.3) and sampling design (4.2.2) are defined such that statistical estimators are available, the standard error can straightforwardly be estimated. This is standard in all types of forest inventory that the standard error for all important variables is estimated and reported together with the estimates (like the mean values).

When reporting only the standard error, one does implicitly assume that there is no other error source reported. Because measurement and model errors, however, are always also there, one may also safely assume that the standard error is the lower bound of the total error.

There are simulation studies that point to the fact that, indeed, the standard error of estimation is, at least for core variables like growing stock or basal area, the by far largest component in the residual variability.

For the "true errors" (= failures) there are many possibilities and only some most relevant are listed here. For all these true errors, one can only tackle them by good training, efficient supervision, and good motivation of field teams (which includes fair payment and fair treatment):

- Bad design of the field forms: inappropriate structure and presentation of questions and tables, and missing or unclear explanations and instructions can cause errors.
- Data entry errors, where required information is not entered or is transcribed incorrectly from paper forms to the computer.

Modern field data loggers offer comfortable options to check the input data directly in the field. For this, the range or realistic values need to be identified for each variable, and values outside that range are not permitted or need to be explicitly confirmed by the user.

- Reading errors at the measurement device.
- Poor field protocols that lead to illogical data or do not provide guidance for how to collect information associated with uncommon field conditions.

To address the components of QA/QC, an NFMS shall develop comprehensive field protocols that address a wide range of fieldwork scenarios (see also chapter 5.4.2), conduct appropriate training (see also chapter 4.3.4) and maintain contact and communication to and between field teams for an exchange of experiences.

When planning for the assurance of data quality, the following should be observed:

- Owing to the complexity of NFMS, there are many sources of error.
- Statistical error (residual variability) cannot be avoided but all design planning and field measurements strive to keep it small.
- Crude errors can best be avoided or reduced by efficient training, supervision (see also following chapter 4.2.7) and motivating the field teams.
- If quantification is possible, all errors shall be reported; this contributes to making the results better interpretable.

4.2.7 Design of control measurements

A very important measure in the context of QA/QC are control measurements by supervision teams, sometimes also referred to as check cruising. As a rule of thumb and as a general measure of QA/QC about 10% of the field plots shall be quality checked by a supervision team. The regular field teams must know about this and they must also know

the importance of high quality measurements and the consequences of not complying with it.

That is: measurement tolerances and measurement quality objectives (MQO) need to be developed and documented. The tolerance is the range of acceptable values, e.g., ± 1 cm for *dbh*. The MQO is the percentage of the time that the measurement must be within tolerance, e.g., 95% of the time.

Possibly even more important than the individual tree measurements are the measurements of the plot size: if the plot area is wrongly determined or the slope correction forgotten or badly done, this may have a big impact on the extrapolation from plot values to per-hectare values. Also very important is the well documented and correct positioning of the plot: when the GPS measurements and the documentation of reference points / landmarks are of low quality or mistaken – this will compromise the possibility to find this plot again in the next inventory cycle.

The recommendation of checking about 10% of the field samples is about as far as the related standards go in national forest inventory. There are no generally established standards so as to how to select the supervision plots and how to determine threshold values and how to define consequences in case of non-performance of field teams. All these points need to be defined specifically in a protocol for supervision measurements for the particular inventory.

The supervision may be implemented by different strategies. It is recommended to employ all of them; the extent to which the different strategies are followed depends very much on the particular circumstances:

1. "Hot checks": Experts accompany field crews to the field and monitor, correct and discuss field team procedures that are either inefficient or may lead to errors. Such supervision has very much the character of continuous training and quality improvement.
2. "Cold checks": The supervision teams go to sample points already measured and they carry a copy of the field sheets. They do then again the measurement, either completely or along a specifically designed supervision measurements protocol. The comparison of the supervision measurements and the prior measurements by the regular field team serves then as the basis for the quality assessment. The results help to identify crews or individuals with quality issues that need to be addressed.
3. Blind checks – expert or regular crews are sent to plots without the previous crew's data or knowledge and measure the plot as if it were a new plot. Producing regular QA assessment reports provides users with the information needed to assess repeatability of measurements and is important for transparency and accountability.

For Cold and Blind Checks, software should exist to quickly compare results and provide a scoring system to see if the data meet MQOs.

The following points shall be observed when designing the technical parts of the supervision of field work:

- Control measurements are extremely important and are standard element of any forest inventory sampling.
- All field teams should be checked.
- All sample points shall have a probability larger than zero to be checked, even if they are extremely difficult to reach.
- Hot checks should be started early during field inventory implementation in order to ensure that correctable errors are not committed for a longer measurement period.
- The results of early hot checks may necessitate an intermediate training workshop or another platform for exchange of experiences between field teams.

