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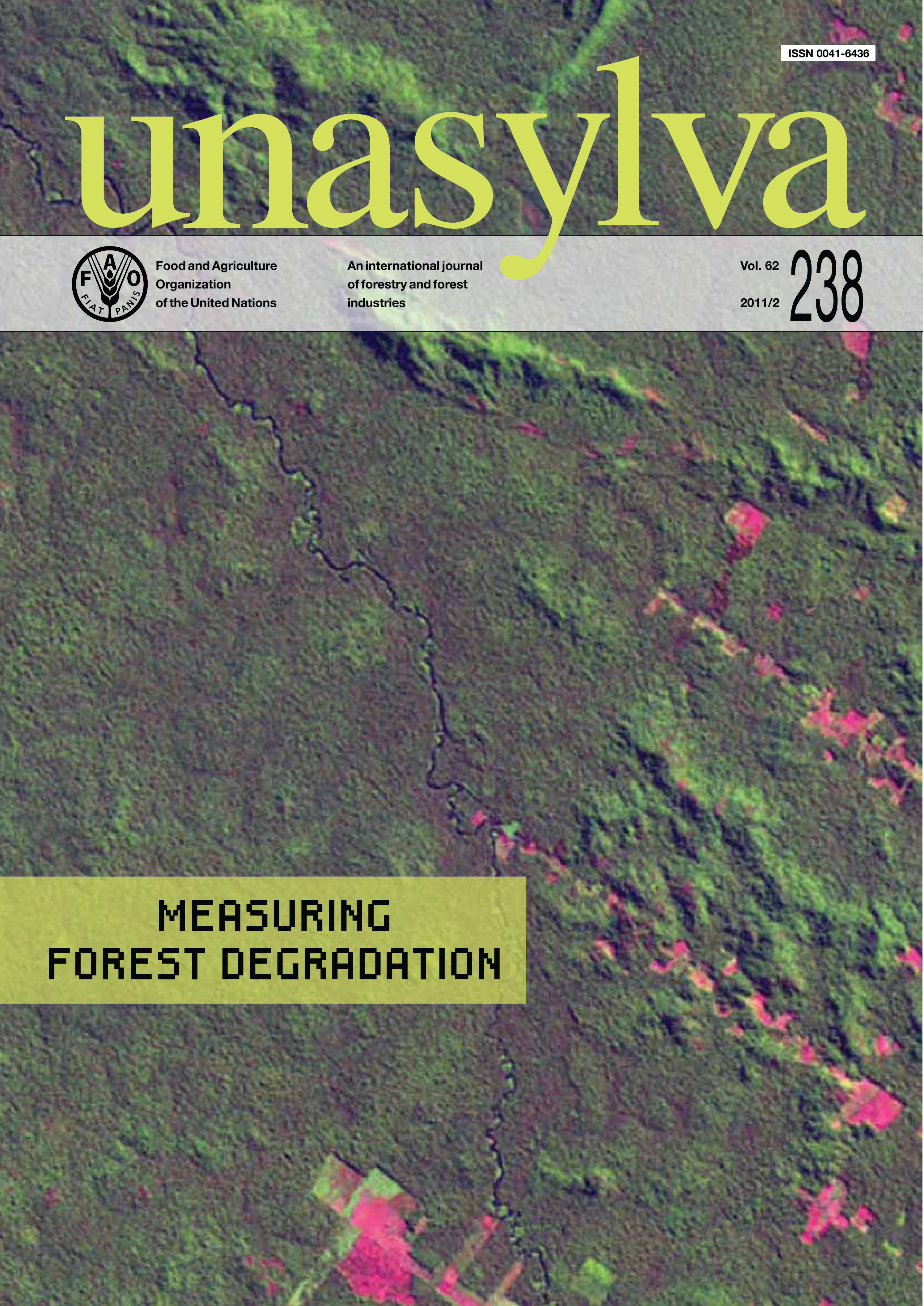


