

## CASE STUDIES ON MEASURING AND ASSESSING FOREST DEGRADATION

### MEASURING AND MONITORING FOREST DEGRADATION THROUGH NATIONAL FOREST MONITORING ASSESSMENT

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Sustainably managed forests have multiple environmental and socio-economic functions which are important at the global, national and local scales, and they play a vital part in sustainable development. Reliable and up-to-date information on the state of forest resources - not only on area and area change, but also on such variables as growing stock, wood and non-wood products, carbon, protected areas, use of forests for recreation and other services, biological diversity and forests' contribution to national economies - is crucial to support decision-making for policies and programmes in forestry and sustainable development at all levels.

Under the umbrella of the Global Forest Resources Assessment 2010 (FRA 2010) and together with members of the Collaborative Partnership on Forests (CPF) and other partners, FAO has initiated a special study to identify the elements of forest degradation and the best practices for assessing them. The objectives of the initiative are to help strengthen the capacity of countries to assess, monitor and report on forest degradation by:

- Identifying specific elements and indicators of forest degradation and degraded forests;
- Classifying elements and harmonizing definitions;
- Identifying and describing existing and promising assessment methodologies;
- Developing assessment tools and guidelines

Expected outcomes and benefits of the initiative include:

- Better understanding of the concept and components of forest degradation;
- An analysis of definitions of forest degradation and associated terms;
- Guidelines and effective, cost-efficient tools and techniques to help assess and monitor forest degradation; and
- Enhanced ability to meet current and future reporting requirements on forest degradation.

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More information on the Global Forest Resources Assessment programme can be found at: [www.fao.org/forestry/fra](http://www.fao.org/forestry/fra)

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**Forestry Department**  
**Food and Agriculture Organization of the United Nations**

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**Case Studies on Measuring and Assessing  
Forest Degradation**

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National Forest Monitoring Assessment (NFMA)

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## **Abbreviations**

BCF	Biomass conversion factor
BCEF	Biomass conversion and expansion factor
DBH	Diameter at breast height
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment
GHG	Greenhouse gas
IPCC	Inter-Governmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
NFI	National Forest Inventory
NFMA	National forest monitoring and assessments
NWFP	Non-wood forest products
PES	Payment for ecosystems services
REDD	Reduced emissions from deforestation and degradation
RS	Remote sensing
RSS	Remote sensing surveys
SFM	Sustainable forest management
WD	Wood density

## **Preface**

Forest degradation is occurring throughout the world at an alarming rate and accordingly it features prominently in recent international objectives, goals and targets related to forests. The United Nations Forum on Forests (UNFF) calls for a “reverse in the loss of forest cover and increased efforts to prevent forest degradation”. Meanwhile the United Nations Framework Convention on Climate Change (UNFCCC) emphasizes the significance of Reductions of Emissions from Deforestation and Forest Degradation (REDD) in developing countries. Furthermore, the Convention on Biological Diversity (CBD) has a 2010 Biodiversity Target which includes an indicator on ecosystem fragmentation and connectivity.

All of these objectives call for the assessment and monitoring of forest degradation in order for countries to report on progress and adherence to these international objectives, yet there is no globally agreed, operational definition of forest degradation or degraded forests. Moreover, perceptions vary greatly depending on the main point of interest (biodiversity conservation, carbon sequestration, wood production, soil conservation or recreation for example). Definitions related to forest degradation and its associated terms are many and varied, depending on the driver of degradation and the point of interest.

This paper is included within a series initiated by the Collaborative Partnership on Forests (CPF) and carried out under the auspices of the FAO Forest Resources Assessment (FRA) process. It aims to present promising methodologies and tools for assessing these different aspects of forest degradation from the point of view of the seven thematic elements of sustainable forest management (SFM). The initiative intends to identify suitable indicators to assess the degree of degradation of a forest at different management scales.

The National Forest Monitoring and Assessment (NFMA) programme of the FAO was asked to produce a case study as part of the working paper series to document its approach and the indicators captured that may be used to assess the different aspects of forest degradation. As the NFMA methodology is broad in scope, consisting of a wide-array of indicators addressing the multi-functionality of forests and their uses, this paper illustrates how the NFMA methodology addresses key criteria of forest degradation linked to the thematic elements of sustainable forest management (SFM).

Each SFM thematic element is examined in the context of the NFMA country experience and how the NFMA approach has facilitated delivery of data on status and extent of forest degradation: extent of forest resources, contribution to the carbon cycle/climate change by forest, forest health and vitality, biological diversity, productive functions of forest resources, protective functions of forest resources, and socio-economic functions of forest. Country-level proxies and parameters are provided for each theme in order to demonstrate concrete examples of the NFMA approach and how it is enabling countries to assess, monitor and report on degradation of forest resources in different contexts around the world.





## **Acknowledgements**

This case study, 'Measuring and Monitoring Forest Degradation through National Forest Monitoring and Assessment', was based upon data derived from a selected number of countries where the program has been implemented over the last ten years. The FAO-NFMA team wishes to acknowledge those governments and their natural resource and forestry ministries who have worked together with the NFMA programme to successfully carry out national forest inventories: Bangladesh, Cameroon, Costa Rica, Honduras, Kyrgyzstan, Lebanon and Zambia.

Further acknowledgement is extended to the Swedish International Development Cooperation Agency (SIDA), whose support has been fundamental in enabling the NFMA programme to build and strengthen its techniques over the last ten years, allowing countries to produce more accurate estimates of the characteristics and use of their forests.

Lastly, the case study might not have been written without the CPF forest degradation case study initiative carried out under the auspices of the FAO Forest Resources Assessment (FRA) process, which presented an opportunity to examine NFMA work with a specific focus on forest degradation in a number of country contexts. The request for this case study enabled review of how the NFMA methodology is contributing to reliable forest data on forest degradation, which is one of the most essential steps towards achieving sustainable forest management and REDD readiness.



## 1. Introduction

The world's forests are increasingly being degraded and primarily by human activities. The loss of forest health and vitality as well as the decrease in social, environmental and economic functionalities of forests are reported as major issues in many countries around the world. In some countries, forest degradation rates actually surpass that of deforestation. In Indonesia, the forest stock is decreasing by 6% per year and forest degradation is responsible for two thirds of this whereas deforestation represents only one third (Marklund & Schoene 2006).

In its most basic of definitions, forest degradation refers to changes within the forest class, i.e. when forest cover is reduced, but still remains as 'forest'. Deforestation, on the other hand, is described as the conversion of forest to a permanent land use outside forestry. According to FAO, degraded forests may still be defined as 'forests', but their capacity to provide goods and services is reduced (FAO 2002). This is a much broader concept than the earlier definition of forest degradation which focused solely on reduced production capacity within forests (FAO 2000). The new definition opens up a variety of interpretations through which to assess forest degradation and its effects on a landscape. Improved timber productivity may be considered forest enhancement to one user, but may lead to reduced capacity of biological diversity, which can be used as one of many indicators of forest degradation. Therefore, whether a forest is regarded as degraded or not depends primarily on the values being considered. Criteria for defining and measuring forest degradation may include loss of forest health and the ability to return to pre-degraded conditions without intervention, loss of biological diversity, loss of watershed protection and other environmental service provisions and loss of wood production.

Since forest degradation is perceived differently by various stakeholders who have a range of objectives and values, fundamental challenges are faced when attempting global and national overviews and comparisons of forest degradation. Without harmonized and nationally-agreed definitions and indicators, assessing forest degradation and analyzing its causes at the national level is made more difficult. This makes monitoring the efficacy of policy responses very difficult as well. Forests are a national resource, and policies which cause or prevent forest loss are largely national in their design and their implementation. Action therefore has to be taken to develop comprehensive national databases on forest and national monitoring activities addressing the different dimensions of forests and trees. But there are few factual data at national level.