- Quality standards to be met need to be defined. There is no such thing like a general standard for measurement errors (admissible deviations) or observation errors (misclassifications). Neither are there standard procedures how to deal with non-performance. All that is part of the technical and operational planning and needs to be defined by the NMFS planners in detail.

4.3 Operational Design

The term operational design refers to all activities in setting up a NFMS that do not directly have to do with the definition of the technical-scientific design but which are nevertheless indispensable for the successful implementation of the NFMS.

The elements of the operational design refer very much to standard project planning. Its definition requires skills in all issues related to project implementation including human resources, communication and logistics.

Eventually, all actions of operational planning serve to implement a cost-efficient system that maintains high data quality: reducing errors is among the most relevant planning criteria.

Yet in the context of statistical design planning and quality assurance (chapter 4.2.6), sources of errors (both residual variability and crude errors) had been addressed.

Any error in field observations propagates directly to the final results and affects data quality. Random errors increase residual variability and systematic errors introduce biases. Both are unwanted.

Reducing errors and maintaining high data quality standards are among the criteria for all planning steps also in operational planning, for this reason, a NFMS shall:

- Put together a field manual considering high quality standards and the best possible consistency for data collection.
- Establish a training program that serves to “calibrate” the field teams according to what is stipulated in the field manual and to harmonize and standardize all observation procedures between field teams; and to eventually motivate the teams to care for data quality also under difficult field conditions.
- Introduce a supervision mechanism of independent control measurements per quality checks of field data collection.

Regarding the principles, the operational design follows and responds mainly to the principles of research infrastructure and capacity building (5), and cost efficiency (11).

4.3.1 [Writing the field protocol \(field manual\)](#)

Data collection process as plot-based observations, interviews, house surveys are among the most expensive and time-consuming steps of the NFMS. Various staff will be contracted in order to constitute the field teams that do the field observations (see also chapter 4.3.3). It is, therefore, extremely important to craft a data collection protocol (= field manual = field protocol) that describes all details of the field measurements and observations in an unambiguous manner and that can be used by all field teams as a reference. Together with an efficient training of the field teams (see also chapter 4.3.4), the field manual is a means to standardize the observations and to support achieving high data quality. It contributes to optimizing the activities related to data-collection and analysis, to promoting the adoption of good routine practices for carrying out measurements, and to efficiently managing time and staff. Also, it helps field staff to better understand their important role in achieving high data quality.

Essential components of the field manual is the definition of terms and variables, the use of equipment, the time allocation to tasks and the minimization of the impact on data

quality of the particular environment or particular local circumstances when carrying out measurements.

Enhancements of the field protocol shall be made whenever measurement procedures need to be specified or more efficiently organized. Feedback from the field teams and emerging new methods may give reason for such amendments. However, caution must be exercised when definitions or procedures are changed: they should not lead to inconsistencies within the data from one inventory cycle to the next thus compromising the comparability of results over time.

In a NFMS, data collection protocols shall:

- Be specifically tailored to the national circumstances and capacities yet seeking to be consistent with national and international standards.
- Provide both a clear guidance and an operational and logical sequence of methodological steps for the observation of the target variables, thus maximizing efficiency of the activities and standardization of the data recorded between the different field teams. Normally, errors committed during the forest inventory field data collection phase cannot be corrected later unless by going again to the same field locations.
- Include an introductory chapter stating the background and justification for the particular inventory. This chapter should help the field teams (and also other interested parties) to better understand the goals and concrete objectives of the study.
- Include a complete list of devices and materials that the field teams should carry to do the measurements. This list serves as a check-list for the team leader before leaving for the forest. Such a list shall also clearly mention the necessity to carry items like spare batteries, first aid kits, and possibly radio communication facilities or satellite telephone.
- Include a clear description – including graphs – of the plot design elements that are implemented per sample point, and a step by step description of the measurements to be taken on each one of the plot design elements.-Each variable in this step-by-step description needs to be defined in terms of its meaning and in terms of its measurement procedure.
- Take into account all possible field situations, both - the definition of the variables and of the definition of the measurement procedure. It must be avoided that the field teams encounter situations in which the field manual does not give explicit guidance and where the field teams make their own individual decisions which are likely different between the field teams and do likely lead to inconsistencies.
- Clearly described for all categorical and nominal variables, all classes and levels, such that the operators in the field know exactly which datum or code to enter for which variable. This refers, for example, to the measurement units and number of decimals for metric variables like *dbh*, and a complete list of names / codes for nominal variables like *tree species* (including the option "unknown" and a list of botanical family names for cases where an identification down to the species level is not possible).
- The annex to the field manual should contain a guide on the correct use of all measurement devices, even of the most simple ones like caliper or tape. This can be extremely helpful, even though one may assume that the field teams should know the devices by heart once passed the preparatory training. Most important, of course, is that the complete instructions for the electronic devices are added.
- Be thoroughly tested in the field under the particular conditions of the national data collection, both by those who wrote the manual and by independent field teams.