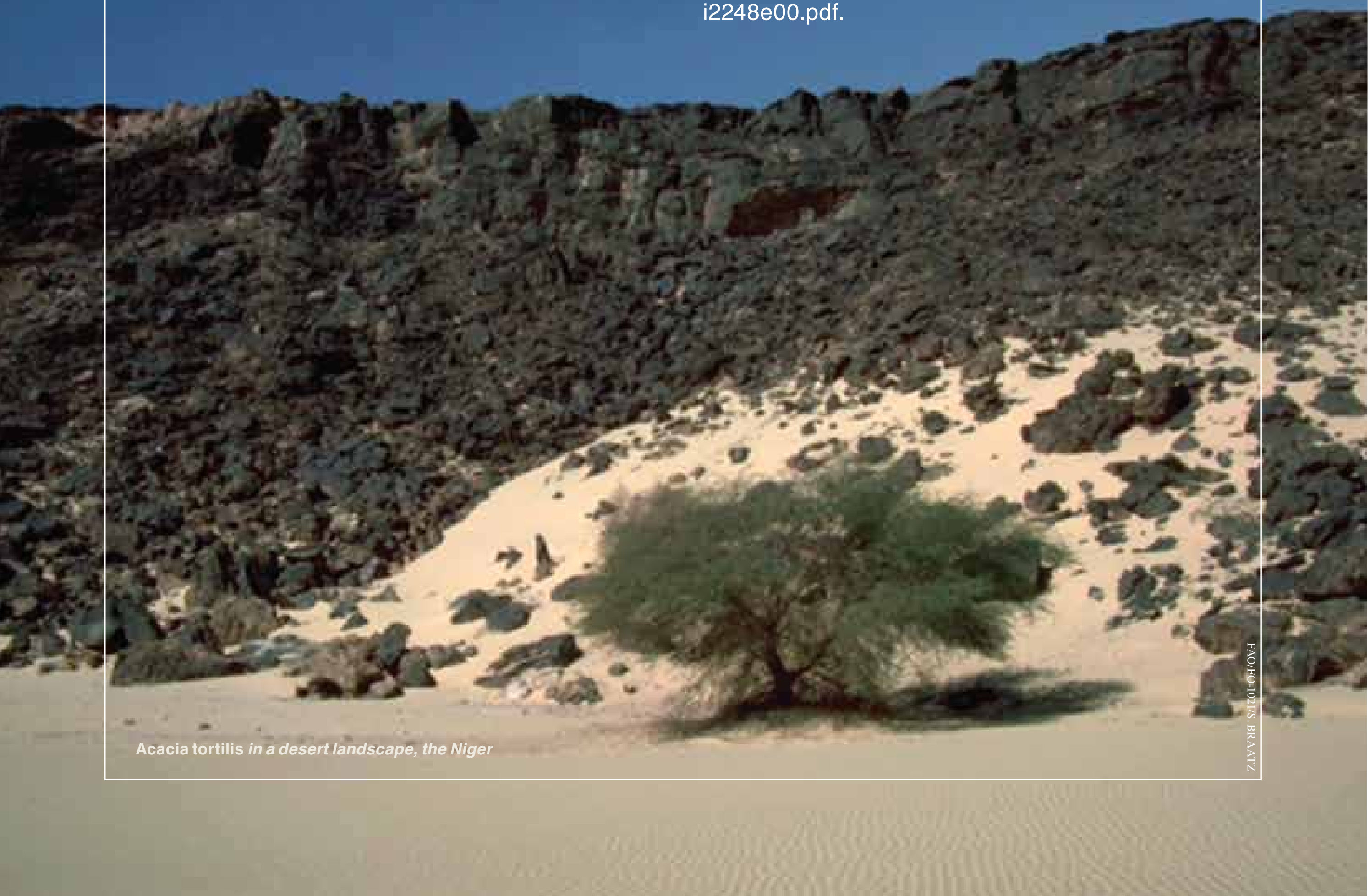
MEASURING FOREST DEGRADATION

IN THIS ISSUE...

Spotlight on the Acacia Operation project

A cooperative effort among countries, local stakeholders and FAO, the Acacia Operation project has involved the planting and managing of Acacia forests in arid lands, helping to combat desertification while providing socio-economic benefits to local communities.

- Read a news item about the project on page 66.
- Watch a video at www.youtube.com/watch?v=AfbM-DNMnNg.
- Learn more about arid zone forestry and the issue of desertification at www.fao.org/forestry/aridzone/en/.
- Download the new publication *Highlands and drylands – mountains, a source of resilience in arid regions* at www.fao.org/docrep/014/i2248e/i2248e00.pdf.