This is where national forest monitoring and assessments (NFMA) can provide valuable contributions to improved tracking and monitoring of forest conditions and change in addition to highlighting causes behind change processes. The approach can be based on field inventory alone or on a combination of field data collection and remote sensing. A well-designed NFMA can aptly respond to the full range of definitions of degradation (e.g. biodiversity conservation, carbon sequestration, wood production, soil conservation or recreation). Since forest degradation is extremely difficult if not impossible to capture from the air, field inventories are the most reliable source of data on the status of degradation. NFMAs can serve to monitor the change over time of forestland and trees outside forests in terms of extent, productivity and composition in addition to shedding light on proxies that can indicate if degradation is in progress.

Unfortunately the costs of NFMAs and the lack of capacities prevent many countries from conducting them, leading to very low numbers of countries with accurate figures on forest stocks, status and extent. In response to this dearth of accurate forestry data, particularly in the most forested regions of the world – the tropics, FAO established a programme with an aim of improving national-level forest data through building country capacities. Since 2000, the National Forest Monitoring and Assessment (NFMA) programme at FAO has been active in

providing valuable technical and financial assistance to countries in need of national-level forest data. The approach to NFMA employed under the NFMA programme is country-driven and cost-effective. To date, it has enabled approximately nine countries to complete inventories producing national scale data on land use and land cover. Through the inclusion of a wide range of country-specific inventory questions covering both biophysical and socio-economic aspects, the NFMA methodology can serve to address a range of issues, including those related to assessing and monitoring forest degradation.

This paper is intended to highlight how the NFMA programme addresses key criteria of forest degradation linked to the thematic elements of sustainable forest management (SFM) in its methodology. Each SFM thematic element is examined in the context of the NFMA country experience and how it has facilitated delivery of data on status and extent of forest degradation: extent of forest resources, contribution to the carbon cycle/climate change by forest, forest health and vitality, biological diversity, productive functions of forest resources, protective functions of forest resources, and socio-economic functions of forest. Country-level proxies and parameters are provided for each theme in order to demonstrate concrete examples of the NFMA approach and how it is enabling countries to assess and monitor degradation of forest resources throughout the world.

## **2. NFMA Methodology**

Forest inventory refers commonly to measurements of several important parameters of forests and trees and to the analysis of abundance, distribution, state, change and trend of forest resources. Forest inventories are most commonly based on sampling. Different options of sampling designs exist to survey a given forest area in a country. Each option is chosen to fit the characteristics of a surveyed population and to satisfy specific information needs on a set of parameters for a given budget.

Systematic field sampling and remote sensing are the pillars of data collection in a national forest monitoring and assessment process. Both data sources complement one another. Field data collection is done continuously or periodically on permanently established sample sites to assess changes and trends of forest resources and characteristics. Remote sensing is used to map the extent and spatial distribution (fragmentation and contiguity) of the forests and land uses based on a stable classification system for change analysis and integration with field data.

The field sample plots serve to collect a wide range of biophysical and socio-economic data through measurements, observations and interviews with different users of resources (FAO 2009b). The field plots are permanently established for re-measurements, to estimate changes and to establish trends. The NFMA methodologies are designed to be accurate and the precision of the estimates depends on how the observations are stratified and on the funds available to make the intensity of the field sample more or less dense. The major issue of national forest inventory is how to optimise the activity cost for a given scope and quality of information. Cluster sampling reduces significantly travels in the field between plots in comparison with single plot sampling. NFMA projects aim to collect a broad range of biophysical and socio-economic data through data collection in the field, which claims the largest percentage of overall spending (36%). Optimization of the NFMA cost is sought through the quantity of data collected. In NFMA projects, transportation from base to field accounts in general for 27% of total fieldwork costs (FAO, 2008a). This figure tends to increase with the reduction of time spent on data collection. Given the transfer costs from tract to tract, cost optimization is increased when a greater amount of data is collected per tract.

Remote sensing serves to gather geospatial data that cannot be collected from field sampling (e.g. geographic location and extent of forests, fragmentation of forests, identification and estimation of rare objects, land use change, mangroves, small forest types with significant economic or environmental values, etc.) and to improve on the quality of the statistics where field sampling has limitations. Remote sensing is used for wall-to-wall<sup>1</sup> or sample-based<sup>2</sup> mapping.

Both field sampling and remote sensing rely on a comparable land use and forest type classification system. The “global” classes of ‘forest’, ‘other wooded land’ and ‘other land’ are harmonized with those used by the global Forest Resources Assessment (FRA). Field sampling uses a range of detailed land use classifications depending on the countries specific needs. Considering limitations in spatial resolution and thematic information of remote sensing data, the land use and forest type classification applied for mapping is less detailed than the classification followed by the field inventory. Maps together with field data can be used for in-depth statistical analysis and modelling.

Forest degradation is a broad concept depending on what SFM thematic area it refers to. As a monitoring process, NFMA generates information on a wide range of forest degradation parameters such as: change in biodiversity, canopy cover, growing stock, biomass and carbon, forest and tree health, site quality and productivity. For these and other information needs, NFMA collects a wide scope of biophysical and socio-economic data.

About 90 variables are measured in the field covering biophysical and socio-economic information as well as environmental problems (see Table 1).

**Table 1:** Example of a parameter from NFMA field form highlighting observed environmental problems

Environmental problems		Severity (H,M,L)
0	Not existing	
1	Loss of water levels in rivers and other sources	
2	Drought	
3	Flood	
4	Poor water quality	
5	Insect pests and diseases	
6	Erosion	
7	Landslide	
10	Wind throw	
90	Not known	
99	Others .....	

The following measured variables can be used to assess forest degradation from different perspectives:

- Biophysical properties of forest and trees: stand origin and structure, tree canopy cover, tree species composition, stem and regeneration count, stump count per species, tree height and diameter at breast height, crown and overall tree health and causative agents;
- Resources management: protection status, land tenure, forest ownership, management agreement, human-induced disturbances, resources exploitation (timber, fuel wood, and other NWFP), forest fire, grazing;
- Site information: soil (type, surface condition, topsoil depth and texture/texture, drainage, erosion) and topography (slope, orientation and relief);

<sup>1</sup> Bangladesh, Zambia, Angola

<sup>2</sup> Brazil, Costa Rica

- Products harvested (category, species harvested, supply and demand, frequency of harvesting, trend, users, uses) and services;
- Livelihood data from households: (income, education, livelihood activities, household gender balance of harvesters, access to products and services, access to inputs).

Additionally, there are ongoing adaptations currently being made to the NFMA methodology in response to reduced emissions from deforestation and degradation (REDD). Further methods are being explored to provide data on the various carbon pools, including litter, soil, living aboveground and belowground biomass and deadwood.

National and international information needs are continuously shifting and expanding. Interest is not only on timber, as it was in the 1960s and 1970s, or on timber and biodiversity, as in the 1980s. Nowadays interest lies on forestry and people. In other words, it is about the social, economic and environmental functions of forests and trees. The approach of FAO's NFMA programme is designed to cover the resources and resource-dependent people from a broad perspective. International negotiations on climate change are placing more requirements on countries and NFMAs remain the only reliable source of the required information. In order to meet the challenges of the changing demands for information, FAO is developing its NFMA programme based on contributions by a large number of experts and policy makers from around the world. Meetings and expert consultations are being held periodically to analyse progress made, strengths and weaknesses and to guide the process of development.

In November 2008, thirty-four external experts from 16 countries and eight international organizations gathered at the second International Expert Consultation on NFMA at FAO Headquarters. The purpose of the meeting was to review the activities within FAO's support to National Forest Monitoring and Assessment activities in the light of new demands on countries to assess forest carbon, land use changes and other reporting requirements. The main recommendations were to establish an Advisory Panel for FAO's NFMA programme, undertake a series of studies covering a wide range of aspects of methodology development, e.g. sampling design, remote sensing, quality control and assurance, impact analysis, international reporting requirements including on GHG emission, REDD and carbon.