- Be printed such that it can easily be used and referenced in the field. A small booklet, possibly laminated, has shown to be very practical. In case that robust data loggers are used for data recording, the field manual may also be carried in electronic format.
- Encouraged field teams to comment on the field manual. At the end, data quality does depend very much on these staff, and their experiences in situ are the most valuable for optimization of the field manual.

4.3.2 [Design of information management system](#)

A NFMS requires a well-structured and compatible information management system to be established where all data of the NFMS are stored, managed and maintained on the long run.

The data management information system needs to be well documented with metadata files describing variables at all scales, and with the identification of categories or ranges of values for categorical and numerical variables. All these descriptions need to be compatible with the field manual that elaborates on the "origin" of the data.

For effective data management, an NFMS shall:

- Document the database and provide metadata on various aspects of the NFMS, such as model coefficients and references, sample design and plot configuration.
- Establish and employ standards in three main arenas: data content, classification and technology used. Harmonization of variables may be required when different standards are applied to the same variable within the country.
- Enter the sample data, preferably by transferring from a portable data recorder rather than re-entering from paper.
- Store and back up both raw field data and "clean" data, preferably on a central server.
- Create a policy on data sharing with special consideration to Personally Identifiable Information and plot coordinates.
- Collaborate with partners on data sharing which helps to create more support and which may help create more robust data bases.
- Ensure that personnel should not be only able to complete tasks regarding data entry and analysis, but also to update or modify data bases when necessary. Training courses can help.
- Local estimation models: facilitate code used in programming estimation, identify direct and indirect models to estimate resources at small scales (i.e., allometric models, species-area curves,..), the variables and parameters for the models and the accuracy measures reported in the models, including residual errors and sampling sizes used to evaluate the models.
- Imagery-based protocols: metadata regarding data sources for processing methods and accuracy assessment protocols, image processing and averaging approaches used to normalize resolutions (i.e., kriging, ...).

4.3.3 [Building the teams](#)

There are various tasks in implementing and running a NFMS, some are permanent tasks and some are temporary. All tasks require specific expertise and staff. Like in all programs, efficiency of procedures and quality of outcomes depend very much on skills, seriousness and motivation of all staff. Recruitment of the right people for the different tasks and generating an attractive working environment for them is, therefore, crucial for

the success of the NFMS. "Attractive working environment" means above all absolute clarity about roles, tasks and responsibilities as well as fair payment and fair formal contractual conditions. The positions of all staff in the whole process (hierarchy and who reports to whom) must be clear as well as the communication structure.

For field teams it must also be taken into account that this is a physically very demanding task that requires a high degree of physical fitness. Field team leaders should show a good ability of leadership.

Building the teams for the different NFMS tasks includes aspects like:

- Recruiting staff with prior experiences in forest inventory field work, if possible.
- Integrating young and ambitious forest technicians or forest academics contributes to long term capacity development in the country.
- The composition of the field teams in terms of number of staff and hierarchical structure needs to be defined as a function of the set of tasks to be carried out. Commonly, it comprises a field team leader, one or two experienced field inventory technicians and helpers who may also be recruited locally so that they can make available their local knowledge to the field teams.
- Terms of reference for each of the team members, based on the NFMS component in which they works. It should clearly indicate what the roles and functions for are that may be assigned to him/her by the field team leader.
- Training and advisory plans.
- Transfer of new technologies and tools for gathering and processing information.
- Clarify quality standards and the joint responsibility of the entire team.
- At least one helper should be contracted locally. This has various positive effects: (1) Their local knowledge helps with orientation in the field and (2) their link to the local communities helps to better generate acceptance for the inventory work and (3) to better understand the type and intensity forest uses in the particular area where the sample point is.
- Distribution of labor in the field is important and should be based on the particular skills of the individual staff. All staff shall be encouraged to make suggestions for improvements of procedures. The field team leader has eventually the say when it comes to the -possibly dynamic- assignation of tasks.
- keep the field staff motivated. Forest inventory field work is physically extremely demanding and after several months of routine measurements, quality may suffer. Starting with the recruitment, therefore, each and every staff member shall be clear about the high relevance of high quality measurements by each!