Acacia tortilis *in a desert landscape, the Niger*

FAO/FO-1021/S. BRAATZ

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Cover: Landsat images demonstrating forest fragmentation: front: 1990; back, top to bottom: 1990, 2000, 2005
Courtesy of the United States National Aeronautics and Space Administration and the United States Geological Survey

Contents

Measuring forest degradation

Unasylva closes the International Year of Forests 2011 with a selection of papers initially developed as part of a special study FAO and its partners conducted on forest degradation.

Although it is more complex to define and to measure, forest degradation is a serious problem comparable in dimension to deforestation. It has adverse impacts on the forest ecosystem and on the goods and services it provides. Many of these goods and services are linked to human well-being, and some to the global carbon and water and climate cycles – and thus to life on Earth.

Countries need information on forest degradation. They need to be able to monitor changes happening in forests. They need to know where forest degradation is taking place, what causes it and how serious the impacts are, in order to prioritize the allocation of scarce human and financial resources for the prevention of degradation and the restoration and rehabilitation of degraded forests.

The goal of the study was to come up with a reasonable set of indicators that can be easily measured and that provide countries with information on the state of forest degradation. It began as a special study under the umbrella of the Global Forest Resources Assessment (FRA) 2010, but later evolved into a multi-partner initiative led by members of the Collaborative Partnership on Forests (CPF) in collaboration with other partners including countries, the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD) and the Global Partnership on Forest Landscape Restoration.

A key output was a document – "Assessing forest degradation – towards the development of globally applicable guidelines". This working paper is intended to provide relevant agencies and other stakeholders with direction on measuring forest degradation. It can be used for the development of programmes for assessing forest degradation, and should be regarded as a precursor to the development of comprehensive globally applicable guidelines in the future.

The study recognized that forest degradation means different things to different people, depending on their point of view or interest in forests, and ways of measuring forest degradation had to be determined to reflect those differing points of view. The articles presented in this issue of *Unasylva* demonstrate the breadth of expertise and variety of perceptions among those invited to participate in the study.

An overview, by M. Simula and E. Mansur, lays out the issue of forest degradation and introduces some considerations in assessing it, including spatial and temporal scales, and the establishment of baseline data against which measurements can be compared.

L. Laestadius *et al*. invite readers to take a satellite's-eye view of forest degradation. A method for gathering information on forest degradation is introduced, showing that expert analysis of satellite imagery alone can provide information on the extent of human disturbance across large forest landscapes.

Methods recommended for measuring forest degradation will often include both analysis of remote sensing images and validation on the basis of field surveys. Yet one or the other is often a challenge, especially for developing countries. M. Herold *et al*. propose that countries combine analysis of historical remote sensing images with consistent, current field surveys to fill in data gaps.

A measure of forest degradation may be in terms of loss of biodiversity, forest health, productive or protective potential or aesthetic value. The next two articles explore the issue from an ecosystem perspective. I. Thompson describes the resilience of forest ecosystems, and how forests may lose their resilience over time, if sufficient attention is not paid to maintaining biodiversity and avoiding thresholds, or tipping points. K.P. Acharya, R.B. Dangi and M. Acharya focus on Nepal, which has a rich tradition of some sixty years of field surveys. Among the thematic elements of sustainable forest management that have been addressed by these surveys, forest ecosystem services has rarely been considered as a way of valuing degradation.

The final two articles also rely heavily on ground-based analysis. C.L. Meneses-Tovar focuses on forest health, describing an effort in Mexico to apply an index to satellite images and then to overlay it on data from field analysis, in order to measure change in "green". R. Nasi and N. van Vliet discuss measuring and monitoring wildlife in Central African logging concessions. From walking transects to counting dung pellets, readers are invited to consider how wildlife is monitored to ensure effective management measures can be developed.

Shorter articles present: a major study that analysed remote sensing imagery to understand forest-cover and land-use change; and a way to use such data to map the myriad opportunities for forest landscape restoration.

And so we hope to end from the perspective that the future holds tremendous opportunity. The special study envisioned that building the capacity of countries to assess, monitor and report on forest degradation can lead to action to reduce current rates of degradation – and to effective restoration efforts. Where it can be done, restoring degraded forests not only improves the amount and quality of the many goods and services they provide, it also enhances and improves their resilience and thus the capacity to withstand natural and human-induced changes or disturbances, including those caused by climate change.

A global challenge needing local response

M. Simula and E. Mansur

A common approach to defining and measuring forest degradation can lead to unique solutions for addressing it.