### **3. Thematic Elements**

This paper highlights the ways in which the NFMA approach can assess indicators of forest degradation linked to the thematic elements of sustainable forest management. The following sections each address a specific SFM theme, ranging from extent of forest resources to socio-economic functions of forests. Related parameters associated with each theme are then explored using examples from countries where the NFMA programme has been active. Planned adaptations and improvements to the NFMA methodology are also discussed, where applicable.

It is important to note that NFMAs are designed to support continuous long-term monitoring over time in order to detect changes in land use and land cover within the permanent sample plots and determine trends. This aspect is critical in determining rates of change such as biomass and forest extent as well as in determining availability of forest resources for livelihood needs. Therefore assessing forest status upon two points in time, through repeat sampling, is also crucial for detecting and measuring forest degradation.

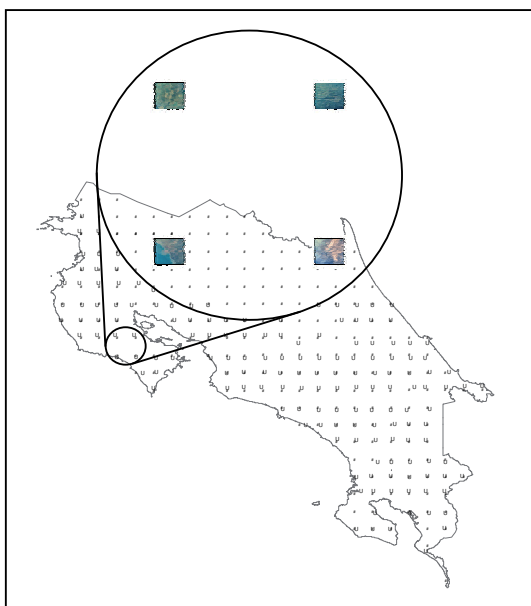
National Forest Assessments have been implemented and completed in a total of nine countries through the NFMA programme over the last ten years: Lebanon, The Philippines, Guatemala, Costa Rica, Honduras, Bangladesh, Cameroon, Nicaragua and Zambia. In many

of these countries, the NFMAs completed are the first of their kind or were previously executed decades ago in the 1960s and 1970s. The first NFMA countries are already planning for their second inventory cycle, but to date, none have yet to be repeated. Since repeated sampling in NFMA countries has yet to be realized, this makes change assessment very complex, if not impossible, without a time series with which to compare the NFMA-acquired data over time.

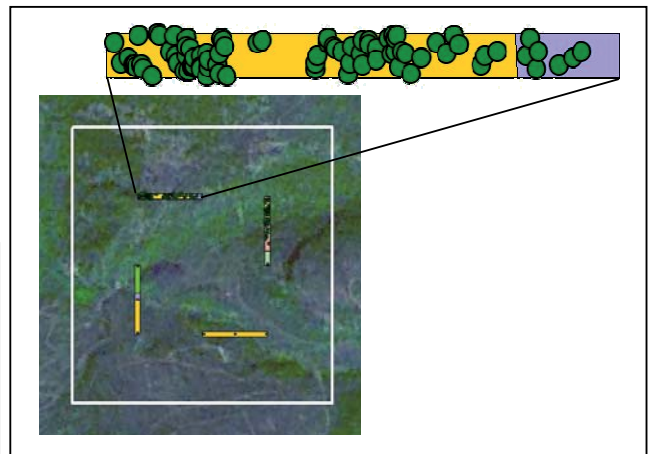
While this may be one constraint of the NFMA-generated data, it does not mean that detection of forest degradation is totally impossible from the field inventories, since in all of the inventoried tracts within an NFMA, there are a wide-range of observational parameters (recorded in the field and through discussions with focus groups) that can give an indication of whether forest degradation has occurred and if so, to what degree. This allows for a more qualitative assessment of forest degradation to take place. Quantifiable changes within the forest related to extent, biodiversity, health, production, protection, carbon content and utilization, however, require repeated assessments and therefore continuous monitoring, which is difficult to achieve without adequate funding and expertise. The following sections provide examples of each SFM thematic element and underline the types of proxies that can be used to establish an assessment of forest degradation using the NFMA approach. Better understanding of the level of forest degradation can be further strengthened quantitatively once continuous monitoring is established.

### 3.1 *Extent of forest resources*

The extent and change in extent of forest resources are main indicators of how sustainably these resources are managed. As stated above, forest degradation refers to changes within the forest class, therefore one must assess



**Figure 2:** Map of RSS for national forest assessment in Costa Rica showing the original 15km x 15km grid of aerial photographs (FAO 2003).



**Figure 1:** Cluster of plots for field data collection in Kyrgyzstan illustrating mapping of forest types (land use / land cover) in the plots during the field inventory and how the tree resources relate to the extent of the forest resources (FAO 2008c).

not just the direct field measurements and observations of forest degradation indicators but also the forest type classification by, e.g., designated function, biomass class, canopy cover, phenology, species composition, management regime, protection status, age-class or diameter distribution, naturalness and development status, among many others. These can all be very good indicators of the degree of forest degradation in any given forest.

In order to derive quantitative estimates of forest

degradation, it is essential to monitor the changes in extent of different forest types. The NFMA programme estimates the extent of forest resources through land use/land cover mapping of the field plots and through remote sensing surveys (RSS).

Mapping of forest resources in the field plots is carried out during the field inventory and makes it possible to detect, from the ground, detailed changes and degradation in the forest characteristics and to directly relate that information to other parameters estimated on the plots (Figure 1).

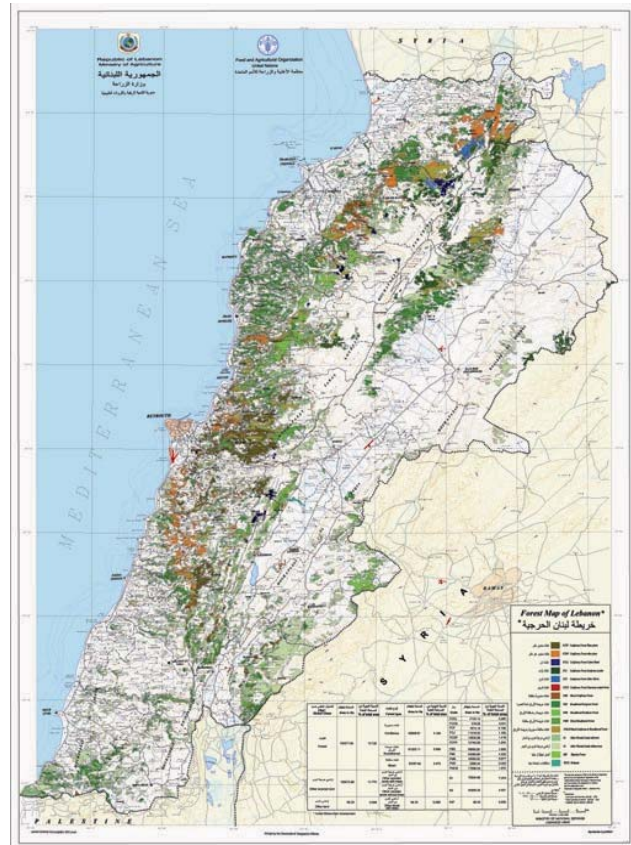
Through integrated interviews with key informants and local users of forest resources the field inventory also collects information on the drivers of changes in the extent of forest resources and also on other reliable indicators of trends in forest degradation like the historical extent of forest types as well as the planned future changes in the extent of forest resources. The latter will be further discussed in ‘socio-economic functions of forests’ SFM thematic element (Section 3.7).

Remote sensing (RS) techniques are applied to map the extent and distribution of forest types. Both wall-to-wall and sample-based remote sensing surveys (RSS) are supported by the NFMA approach.