4.3.4 [Training](#)

Specific and sufficient training before field implementation of the inventory work is fundamental. It is only by a standardized training that the field teams can be "harmonized" to consistent field procedures. Well organized training workshops provide the "technical background" for data quality and consistency, but they also provide a "team building background" by bringing various field teams together and generating a sort of corporate identity.

If possible from an organizational point of view, all field teams should receive the same training, partly at least simultaneously: this fosters communication between the teams. This communication between the teams shall be maintained also during implementation of the field inventory work. It may lead to more comprehensive discussions about the field procedures and the field manual. It is not uncommon that adjustments of the field manual are made as a result of observations and suggestions during the trainings. It is, therefore, important that those experts who defined the field procedures and developed

the field manual, participate in the trainings -which is at the same time an excellent chance for them to possibly identify weaknesses of the protocol that need to be improved before implementation.

Some aspects are important to take into account:

- The training should be calibrated to the national capacities and based on a stepwise approach.
- All teams shall receive the same training. Overview training can be done in larger groups; practical trainings of measurement devices require smaller groups – or more instructors. Training directly on sample points (field sites) need to be done in smaller groups (2 field teams together, maybe).
- At the end of the training, each field team should do one or two real field sample points of the inventory under the supervision of instructors.
- The duration of the training will depend on the complexity of the plot design and the prior experiences of the field teams. Covering all relevant topics -including both general introductory information about the relevance of the NFMS and specific training of the field protocol- takes commonly at least one week and possibly more.
- The training workshop should be part of an integrated, durable and effective country capacity development strategy.
- The training workshop may include a sort of exam at the end where a formal certificate is issued.
- Exchange of knowledge and experiences among field teams is important. One may, therefore, establish a direct contact with the participants through a mailing list.
- To formalize such exchange, one may plan for an intermediate “training workshop” after the first month of field implementation, which then serves as a platform for the field teams to exchange experiences and address particular difficulties encountered. Such meeting is also of great relevance for those who developed the field protocol – and it helps to keep motivation of field teams high.

4.3.5 [Field work planning](#)

Operational planning refers to the development of the implementation plan of the field inventory in a given period of time, by defining and prioritizing all necessary activities and their sequence so that the specific goals of each of the components of the NFMS can be achieved as efficiently as possible. This entails a planning process for the completion of the proposed activities, where the inputs, resources, and responsibilities should be identified and documented. This planning process defines the work plan for the technical teams and requires both planning skills and forest inventory technical skills.

It is important that the operational planning is complemented with a monitoring and evaluation system, which ensures compliance with the activities, systematization of learning experiences and innovation of the NFMS management.

In this regard, some aspects to take into account during operational planning of field work are:

- Ensuring compatibility of the operational planning with the objectives and expected results of the NFMS, in the medium and long term.
- Analysis of resources for national funding and international cooperation and striving to achieve a high degree of cost-efficiency.
- The operational plan needs to provide for all logistical issues including transport, measurement devices, emergency plans in case of accidents in the field, provision

of spare measurement devices, communication strategies between field teams and between the NFMS headquarters and the field teams.

- The result of the operational planning is the NFMS Operations Plan. It shall clarify the goals and guiding principles (in particular regarding data quality), define general and specific activities, specify the resources available, and define duties of teams and staff members, and scheduling of their activities.
- The operational plan defines the work load (the sample points to be measured) for each field team. The detail planning is then task of the field team leaders.
- As far as possible and sensible, the operational planning shall involve the actors.
- A system for the continuous monitoring, assessment and update of the operational plan shall be generated which includes also the management and monitoring of funding for the implementation of the operational plan.
- Operational planning does also embrace the planning for the supervision of field work (4.3.7). It refers then to the constitution of supervision teams, the selection of sample points to be supervised, the definition of the supervision measurement protocol, the definition of quality standards for a core set of variables and the definition of consequences when these standards are not met by field teams.

4.3.6 [Field work implementation](#)

“Field work” refers here to the process of collecting biophysical data in the course of specific forest inventory work. This work takes place directly on the ground and mostly plot-based observations are related to forest structure and composition and other relevant characteristics, and may also include interviews with forest users and forest owners. The main purpose is to collect original data on the status of the forest ecosystem and the forest resource at a given place and time, both in terms of qualitative and quantitative variables. Field work is also important to establish relationships between remote sensing and ground data.

The basis for the technical part of the field work is the field manual (see also chapter 4.3.4) and the basis for the organizational and logistical issues is the operational planning (see also chapter 4.3.5).