E. MANSUR

Forest degradation involves a change process that negatively affects the characteristics of a forest

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Eduardo Mansur is Assistant Director, Reforestation and Forest Management, International Tropical Timber Organization, Yokohama, Japan.

Forest degradation is a serious environmental, social and economic problem, particularly in developing countries. Yet it is difficult to define and assess. Degradation is viewed and perceived differently by various stakeholders who have different objectives. It is technically and scientifically difficult to define, and its definition can have policy implications, which further complicates reaching consensus and developing common approaches applicable at both international and country levels.

Quantifying the scale of forest degradation is difficult because it has many causes, and occurs in different forms and with varying intensity. Ten years ago, the International Tropical Timber Organization (ITTO, 2002) estimated that up to 850 million hectares (ha) of tropical forest and forest lands could be degraded. This figure is larger than that of the existing area of non-degraded tropical forests.

However, more recently, the Global Partnership on Forest Landscape Restoration (Laestadius *et al.*, 2011) suggested that more than two billion ha worldwide of forest land that has either been completely cleared over the

E. MANSUR

One person's degraded forest is another person's livelihood

centuries or has been degraded offers opportunities for restoration (see Mapping opportunities for forest landscape restoration, in this issue).

In practice, *local* response should be the main focus in addressing forest degradation as a global challenge.

WHY DOES FOREST DEGRADATION MATTER?

Forests provide a wide range of ecosystem services such as protecting soil from erosion, regulation of the water regime and provision of freshwater, capturing and storing carbon, producing oxygen and maintaining habitats for biodiversity. In addition, production of wood-based products, fibre and various non-wood products is critical for satisfying the needs for shelter, communication, packaging, food and many other uses of the global population.

There are about 300 million people in the tropics, consisting of indigenous peoples, local communities, settlers and smallholders, who depend on degraded forests and forest lands for their livelihoods, and they are often suffering from extreme poverty (ITTO, 2002). Bringing degraded areas under sustainable management would not only help in mitigation of and adaptation to climate change, but would also create employment and income for millions of people.

Forest degradation is one of the major sources of greenhouse gas (GHG) emissions, as shown by some regional and country studies, but its significance has not been quantified on a global scale.

WHAT IS FOREST DEGRADATION?

Perceptions of forest degradation are many and varied, and so are its drivers. Therefore, it is difficult to find a common approach for defining forest degradation: one person's degraded forest is another person's livelihood. For example, for a conservationist, any change in natural forest induced by human action can represent "degradation". A sustainably managed planted forest may be regarded as "degraded" if consideration is based only on the criterion of biodiversity. Degradation is, therefore, a relative concept that has to be linked with the forest's management objectives.

An Expert Meeting (FAO, 2002) developed a common definition of forest degradation: *The reduction of the capacity of a forest to provide goods and services*.

However, the definition, being generic, has proved to be difficult to operationalize. In practice, the focus has been given to productivity, biomass or biodiversity. Definitions that refer to multiple forest benefits may treat forest values in a comprehensive manner, but are more difficult to use beyond national purposes, for international purposes, in a consistent, transparent manner. A particular issue is definition of suitable thresholds for degraded and non-degraded forests, especially with regard to the international negotiations on climate change.

From the perspective of reporting on forests at an international level, a coherent, comparable and harmonized definition of forest degradation is desirable. However, national circumstances have implications for how internationally agreed definitions can be applied. Nevertheless, the general definition of forest degradation given above is compatible with an ecosystem services approach; as such, it provides an adequate umbrella at the international level and a common framework for developing more-specific interpretations for particular purposes.

WHY SHOULD FOREST DEGRADATION BE ASSESSED?

Forest degradation involves a change process that negatively affects the characteristics of a forest, reducing the value and production of its goods and services. This process is caused by disturbance (although not all disturbance causes degradation), which varies in origin, extent, severity, quality and frequency. Disturbance may be natural (e.g. fire, storm or drought), human-induced (e.g. harvesting, road construction, shifting cultivation, hunting or grazing) or a combination of the two. Human-induced disturbance may be intentional (direct), such as that caused by logging or grazing, or it may be unintentional (indirect), such as that caused by the spread of an invasive alien species (FAO, 2009). We need to know if forests are being degraded and, if so, what the causes are and to what extent the ecosystem has been impacted, so that measures can be taken to arrest and reverse the process. Information on the degradation process is also necessary to adjust national policies that may directly or indirectly lead to it.