Estimations of forest resources using RS techniques have an advantage compared to field plot mapping, in that they are more cost-effective, easier to cover larger areas and thereby able to detect rare occurrences of forest types. Moreover, it is easier to understand the larger context in which a specific forest resource is located and to detect patterns in the landscape, such as fragmentation.

Costs for sample-based RSS are lower than for wall-to-wall RSS and therefore it has the advantage of allowing in-depth studies to monitor land cover and land cover changes using RS data of very high geometric and radiometric resolution (see example from Costa Rica in Figure 2), while wall-to-wall RSS can produce a full cover land use/land cover map representing the spatial distribution of the forest resources (Figure 3).

The combination of field-based inventories on systematically sampled field plots and remote sensing surveys offers a unique possibility to integrate data from different sources that, if taken individually, would otherwise have some weaknesses. This enables the generated data to be optimized for its particular scope and strength. Therefore, it is also recommended to combine an in-depth RSS through sampling with a wall-to-wall RSS in order to optimize information generation on extent of a country’s forest resources.



**Figure 3:** Map of forest types derived through a combination of Landsat TM and Spot PAN data for the NFI in Lebanon (FAO 2005a)



### **3.2 Contribution to the forest carbon stock**

Global greenhouse gas emissions from forests, either as a result of deforestation or forest degradation, account for nearly 20% of annual global carbon dioxide emissions (IPCC 2007). In an effort to stem this contribution to CO<sub>2</sub> levels, payment for ecosystems services (PES) initiatives, such as the reduced emissions from deforestation and degradation (REDD +) mechanism, have considerably elevated the interest in forest carbon monitoring during the last few years. Consequently, this has increased the demand on the NFMA programme to respond accordingly in quantifying emissions levels of carbon from deforestation and forest degradation.

While it represents one of many criteria for estimating the presence and extent of forest degradation, assessing and monitoring the change of forest carbon sequestration, particularly in the context of REDD, is essential to any successful PES scheme. Reliable carbon estimates, however, are derived from accurate aboveground and belowground biomass estimates, which rely heavily upon either (a) eco-zone or species specific volume functions as well as accurate biomass conversion factors (BCF) or biomass conversion and expansion factor (BCEF) converting volume to dry weight and wood density (WD), or (b) allometric equations derived from a sizeable number of tree inventory data.

Traditional ground-based forest inventories, such as those promoted by FAO's NFMA programme, are based on the most common and most accurate methods for estimating carbon stock and potentially carbon change. NFMA fulfils the requirements of forest carbon assessment through establishing national permanent sample plots which serve well the requirements of long-term monitoring of carbon stock changes also from degradation. NFMA parameters which are measured and later analyzed to provide carbon-related information include: tree species, tree height and diameter at breast height (DBH), diameter of big tree branches, standing dead wood DBH, downed dead wood DBH, litter depth, soil characteristics and type, soil organic content and regeneration count.

The NFMA approach has the ability to provide accurate information on the status of and changes to the forest carbon stock, particularly where financial resources and reliable ancillary data and models (volume functions, BCF, BCEF, and WD) are available. Despite the fact that budgets for implementing NFMA have been very limited in the past, therefore constraining sampling intensity, NFMA inventories have managed to provide reasonable area, volume and aboveground biomass estimates for 'forest' and 'trees outside forest' classes, particularly when they are the dominant feature in the landscape. Where forested landscapes are fragmented, due to highly intensive land-use patterns, it becomes more challenging to produce accurate figures.

**Table 2:** Total aboveground biomass and biomass density in the major land use classes and by forest types in Cameroon (FAO 2005b)

Global class	Forest type	Aboveground biomass				Aboveground carbon stock		
		Average biomass per ha	Standard error (SE%)	Total biomass	% of total biomass	Average C stock per ha	Standard error (SE%)	Total C stock
		t/ha	%	t	%	t/ha	%	t
Forest	Dense humid evergreen forest	328,7	1,7%	3 743 795 694	60,2%	164,4	1,7%	1 871 897 847
	Dense humid semi-deciduous forest	296,3	3,1%	1 865 317 062	30,0%	148,1	3,1%	932 658 531
	Gallery forest	131,3	12,2%	224 109 847	3,6%	65,7	12,2%	112 054 924
	Swamp forest	213,6	4,8%	380 170 600	6,1%	106,8	4,8%	190 085 300
	Other natural forest	22,8	26,0%	1 307 805	0,0%	11,4	26,0%	653 902
	Plantations	69,1		457 951	0,0%	34,5		228 976
	<b>Total Forest</b>	<b>292,7</b>	<b>1,7%</b>	<b>6 215 158 960</b>	<b>100,0%</b>	<b>146,3</b>	<b>1,7%</b>	<b>3 107 579 480</b>
<b>Other wooded land</b>	<b>27,7</b>	<b>8,1%</b>	<b>410 689 161</b>	<b>5,9%</b>	<b>13,9</b>	<b>8,1%</b>	<b>205 344 581</b>	
<b>Other lands</b>	<b>34,3</b>	<b>13,3%</b>	<b>384 685 146</b>	<b>5,5%</b>	<b>17,1</b>	<b>13,3%</b>	<b>192 342 573</b>	
<b>Total</b>	<b>147,5</b>		<b>7 010 533 267</b>	<b>100,0%</b>	<b>73,7</b>		<b>3 505 266 633</b>	

Typical sampling intensity for national field-based inventories is usually not appropriate for accurately estimating landscape-wide land use change and remote sensing can more accurately assess forest area changes, in particular deforestation. Remote sensing, on the other hand, has shown limitations to accurately assess forest degradation. However, field sampling, with even sparse intensity, is the most reliable source of information on both forest degradation from every perspective, i.e. biodiversity, commercial timber stock, biomass and carbon, ecosystem productive functions, as well as the drivers of carbon change from land use change and forest degradation. Both field sampling and remote sensing, the pillars of the NFMA approach, are complementary sources of information of carbon and changes and their causes and should be used in combination.

Monitoring of change in the carbon stock due to degradation may become more expensive due to difficulties in measurements of slowly changing processes often occurring in small areas of land use units clumped or randomly distributed depending on the causative factors. Change in the carbon stock (C-ton/ha) in a clear-cut rainforest may be tens times more than that of a forest where only selective cuttings have taken place, if the removal of biomass by clear cutting is permanent and leads to land use change. But, the change in carbon stock may be temporary if the clear or selective cutting does not lead to permanent change of land use or forest cover and composition. In many countries, however, degradation may be a higher source of carbon emission than deforestation. Therefore monitoring the decrease in forest carbon stock within forest land is important. This is the case especially in Sub-Saharan Africa where the activities by the local populations such as setting bushfires, overgrazing, collection of fuel wood, timber poaching, greatly diminish the forest cover, contributing to carbon emission and altering forest integrity as well as its productive and protective functions.

Strengthening NFMA methodology to take further consideration of carbon monitoring needs, such as facilitating the research and establishment of reliable volume and biomass functions, is a significant goal. In order to improve the carbon monitoring readiness, NFMA methods are being developed to provide reliable information on all carbon pools, not only on aboveground biomass. Selection of carbon pools, however, should be based on national conditions and importance from the point of view of carbon stock changes. This means that field measurements, combined with the use of remote sensing, must aim at good accuracy of the changes in the carbon stock. The systematic sampling grid can be intensified with temporary plots for key areas where carbon changes are concentrated, identified by looking at data from previous inventories or time series of satellite images. However, FAO and the countries must balance it with other national and international reporting data needs and NFMA information must be representative to cover the whole country.