Important aspects to take into account are:

- Along the assignment of tasks as formulated in the operational planning, the field teams organize their field work independently – but always coordinated with the NFMS headquarters so that compatibility with the NFMS goals and overall procedures is guaranteed.
- Field work implementation refers to the concrete scheduling of field work according to road and weather conditions, accessibility, fitness of the field teams and other practical criteria.
- The usability and calibration of measurement devices must be regularly checked.
- In cases of doubts on any of the working steps, the NFMS headquarters shall be consulted in order to maintain consistency with the overall system.
- Field work procedures will be gradually optimized in the course of the field work, depending on the experience and skills of the team members and internal communication.
- Again: the major guiding principle in field work implementation is to strictly follow the field protocol and to maintain high data quality standards.
- Forest inventory field work has not only a technical side but also a “team dynamics” side. It is, therefore, an important task for the field team leaders to try to keep the motivation of all field teams’ members high, by appreciating the

contributions and permanently pointing to the high relevance of the contributions of all to the whole NFMS.

4.3.7 Supervision of field work

Supervision of field work – sometimes also called “control measurements” or “check cruising” is necessary to ensure data quality. Technical aspects of planning for supervision measurements are dealt with in chapter 4.2.7 and more details about error sources are given in chapter 4.2.6. There are many possibilities to commit errors and after some time of tiring field work, the care with which it is implemented may suffer. Independent supervision shall serve to motivate the field teams to maintain high quality standards – but also make clear that non-compliance and crude errors may have consequences. At the end, supervision may be considered a sort of “continuation of training”.

For the operational planning of the supervision measurements, the following points shall be observed:

- The supervision teams must be forest inventory experts who are absolutely familiar with the field protocol and are skilled forest mensurationists.
- Independence between supervision teams and regular inventory teams must be guaranteed to the extent possible.
- The results of hot and cold checks need to be analyzed rapidly and feedback given to the field teams. There may be cases of non-performance where field teams’ contracts need to be terminated immediately - but there may also be cases where field teams come up with excellent suggestions to improve the implementation of field procedures.
- To properly use the supervision of field work for the benefit of the complex goals of the NFMS is eventually a matter of human resources management and leadership.

4.4 Data management, data analyses and reporting

Once the field data are collected, the data must be safely and permanently stored so that they are later easily available for reference and further analyses. This permanence of data availability is one of the constituting elements of an efficient NFMS. Another quality control is done once data have been entered and stored, and before analyses. Statistical data analyses shall be designed to respond to specific questions as formulated in the information needs assessment and also to produce additional results that may come from research questions. Results need then to be converted into reports for broader audiences. While such reporting is done to the “exterior”, there should also be an “interior reporting”, meaning that it is recommended to do a thorough analysis of experiences in the specific cycle of national forest inventory implementation, both in terms of technical implementation and in terms of compliance with stakeholder expectations. With these “lessons learned” the NFMS will gradually improve on all planning and implementation levels.

Diverse expertise is required also in this context: data management and storage requires expertise in informatics, statistical data analyses require expertise in sampling statistics and reporting requires expertise in understanding the resource, communication and public relations. The final steps of critical reflection and impact analysis (lessons learned) require expertise in the whole process of national forest monitoring.

The “Data management, data analyses and reporting” element responds and refers mainly to the principles 5 (Research infrastructure and capacity building), 12 (Data sharing policy) and 13 (Transparency).

4.4.1 [Data entry and management](#)

A NFMS requires an efficient data management system which involves data entry, quality control, archival and long-term accessibility of both collected data and associated metadata.

Once the information management system has been designed and installed (see also 3.6), a complete documentation needs to be added, including metadata (e.g., description of all variables, individual fields and tables). This documentation needs to be entirely compatible with the field manual, where the "origin" of the data is documented. A metadata standard is a set of terms and definitions that describe the data to let data users know what data are available, whether the data meet their specific needs, where to find the data and how to access them. Many such standards have been published for geospatial data.

The metadata should also comprise all other components different than data themselves as needed for estimation, such as model coefficients and references, and background information on sampling design and plot design.

The next step is entering the data. If no portable data recorder was used, then the data must be entered manually from the paper field sheets. Raw field data and "clean" data need to be permanently stored and backed up. Ideally the data are stored on a central server with a single current version rather than as multiple versions on multiple individual PCs. This facilitates data integrity, currency, and sharing.

For effective data management, an NFMS shall:

- Ensure that personnel should not be only able to complete tasks regarding data entry and analysis, but also to update or modify databases when necessary. Training courses can help.
- Ensure that the personnel in charge of the analysis, have a well knowledge of the database and the different variables and models to be used.
- Provide protocols for data clearing, and apply it to the data base in order to get the full consistency of the data. – Data should be reviewed and clean before data analysis start- (see chapter 4.4.2)
- If different analysis protocols are used for data analysis, they have to be well documented in order to provide the option to others to perform the same analysis (see chapter 4.4.4).
- If part of the data is exported to be analyzed in different software, the integrity of the source database have to be ensured.
- All results have to be related with the data collection procedure and the sampling frame, in order to avoid conjectures.