Countries are required to report on the state of their forests, including their efforts to tackle forest degradation, at the international level, to various fora. The tenth Conference of the Parties to the Convention on Biological Diversity, for example, adopted the Strategic Plan for Biodiversity 2011–2020 with the Aichi Biodiversity Targets, including reduction of forest degradation. To determine if the targets are reached, an effective process for monitoring and reporting on forest degradation is required.

The agreement to establish a mechanism under the United Nations Framework Convention on Climate Change (UNFCCC) aimed at Reducing [GHG] Emissions from Deforestation and Forest Degradation (REDD+) provides another reason to measure forest degradation. The REDD+ mechanism has the potential to generate substantial funds for developing countries for reducing forest degradation and restoring, or otherwise improving, the management of forests (thereby increasing forest-based carbon sequestration). How degradation is defined will have significant implications for the financing volume and respective benefit-sharing among stakeholders.

HOW CAN FOREST DEGRADATION BE ASSESSED?

The articles in this issue of *Unasylva* provide in-depth information on assessing forest degradation from different perspectives (productivity, biodiversity, soil and others). Some considerations in assessing degradation relate to spatial and temporal scales and thresholds.

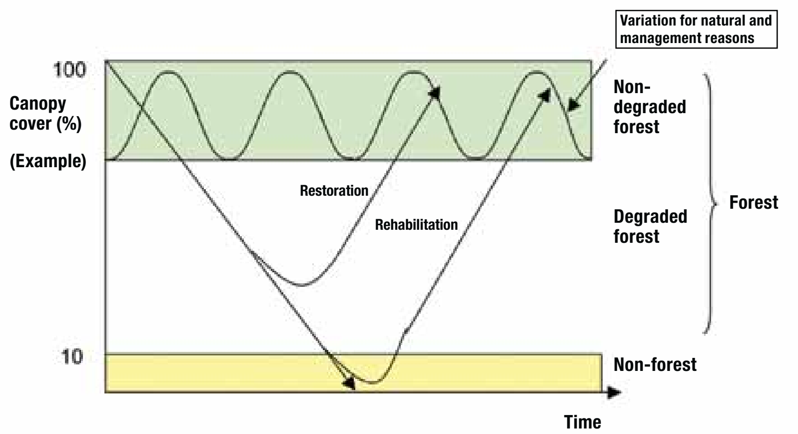
Forest degradation needs to be assessed at different spatial scales for different purposes. Assessment at the scale of a stand or site is needed for taking effective corrective action at the local level; many indicators of a forest's capacity to supply goods and services vary over time within a stand, without implying forest degradation. Degradation is also to be assessed and monitored over an entire forest management unit, and over a landscape (see Global forest alteration, from space, in this issue). Assessment over higher scales is necessary for national and international reporting and other purposes.

Temporal scale is another important aspect in assessment of degradation (see NDVI as indicator of forest degradation, in this issue). Short-term fluctuations in the capacity of a forest to produce certain goods and services are often part of a natural cycle or the result of planned human interventions (e.g. silvicultural treatment) (Figure). In forest management, the objectives are always set in the long term, which also holds true for the maintenance and enhancement of carbon reservoirs. For example, we should avoid a situation in which, although a forest is under sustainable management, short-term fluctuations in the growing stock resulting from harvesting in some stands are counted as emissions. Including such data would make sustainability an unattainable goal, and thereby lead to significant losses of other benefits. What matters is that the carbon pools be maintained and enhanced in the long run in the entire management unit or forest landscape.

A forest that is considered degraded has passed a threshold, i.e. the value set for an indicator of measurement. As forest types and biophysical situations vary extensively, it will not be possible to establish common thresholds. Similar to the concept of a threshold is that of a tipping point – the point at which a process of degradation becomes irreversible. Avoiding irreversible change – tipping points – may be one of the most important measures towards sustainability (see Biodiversity, ecosystem thresholds, resilience and forest degradation, in this issue).

WITH WHAT CAN DATA BE COMPARED?

The assessment of degradation requires the establishment of a reference state – a baseline or "ideal state" – against which the changed situation can be assessed. In practice, establishing a reference state is not an easy task. Primary forest could theoretically serve as a baseline, but this approach is sometimes problematic



Source: FAO, 2011.
Note: Canopy cover is used here as an example of an indicator of degradation. Restored or rehabilitated forest may not be similar to the original one.