### **3.3 *Forest health and vitality***

Many natural factors and human activities can affect forest health and vitality leading to a gradual or sudden decrease in forest growth and tree mortality, and to a decline in the provision of forest goods and services. Wild or human-induced fires, pollution, floods, nutrients and extreme weather conditions such as storms, hurricanes, droughts, snow, frost, wind and sun are among abiotic agents that may be responsible for a loss of health and vigour of forest ecosystems. Biotic influences of forest conditions include insect pests, diseases and invasive species and can either consist of fungi, plants, animal or bacteria. Humans are also a major factor of forest health deterioration as overexploitation, competing land uses, poor harvesting techniques or management can negatively impact forest ecosystems.

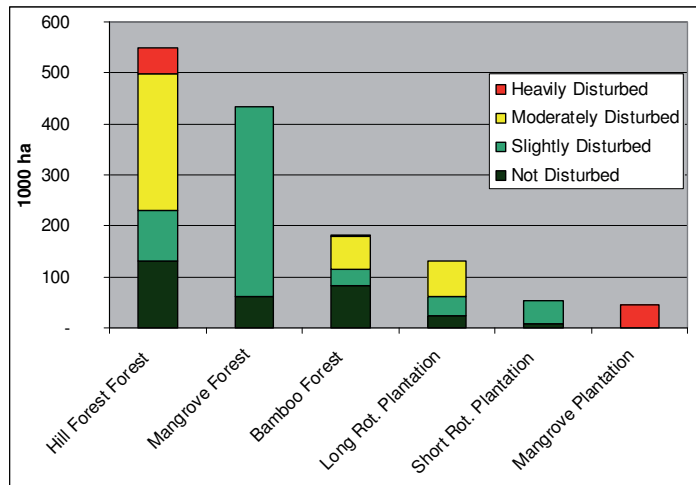
The NFMA approach assesses the health and vitality of forests through selected ecological indicators. Those indicators are mainly observations on the presence or absence of affecting biotic or abiotic agents and environmental problems (or their symptoms) as well as overall assessment of the condition of forest and trees. They are recorded in the plots either at tree level (overall tree condition and crown condition, causative agents) or at forest stand level (environmental problems observed, degree of severity and trends, human disturbances). The information on forest health and vitality is derived from both field observations as well as from interviews with local population and key informants. Table 3 summarizes some of variables captured through the inventory.

**Table 3:** Indicators of forest health and vitality measured in a NFMA (FAO 2009b)

Level	Indicator assessed	Criteria/ Data source	Options
<b>Tree</b>	<b>Invasive tree species</b>	Name of inventoried species List of invasive woody species in the country	
	<b>Crown condition</b>	Crown transparency and evidence of top dieback	Healthy, Declining health, Unhealthy, Dying, Dead
	<b>Overall tree condition</b>	Severity in the symptoms of disease, pest or other stress	Healthy, Slightly affected, Dead/Dying standing tree. Dead/Dying fallen tree
	<b>Causative agents</b>	Presence or symptoms of affecting agents: defoliation, leaf feeding, cuttings, bark damage, logging, fire evidence, broken branches, presence of fungi, leaf spots, leaf or needle discolouration	Not applicable, Insects, Disease/Fungi, Fires, Animals, Humans, Climate, Other
<b>Forest stands</b>	<b>Environmental problems</b>	- Presence or symptoms of affecting environmental problems (e.g. gullies, fallen trees) - Collective evaluation by field surveyors and key informants	None identified, Reduced water levels in rivers / wetlands, Dried up of water source, Rainfalls variability, Drought, Floods, Poor water quality, Dust storm, Hail storm, Wind fall/ wind blow, Air pollution, Erosion, Landslide, Loss of soil fertility, Uncontrolled burning, Overexploiting resources, Overgrazing, Loss of habitats, Reduced species diversity, Animal/wildlife disease and mortality, Plant pest, disease, invasive species
	<b>Severity of environmental problems</b>	- Severity in the symptoms - Collective evaluation/ judgement by field surveyors and key informants	Low, medium, high
	<b>Trend of environmental problems</b>	Collective evaluation by key informants on the trend during the past 5 years	Decreasing, no change, increasing
	<b>Fire disturbances</b>	Fire evidences: burnt vegetation or soil	No evidence, recent fire, old fire
	<b>Fire area</b>	Measurement of burnt areas in the plots	
	<b>Fire type</b>	Burnt vegetation (leaves, soil, grasses) Information from key informants	No fire, Underground fire, Surface fire, Crown fire
	<b>Fire purpose</b>	Information from key informants	Not applicable, Clearing of new land, Clearing of weeds and residues, Pasture re-growth, Pest and vermine control, Arson / Malice, Accidental Natural, Not known, Other
	<b>Human disturbances</b>	Degree of exploitation of goods and services Observations of human-induced disturbances (fires, logging) Accessibility to forest	Not disturbed, Slightly disturbed, Moderately disturbed, Heavily Disturbed
	<b>Insect, pest and invasive species categories and name</b>	List of invasive species by category according to the perception from local population (focus groups) and information from key informants	Insect pest, Disease, Animal wildlife invasive sp., Woody invasive sp., Herbaceous Invasive sp.
	<b>Categories affected by pest and disease</b>	Perception from local population (focus groups) and information from key informants	Not applicable, Humans, Livestock, Fishes, Animal wildlife, Herbaceous plants, Woody plants
<b>Severity of invasion, pest and disease</b>	Perception from local population (focus groups) and information from key informants	Low, Medium, High	

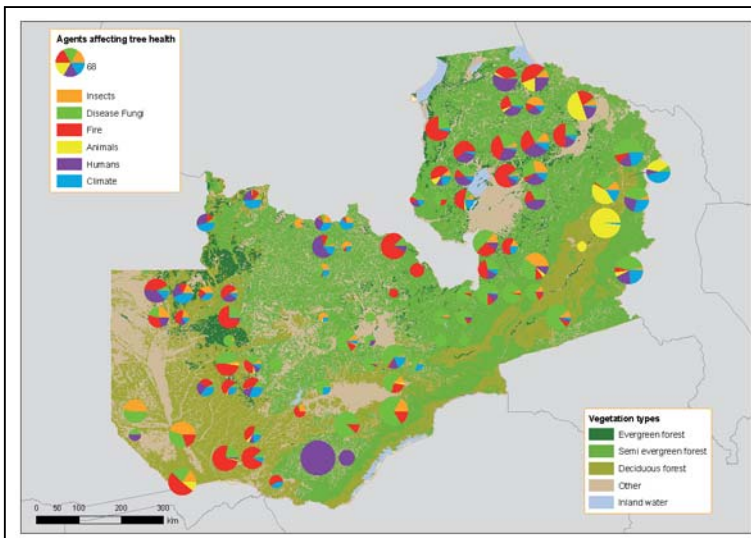
*Notes: this list is indicative as each country customizes the methodology, indicators and options according to its own needs and to national social, environmental and economical context.*

The methodology is designed to assess widespread deterioration processes and agents at the national level. The collected data allows one to estimate the proportion of forests in good or poor condition in a country, as well as the forest area affected by different deteriorating agents, which can be ranked according to the importance of their spread. Frequency of tree invasive species in the forest or proportion of unhealthy trees can be calculated.



**Figure 4:** Degree of human disturbance by forest types in Bangladesh (FAO 2007)

Incidence of insect pests, diseases and invasive species maps can be produced (Figure 5 and Figure 6),



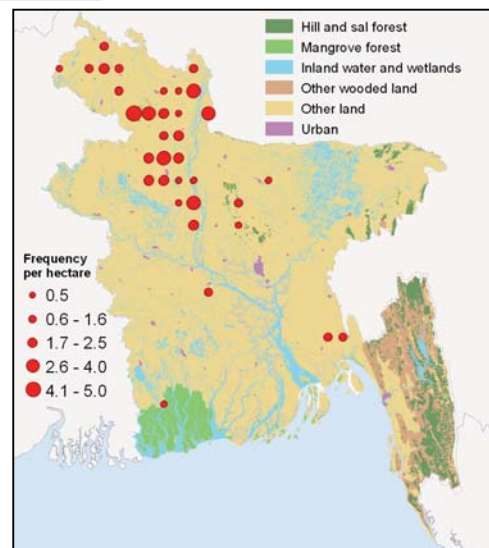
**Figure 5:** Distribution map of deteriorating agents of tree health in Zambia forests\* (FAO, 2008b)

\* Note: the size of the pie is proportional to the percentage of surveyed trees affected by the different factors

interrelation between forest health with, for example, species composition, soil and terrain.