4.4.2 [Data quality control](#)

A final data quality check should be enacted in the data management system. Only a limited set of errors can be detected and corrected at this stage; a cross-check with the situation in the field is usually not possible and the errors that can be detected are mainly referring to internal inconsistencies and values beyond realistic ranges. A correction will be easy in some cases (if, for example the decimal point was obviously shifted for a measurement value) – and impossible in others (if, for example, a species was incorrectly identified or the plot location incorrectly determined).

QA/QC actions when managing the data base shall embrace:

- Re-check the data in the office. Edit checks that should have been conducted in the field should be applied to the raw data, especially if a field data recorder is not used. Raw data should be archived. Changes should be made to a copy of it. Further checks can be performed using graphical and summary statistics to identify outliers to examine further. Finally, appropriate methods for filling in

missing data or correcting obviously incorrect data should be devised and implemented, wherever possible.

- So-called outliers need to be very carefully checked before eliminating them. Frequently they represent extreme cases, and not errors.
- Develop procedures to perform quality assurance of estimates produced by the estimation system. This can be conducted by implementing the estimation algorithms using a parallel, unrelated system. For example, the appropriate estimation procedures can be applied in a spreadsheet to verify the integrity of the corporate system.

4.4.3 [Define the specific analysis steps in order to answer monitoring questions](#)

Data analyses and estimation (see chapter 4.4.4) typically is to produce pre-defined figures, tables, graphs and maps of target forest variables. These estimates are the numerical results that need subsequently to be further analysed and interpreted to answer the monitoring questions identified in the information needs assessment. The results should produce the information needed to achieve strategic goals, reach set targets and fulfil stakeholders' needs.

In order to ensure that the analyses performed on the NFMS data does specifically answer the questions for which it was designed, before doing the data analyses, a NFMS shall:

- Define the expected type of outcome of the analyses as specifically as possible according to what had been expressed in the information needs assessment.
- In particular, document any potential shortcomings in data and/or data collection for future reference and use in improving the NFMS program.

4.4.4 [Data analyses and estimation](#)

Data analyses and estimation is the step in a NFMS in which the questions posed in the information needs assessment are addressed; but also, exploratory analyses is extremely useful in which the analyst "asks questions" to the data. The results are calculated for the defined units of reference with algorithms that are in line with the statistical design of data collection (sampling design and plot design). The approach to "data analyses and estimation" is, therefore, also called "estimation design".

Generally in forest assessment, all results of sample based national forest inventory are estimates and as such the point estimates (for example estimated mean values) shall always be accompanied by their interval estimates (or error variances): not only the target value is estimated (for example biomass per hectare) but also a measure of uncertainty of this target value (for example the estimated confidence interval of this estimated target value). As mentioned in chapter 4.1.3: such confidence interval does not quantify all sources of uncertainty in a national forest inventory, however in any case: it yields at least a very useful order of magnitude.

The data analyses and estimation process needs to be carefully documented in all details and be part of the inventory report, commonly within the "methods' chapter" of the reports. A transparently documented methods' chapter is a crucial element of credibility for the whole NFMS process.

Box 12

When producing sample based estimates for defined spatial units or reporting, it must be observed that there are, of course, downward limits to the size of such reference units.

Meaningful estimates can only be produced when a sufficiently large number of sample plots falls into the corresponding region.

For very small areas, estimates may be meaningless.

Regarding data analyses and estimation, a NFMS shall:

- Ensure that data analyses and estimation are led or supervised by experienced forest inventory biometricians who are familiar with the numerous analysis pitfalls in forest inventory data analyses.
- Strictly consider all statistical design elements of sampling design and plot design and follow generally accepted estimation procedures for point estimation and interval estimation: once the design elements are defined and fixed, there are commonly not many choices for the estimation design.

Here, it must be observed that for the most commonly used sampling design, the systematic sampling, unbiased variance estimators for design based sampling do not exist (see also chapter 4.2.2 and Box 7.). However, the commonly used estimators tend to be conservative (that is, overestimate the variance).

- In the ideal case, the estimation design has been clarified and tested with test data prior to the data collection phase in order to make sure that no design element is employed in data collection for which a proper statistical estimation design is not available.
- Use ancillary data from other data sources when estimation can be made more precise by that, for example remote sensing data for stratification.
- If it is a repeated inventory, estimates of the components of change (ingrowth, growth, mortality and removals) should be computed.
- Estimates shall be provided for the whole country (national level estimates) and for sub-national units of reference, as defined in the planning phase (see also Box 12).
- Identify appropriate software. If available the use of existing, tested forest inventory estimation software is recommended, since the opportunities to introduce errors in programming are significant.
- It is common that data inconsistencies and errors are detected during analyses that were not identified before during the explicit QA/QC process (see chapter 4.2.6). These errors, of course, need to be checked and adjusted as completely and correctly as possible.

4.4.5 [Reporting](#)

Reporting is an extremely relevant step in the NFMS as it serves to communicate results and findings of the NFMS to the users and other interested groups. Reporting shall therefore follow the commonly accepted criteria of project reporting which does refer to credibility generated by completeness, consistency, transparency and understandable/accessible presentation.

Reporting shall deliver (1) scientifically-sound results derived from the NFMS to the stakeholders that need it, (2) inform about the methodological approach and (3) form the basis for further interpretations and for the translation of technical results into meaningful stories that contain clear and science-based messages for information of decision makers, research units and other stakeholders.

The ultimate value of the NFMS depends on how well it delivers the required forest-related information in a specific timely manner.

Timely, accurate NFMS reporting is also most relevant for some international processes. Participating countries have to inform international processes on a regular basis about the status of their forest resources and their efforts to monitor them, often with very specific reporting guidelines.

Important points to observe for NFMS reporting include:

- The report should be in itself complete and “self-sufficient”, that means: it shall allow the reader to directly understand the results without the need to refer to many other sources.
- The report shall explain about the strategic goals and about the political mandate and scientific justification of the NFMS, present the numerical results for all spatial units of reporting (national and sub-national levels) and give a complete description of the methodology.
- Because both results and methods are commonly very comprehensive and lead to lengthy reports that are difficult to read, it may be a good idea to publish for both results and methods two separate volumes: one complete volume that contains all information and one executive summary volume that contains the most relevant results, viz. a summary of methods without going into all details.

In general, the complete and detailed reports are directed to the inventory experts, and the summary reports are directed to the inventory laymen including policy decision makers and the general public.

- Ensure that the report provides answers to the questions for which the NFMS was designed. If shortcomings are found during the process of reporting, establish the means by which that feedback is used to refine and improve NFMS procedures (see also chapter 4.4.8).
- The way of reporting -both in quantitative and in qualitative terms- shall be tailored to specifically meet the stakeholders’ information expectations.
- Different strategies of reporting may be pursued depending on the identified stakeholders / interested groups. A core report, of course, is directed towards the policy processes and their decision makers. However, research institutions may have a great and continuous interest in NFMS data and an online database may be good for them with built-in standard reporting functions.

4.4.6 [Communication and dissemination](#)

The importance of communication and dissemination of information was discussed previously as being a critical part of the initial information needs assessment and stakeholder engagement. It is again of primary importance in the reporting process after data analyses. At the end, a NFMS’s is not a process for itself but defines its relevance and justification from the fact that it responds to information needs. Therefore, the NFMS’s overall value is limited if the data collected are not converted into useful information for the forest resource stakeholders. In addition, this useful information has to be delivered to stakeholders in a form they can readily understand and use. Sometimes it is said that the scientific-technical results of an inventory need to be “translated into meaningful stories of relevance” to the data users.

Good (that means: goal oriented and well packaged) reporting and dissemination also creates more interest and utilization of the NFMS data by generating new ideas through its examples and informed interpretation.

Box 13

It is frequently observed that planning for and implementation of communication and dissemination is not as intensively covered in the NFMS process as the more technical steps are.

This has probably also to do with the fact that inventory statisticians and resource analysts are not necessarily well-trained and well-experienced communicators.

Sufficient resources shall be allocated to the process of communicating and disseminating the results; contracting a professionally trained communication expert who accompanies the whole NFMS process and does active “marketing” of the NFMS process and results may be a good options.

Also in this context, much can be learned from experiences in other countries – both success stories and failures.

Communication and dissemination of NFMS reporting shall:

- Identify the means by which you will communicate results to all the stakeholders previously identified and possibly others.
- Encourage dissemination to a wider audience because there may be more interested parties, now that NFMS results are readily available.
- View reporting activities as a way to promote networking, further stakeholder participation and engagement, and encourage collaborative efforts across different public and private sectors.
- Be mindful of opportunities to engage the national and international scientific communities with studies that explore the data for more technical questions that can be presented in the peer-reviewed scientific literature. Results and experiences of one NFMS cycle are excellent starting points for research in optimization of the next cycle.
- Use the process of analysis, reporting and responding to subsequent information demands as an opportunity to build national capacity and reach new audiences for the NFMS, further building institutional, social and political support.
- Highlight the value of the NFMS both domestically and internationally through high quality reporting, thereby strengthening institutional and political support for the program.