While some agents are easy to detect as the symptoms or signs are clear, indirect influences of forest health and vitality, such as economic factors, climatic stresses, atmospheric pollution are difficult to assess. Therefore more thorough studies and time-series will be required in order to understand the driving forces behind forest health and vitality decline, invasion of insect pests and diseases and overexploitation of forest resources.

if they are not rare events, to indicate their spatial distribution at the moment of the inventory. The severity and trends of those threats can be evaluated. Forest health and vitality can also be monitored as the plots are permanent and the survey should periodically be repeated. Other data collected in the field can be used in combination with the abovementioned health indicators to analyse the

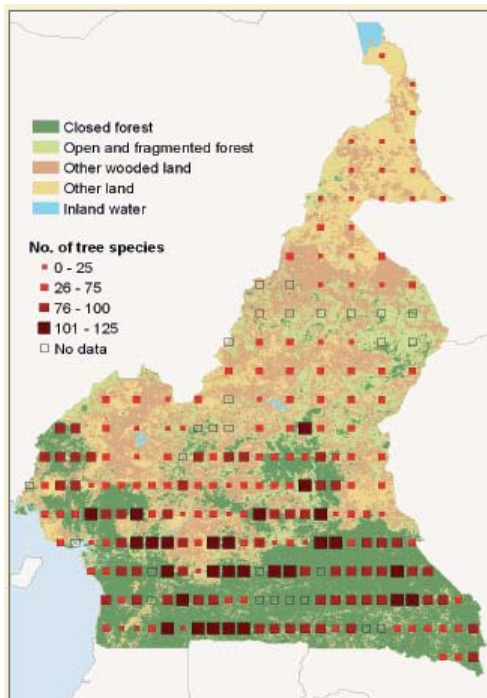


**Figure 6:** Distribution of invasive species (*Eucalyptus sp.*) in Bangladesh (FAO 2007)

### 3.4 Biological diversity

A loss in biodiversity within an ecosystem clearly indicates an impoverishment of the site conditions which, in this context, can be related to degradation – both natural and human-induced. Biodiversity loss can occur under a variety of forms such as the reduction in total species diversity within a defined area or a reduction in the evenness of the species distribution, meaning that the majority of the trees belong to a limited number of species. A site's biodiversity, however, is also expressed in terms of the characteristics of its soil, fauna, forest structure, forest type distribution, forest area fragmentation, protected forest area by type and protection category. DBH distribution by species and regeneration levels also provide an indication on the current status of each species. The collection of all this information is part of the standard NFMA methodology.

As is customary of any NFMA project, national needs for forest biodiversity information are identified and included in the inventory. A fundamental part of national assessment efforts is working with policy and decision-makers in articulating these needs in order to ensure that the assessment meets national (and international) interests to the greatest extent possible.



**Figure 7:** Number of tree species – Cameroon, 2003-2004 (FAO 2005b)

The NFMA methodology captures a variety of parameters useful for assessing biodiversity: number and types of tree species, DBH and height by species, forest structure, forest type spatial distribution, observations of rare species (both fauna and flora). It is at the analysis phase that conclusions can be drawn by correlating sets of variables. In particular, information gathered through socio-economic interviews, when correlated to biophysical variables, can shed light on the impact of humans on forest resources (e.g. a correlation between tree species frequency and degree of human-induced forest disturbance).

Information on fauna species are indicated as a priority for the National Forest Inventory (NFI) in some countries where observations, in particular wildlife species, are made (indication of species presence or absence through direct and indirect observations). For instance in the Republic of Congo, data on elephants and big monkeys were recorded. In Angola, observations on the major big mammals are recorded. In its standard methodology

the NFMA socio-economic interview scheme allows for the collection of indicative data on wildlife consumption and use as well as human-animal interactions, depending on the country's specifications.

Examples of biodiversity data and analysis include the mapping of the number of tree species by forest type (Figure 7) and species diversity (expressed using, e.g., Shannon's index) and equitability (Table 4). Species frequencies are also estimated, showing for instance the proportion and distribution of indicator species by degree of forest perturbation such as pioneer species or threatened species, according to the IUCN Red list, or of species of interest such as commercial tree species. For example, the National Forest Assessment in Cameroon

showed that tree species such as *Musanga cecropoides*, *Pycnathus angolensis* or *Albizia zygia*, which characterize secondary or disturbed forests, are among the most abundant in forests.

The NFMA methodology provides for the utilization of Remote Sensing (RS) techniques in order to perform additional analysis of the data gathered in the field. The combination of field measurements, RS and socio-economic interviews provide a valuable set of data and analysis opportunities to uncover instances of biodiversity loss and corresponding forest degradation.

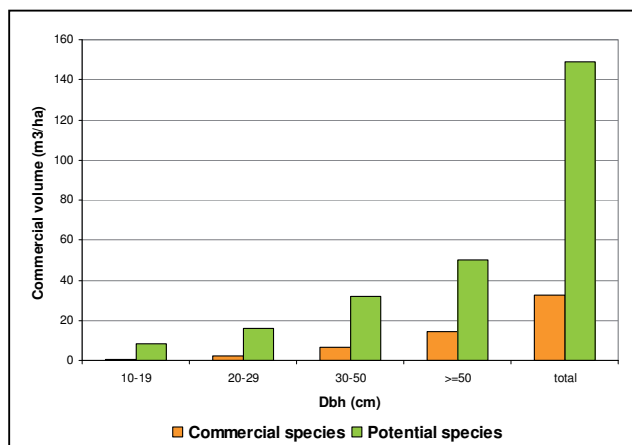
**Table 4:** Index and Equitability – Bangladesh, 2005–2007 (FAO 2007)

	Total	Forest	Cult. Land	Villages	Urban Areas	Inland Water
No. of species	258	129	137	198	28	33
Diversity (Shannon's index)	3.57	3.03	3.31	3.23	2.22	3.08
Equitability	0.64	0.61	0.72	0.61	0.67	0.87

### 3.5 Productive functions of forests and trees

For years, the single most recognized value and economic contribution from forests and trees was wood: fuel wood, timber, logs. In recent years, there has been an unequalled recognition of the wider social and economic dimensions of forests and trees being sources for material to create shelter, warmth and energy to cook and provide material for furniture, housing, ships and bridges. Forests also offer food (bush meat, fruits, mushrooms, honey), essential oils, exudates, medicinal plants, soap and cosmetics, dying and tanning, herbs and species, handicrafts, fibre, fertilizers, and various other products (e.g. seeds, beeswax, hides and skins, medicines, colorants, fodder). Decline in a forest's ability to provide these goods and services can serve as an indicator of forest degradation.