4.4.7 Discourses on inventory approaches and results

Reporting (see chapter 4.4.5) and communication and dissemination (see chapter 4.4.6) is (1) to inform the stakeholders by responding as comprehensively to the prior expressed information needs, (2) to receive broad feedback on scope, focus and technical scientific approaches and value of the NFMS and (3) to begin discourses on all aspects of national forest monitoring with any interested party.

The NFMS responsible officers must acknowledge that a NFMS has not only a challenging technical-scientific side but an equally challenging political side.

At the end, NFMS data and information serve to inform with scientifically sound results and by that to reduce speculation: frequently, forest related discourses both within the government and between government and NGOs or the general public are quite controversial - and scientifically sound information may help to bring these discourses on a better informed level.

While it will be impossible to anticipate all possible questions that might be asked from a future national forest inventory the NFMS process should foster discourses by organizing workshops and discussion on the approaches and results of the forest inventory cycles. These workshops may be of a general type or be focused on groups of stakeholder with similar expectations, for example conservation NGOs, forest research institutes, wood processing industry, rural development NGOs etc.

Making inventory data publicly available has the potential to allow interested users to turn the data into useful information on their own.

Fostering discourses on the NFMS program and results, an NFMS shall:

- Identify a suitable format of workshop for each particular stakeholder group.
- Involve representatives of stakeholder groups into the preparation of these discussion fora.
- Ensure that such workshops are prepared in a manner that experts are there who can inform about all methodological details and results and who can also clearly explain about the strategic background of the NFMS.

- These workshops need high level involvement of the NFMS management and planning team, and should also involve partners.
- Prepare examples of results that support or contradict arguments that had been used in forest related discourses before new inventory results were available, for example regarding deforestation rates, development of species composition and other biodiversity related topics, regarding illegal logging, invasive species, the potential effect of incentives for sustainable forest management etc.
- Adapt and strengthen the program and its associated institutions by documenting and learning from the stakeholder feedback and discourses to better focus future efforts within what is feasible (see also chapter 4.4.8), including information needs, technical aspects, inclusion of neighboring sectors, and internal and general capacity development.

4.4.8 Evaluation and impact analysis

In the final phase of each cycle of the NFMS a systematic evaluation of the NFMS should be done in order to both learn from the process and to prepare for the next cycle. Actually, the reporting, communication and dissemination steps offer plenty of opportunities for critical reflections and may generate considerable feedback.

All actors of planning, implementing and analysing the inventory, and all stakeholders may have potentially relevant observations: the evaluation and impact analysis shall try to gather as much of this feedback as possible. A NFMS is a complex system and each cycle of national forest inventories is a technical complex project involving many staff with different responsibilities, so that many and also contradicting recommendations will come up.

In addition to the evaluation, a systematic impact assessment should be carried out in order to find out to what extent the NFMS does really make a difference. This is important when justifying the funding required for an NFMS. The major questions are: who is using which results of the NFMS, how often, and for which purposes? There is hardly any NFMS that has a systematic impact assessment in place, while it is extremely important information for the NFMS managers to learn also about the mostly referenced and the least referenced results. Consequently, there is no standard in place and it is usually very difficult to track the uses and impacts of NFMS results.

It is commonly a task of the high level NFMS managers to be involved and pursue both evaluation and impact assessment which shall embrace the following:

- Compare the actual results with the information needs as expressed after the inventories. It may be that pieces are missing, and it may be that some results are not actually demanded by stakeholders.
- Analyze whether the precision requirements were met for the key variables and identify potential solutions in the case that they were not met.
- Evaluate the procedures of field data collection. This shall be done in communication with the field teams and in particular evaluating the experiences and reports by the supervision teams.
- Make a cost analysis and identify the most costly components that possibly need adjustments.
- Find out - as part of the impact assessment - whether policy and management decision makers received the results in forms that meet their needs.
- Install a mechanism that allows to track who is using which result for which end how often.

5 CONCLUDING OBSERVATIONS

Establishing and running a NFMS is a complex governments' task that serves to better inform forest related decisions and thus supports to sustainably develop the forests on national level. It requires a long-term vision and interdisciplinary collaboration and is equally a demanding and exciting endeavor.

Typically, NFMS will be established in a step-by-step approach with continuous enhancements according to the experiences made and to the specific resources available.

The authors hope that these guidelines support this process by putting NFMS into the broader context of national forest-related decision processes and by addressing a number of relevant strategic, operational and technical points.