FAO's NFMA approach is designed as a multi-resources inventory and monitoring process covering all productive functions of forests and trees. NFMA methodology can accurately assess changes in forest productivity and potential forest degradation through field measurements (DBH, height, species composition) which can indicate growing stock for, in particular, commercial species and equally as important through interviews with local communities that utilize and rely upon forest resources (see Figure 8 and Figure 9). Field



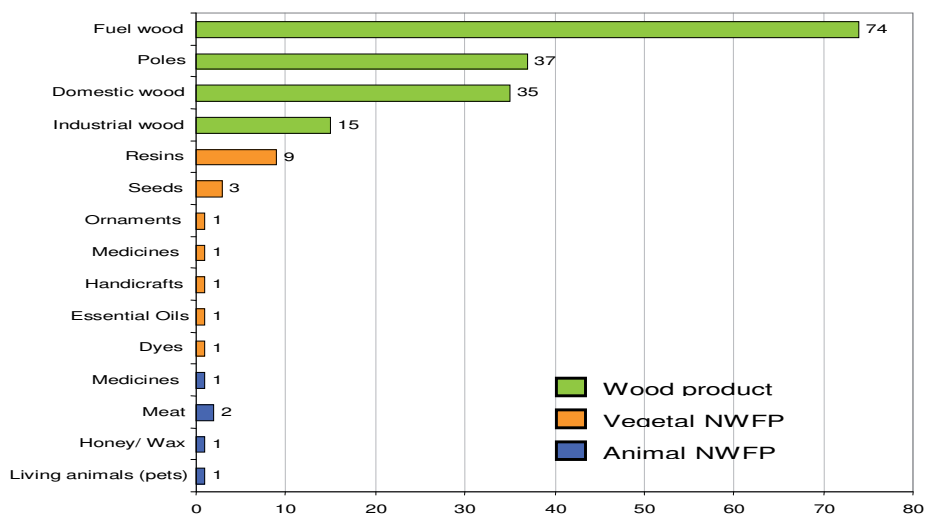
**Figure 8:** Commercial volume of commercial and potential species, by diameter classes, in deciduous forest in Honduras (FAO 2006)

interviews can capture valuable information on the presence and intensity of productivity decline or degradation. For every product, a series of other attributes are collected in the field from the interviews with a representative sample of the users and managers groups. These attributes include tree species providing the product, end-use of the product, demand and supply trends, reasons of change in supply and demand, period and frequency of harvesting, user groups, user rights, conflicts, organizational level of users, gender and child participation in harvesting.

The scope of information on wood and non-wood-forest products that NFMA can generate is very broad. The reason for this is to meet the national needs as well as to enable countries to report to the international processes and conventions. Some products (timber and total wood) are quantified with high accuracy. Other non-wood forest products (NWFP)<sup>3</sup> provided by forests and trees, which due to their specific characteristics (uniform, clumped or random distribution; varying frequency; seasonality) might require specific sampling designs for quantification. Knowing that the NFMA sampling design cannot fit every NWFP distribution and frequency, the products are simply identified and ranked low, medium or high based on the importance attributed to each product by the local users. In some countries, the design was adapted to bring quantitative information on some non-timber forest products with high commercial importance, such as bamboo and rattan in the Philippines or aromatic plants in Lebanon.

Policy makers are now more than ever concerned with the state and trends of forest resources. Development policies, poverty reduction strategies and food security require accurate information on all resources, their uses and users as well as on their management being of sound design through management plans and/or through customary use of resources by local communities.

Periodic data collection in the field on the wood and NWFP with the many other forest and tree characteristics such as tree height, diameter and species, crown closure and stem density, resources management, can be used to assess the process of forest degradation and improvement. The change in the distribution of a given resource when related and explained by the distribution of the socio-economic activities (grazing, slash and burn, timber and wood fuel removal, hunting) of local populations allows for the identification of causes and their monitoring over time. Ancillary information on poverty, rainfall and temperature can also be used to establish relationships with the changes occurring in the wood and NWFPs as well on the state of the forests and trees.



**Figure 9:** Use frequency, in percent, of products in forest in Honduras (FAO 2006)

<sup>3</sup> The term NWFP originated in the late 1980's for use in tropical forestry to define those products which were not the normal concern of foresters at that time but which were increasingly being used by social foresters to engage local people in forest management, Jenny Wong, Nell Payne and Rosie Boden, 2005.



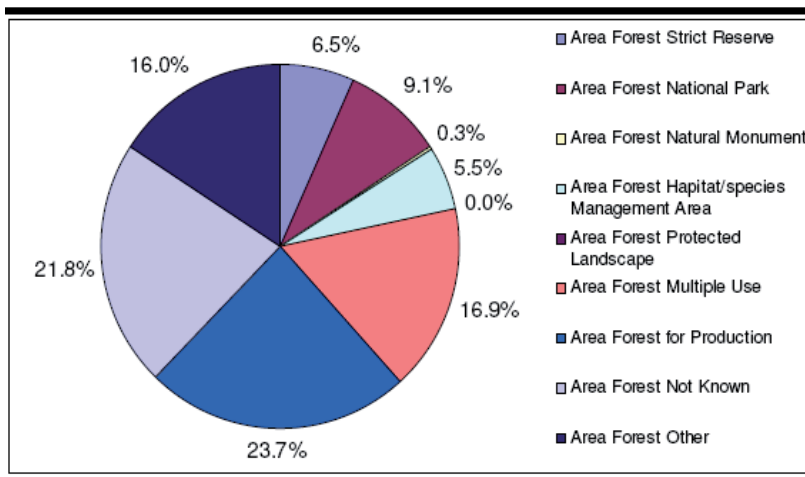
### 3.6 Protective functions

Forests provide livelihoods to more than 1 billion people, protect 80% of the world's biodiversity, and are a watershed source for most of the clean water upon which all life depends. Forest protective functions have both local and global benefits, ranging from soil erosion protection, coastal protection, protection from avalanches, air-pollution filters, and water resources protection, among many others.

Recently, the world's attention on forests has focused from fuelwood production to their capacity to sequester carbon, thus contributing to the mitigation of climate change due to global warming. However, timber and carbon should not overshadow the wide range of protective functions of forests on ecosystems and livelihoods. When forests are in decline or degraded, their ability to provide these services decreases and therefore places a tangible burden on the adjacent communities and wildlife that depend upon them for clean water and wind breaks. For this reason it is important to assess the status of a forest's protective status in order to monitor and respond to forest degradation where it occurs.

In many cases, the specific environmental processes that forests enable are known, but difficult to ascertain quantitatively from an NFMA alone. For example, we know that tree roots serve as sponges and therefore serve as reservoirs for capturing water – thereby restoring the water table and simultaneously preventing runoff-induced soil erosion. However, NFMA-generated data does not specifically quantify and monitor these particular ecological processes. Instead, qualitative data from observations and interviews are captured to assess the environmental services obtained from forests (according to the perceptions of local people) as well as management designations of forests for protective reasons.

Many countries have identified forest areas that serve a protective function and have given them special status. In order to provide quantitative information on the extent of protected forests in the world, FAO's NFMA programme has facilitated countries in collecting data on area of forest designated for protective purposes (as the primary function or as one of several functions) and on area of protective forest plantations. The level of protection can range from strict protection such as wilderness areas to milder forms of conservation obtained through active management.



**Figure 10:** Proportion of forest area by protection status in Zambia (FAO 2008b)

In this context, the NFMA methodology includes in its standard approach a range of variables aimed at assessing and measuring indicators of forest protection. They include: total area for all land use/forest cover classes, classes of protection level that can include reserves, national parks, multiple purposes conservation. This data is collected at the plot level (0.5 ha),

and can be monitored at that level but is typically expressed as a national percentage of forest area for the purpose of international reporting (Figure 10). The same areas are also typically expressed by different forest types (including plantations) thus allowing a wider picture of the protective status of a nation's forests.

This information, if correlated to data on the occurrence of environmental problems such as, drought, flooding, erosion, loss of soil fertility, burning, landslide, wind throw or overgrazing, can help to obtain a better picture on where the conservation is having a positive impact on the forest condition and where, instead, protective measures should be introduced to alleviate existing environmental concerns.

In addition, the information on the management status (formal *vs.* no management) is also indicative of the protection level of a forest while, on the other hand, the assessment of the degree of disturbance of a certain area gives an indication of where stricter management is required.

### **3.7 Socio-economic functions of forests**

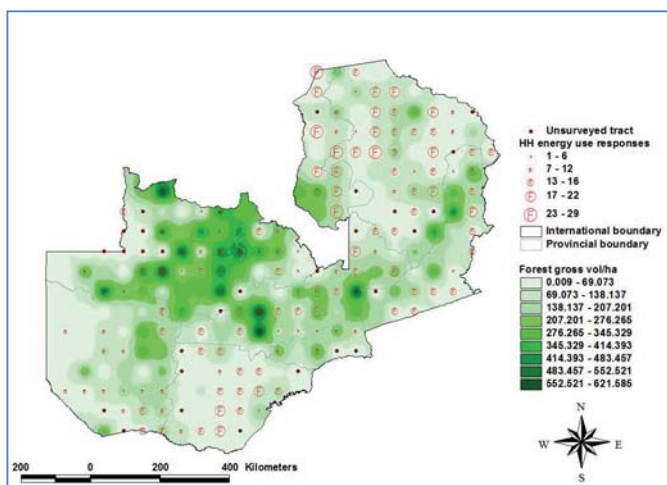
All of the forest functions previously described provide innumerable benefits to mankind, both in terms of products and environmental services. Therefore changes in a forest's ability to contribute to the carbon cycle, defend against pests and diseases, host a variety of species, sustain a desired productivity level and protect the drinking water supply will have both direct and indirect impacts on communities and individuals that rely upon those goods and services for their livelihoods.

It is this impact that can also be measured within an NFMA in order to gauge the level of forest degradation occurring in any given forest. Moreover, socio-economic surveys can serve to provide qualitative understanding of the past state of forest resources and trends in supply and demand, proving invaluable where past data is sorely lacking. In addition to directly measuring and monitoring the biophysical status of forests and trees outside forests, the NFMA approach also consists of surveys that focus on which forest resources and services are being used by neighbouring communities and how. Within the NFMA methodology, interviews are undertaken with a wide array of forest users in order to assess and monitor the role of forests to livelihoods and the pressures faced by forests from competing land uses.

The NFMA methodology assesses the socio-economic function of forests through a series of interviews with three major informant categories: (1) key informants, (2) focus groups or individuals, and (3) randomly selected households. In sparsely populated areas and in the absence of local inhabitants, many of the social economic variables will essentially be collected from observations or from key informants. Key informants are individuals with particular knowledge about the area, the land/natural resource use and the local community, which might otherwise be difficult to assess through observations alone. Focus groups and individuals are considered user groups that relate to and use the land and resources on a frequent basis. These are people that live in or close to the sampling unit. They may be interviewed in groups (focus groups), or individually. A household is defined as a unit that consists of all individuals who live together in one house or closely related premises. They are selected in a systematic process for a given radius around the sampling unit that can vary from 1 to 5 km, depending on the density of the country.

In its standard approach, the NFMA methodology includes a range of variables aimed at assessing and measuring the services and products derived from forests and trees outside forests. These variables can serve as indicators of livelihood potential and can subsequently contribute to monitoring the state of the forests and trees within and around the sampling unit. Standard field data collected from these interviews include: historical background of the land use, information on the local population, distance of households/access to forest in sampling unit, ownership, protection status, management and ecological problems within sampling unit, local uses and importance of forest products and services, temporal changes in land resources, biodiversity and livelihoods, invasive and threatened species and fuelwood consumption (Figure 11). More in-depth data may be collected at the household level, depending on country-specific needs. Household surveys can be adapted to assess and monitor such

variables as: accessibility to credit and extension services, crop production systems, total annual household income, total sales of livestock, poultry and bee-keeping products, etc.



**Figure 11:** Forest volume per hectare and household energy use per tract in Zambia (FAO 2008b)

While socio-economic surveys do add considerable time to the implementation of an NFMA (on average consuming 24% of the fieldwork time), the data obtained are invaluable and essential to natural resource decision making and planning. Moreover, the proportional costs of conducting interviews are minimal, at approximately 4.8% of the total cost of an NFMA, or 13.4% of the total cost of fieldwork.

The data obtained from NFMA interviews with a variety of user groups can assist in highlighting management strategies that may be able to reduce the severity of forest

degradation. The data captured within the interviews are essential to understanding and responding to drivers of forest degradation and deforestation such as shifting agriculture, changing rainfall patterns, fire, harvesting of fuelwood. Gleaned from interviews are data on human needs from the land, which when analyzed in combination with biophysical data from each sampling unit tells a story of land use change that may provide potential solutions to resolving conflicts.

#### 4. Conclusions

In recent years, there has been considerable interest in the appraisal of the full benefits of forests and trees to society. For decades, since the (national) forest inventory concept was introduced to forestry practitioners, the focus remained far too narrow on timber production. In many countries, particularly in the tropics, timber is a minor product compared to the wide range of forest benefits from trees and forests. In many countries, policy makers have ignored the importance of forests and trees due to a lack of information on the real extent of their social, economic and ecological contributions.

During the last two decades substantial efforts have been made to design and develop multi-resource inventories which are intended to provide data on timber production, NWFPs, forest health, biodiversity as well as ecosystems services, all of which are critical indicators in determining the presence and extent of forest degradation. These inventories, although often less than optimal for specific products or services, have been useful in providing indicative knowledge on these resources. Appropriate measurement protocol can be designed to generate more precise information on resources with high social, economic and environmental importance.

FAO's NFMA programme has been originally designed to support national policy making processes, national forest programmes and sustainable forest management. While it initially did not aim to specifically support inventory and monitoring of carbon and carbon change, it comprises the collection of the essential data parameters to produce the carbon statistics required by the Inter-governmental Panel on Climate Change (IPCC) at all three tiers. In order to reach higher tier levels of reporting the inventory data need to be supported by national (or sub-national) level carbon models, so the raw data from completed inventories designed under the NFMA programme can meet different tier reporting requirements depending on the status

of national carbon models developed under forestry research programmes. The NFMA programme has already been collaborating with forest research institutes and forestry universities in several countries so as to stimulate further national efforts in forestry research and the programme is currently exploring further support that can improve upon carbon estimates (wood density, biomass conversion factors) in an effort to enhance a country's compliance with IPCC carbon reporting requirements and therefore enable participation in potential carbon-trading schemes under REDD. Costs of such additions must be seriously weighed, however, since producing increased accuracy of carbon estimates comes with a potentially steep price tag, depending on country capacity.

While a decrease in carbon stocks may be one of the most objective ways to detect and monitor forest degradation, it does not always tell the entire ecological and human story, which is why full-scale national forest assessments that take into consideration a broad range of variables from forest health to biodiversity to economic needs of communities are so vital to understanding whether forest degradation is taking place, in what respect, how much and why.

The NFMA approach is designed as a multi-resource, cost-effective inventory that yields a wide range of information and therefore can adequately assess and monitor an array of criteria that can be used for assessing the presence and extent of forest degradation. For some products the precision is high and for others the information is indicative. If a country requests detailed information on a particular species/resource within a forest, a protocol tailored to the characteristics of the species/product and location is designed within the NFMA.

Being a monitoring process, the NFMA design is the most encompassing compared to any other national level inventory model. As the demand for information is constantly growing, a comprehensive approach will support the countries in responding to present and future information needs. There are no lack of justifications for this type of survey that combines field and remote sensing data to generate information and knowledge on all the benefits provided by the forest and trees. Each user has his or her specific interest in information and the usefulness of the NFMA is increased by meeting many user needs. NFMA costs are better optimized if the scope of field data is broadened to cover parameters that describe the state of the resources, assess the change and their drivers, establish trends, and support policy adaptation and design of integrated rural development programmes. The added value of such scope of information is invaluable for a country's readiness for reduction of emissions from deforestation and forest degradation (REDD) and to become a strong party in international negotiations. Of course, most of the value for establishing a monitoring system is the ability to have long time series of measurements and observations, so degradation indicators can be used to assess policy and management responses. Therefore much effort has still to be undertaken to help countries not only in establishing such a system but also to maintain it.

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