Degradation process and thresholds

E. MANSUR

Human-induced disturbance may be intentional (direct) or unintentional (indirect)

because of past changes in the ecosystem. Sustainably managed forests for production could also serve as a reference state, even though they may lack some species, processes, functions or structures found in a primary forest. In addition, all forest ecosystems are characterized by inherent change and natural variation. Degradation occurs when the production of an identified good or service is consistently below an expected value and is outside the range of variation that would be expected on the site under the selected management regime. Therefore, assessment often tends to be based on judgement, because the range of natural variation can only be known through long-term research or monitoring, and data available for a given time are usually deficient. (See A review of methods to measure and monitor historical carbon emissions from forest degradation, in this issue.)

Natural and human-induced degradation are often interdependent. Human actions can affect the vulnerability of a forest to be degraded from natural causes, while natural damages can lead to increased human-induced disturbance. Distinguishing between natural and human-induced causes may be difficult when abiotic and biotic factors are triggered by changes in weather patterns that lead to a greater frequency, scale and impact of forest degradation.

Degradation can be, but is not necessarily, a precursor to deforestation. Forests may remain degraded for a long time but never become completely deforested; change can also be abrupt, such as when an intact forest is converted to another land use. At any stage on the continuum depicted in the Figure, forest degradation can be halted or reversed by forest improvement or other management interventions, including restoration through silvicultural measures and the rehabilitation of degraded non-forest land through reforestation.

HOW CAN THE GLOBAL CHALLENGE BE ADDRESSED?

The more than two billion ha of degraded forest land – a global combined area greater than that of China – offers huge opportunities for restoration and rehabilitation. Degraded areas are not usually subject to intensive land use, even in areas that may be densely populated. Sometimes, reversing degradation may require significant investments. However, more often it can be achieved through low-intensity interventions, such as extension of fallow periods and setting aside for natural regeneration.

Rural populations living in or near degraded forests can take remedial action when awareness is raised and economic incentives are made available. The successful restoration of the Loess Plateau in China is one such example. Restoration could provide many co-benefits, such as reduced erosion, reduced risk of flooding, improved agricultural productivity, and production of fuelwood, timber and other forest products. Useful guidelines for remedial action exist on both an international level – e.g. ITTO (2002) – and a national one – e.g. CONAFOR (2007). The Global Partnership on Forest Landscape Restoration (2011) provides a platform for information and exchange of experiences.

The REDD+ mechanism under the UNFCCC negotiations has raised great expectations for financing of restoration, rehabilitation and sustainable forest management. There is, however, a risk that the rural poor may not be able to benefit from REDD+ and that their forest tenure and use rights might be

Degraded forest land offers tremendous opportunities for reforestation

E. MANSUR

E. MANSUR

Solutions to degradation have to be adaptable and flexible over time to meet the needs of different forest stakeholders

negatively affected when maintenance and enhancement of the forest carbon pools become a binding objective by REDD+ financing. Without establishing clear and secure land tenure, building capacity, providing financial support and taking due consideration of the values and needs of local people, it is unrealistic to assume that these people will really benefit from REDD+. Another issue is that, in many countries, lands that have been transferred to community ownership have often been degraded and require significant investment through restoration.

REDD+ payments should be sufficient and differentiated to address variation in local conditions. By the same token, if forest owners, communities and dwellers are paid for "doing nothing", the system is not likely to work. Many payment schemes for forest environmental services have suffered from becoming simple subsidy schemes in which the link between the payment and the obligation for corrective action by the owner has remained unclear. Mitigation of climate change requires quick results, and restoration of degraded forests can absorb more carbon dioxide fast. As such, it represents an excellent bridging strategy. At the same time, resilience can be improved, and the recovery capacity of vulnerable biodiversity can be enhanced. The opportunity costs are low, and the results have important co-benefits. Time will be needed for capacity-building, tenure reforms and strengthening of governance, but action cannot be delayed.

There is no one size that fits all; solutions for degradation are always unique to their setting. They have to be adaptable and flexible over time, because they seek to channel the needs of many different forest stakeholders towards sustainable practices that create change. ◆

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Global forest alteration, from space

L. Laestadius, P. Potapov, A. Yaroshenko and S. Turubanova

A novel approach examines evidence of alteration to establish intact forests.

Assessing forest degradation at the regional and global scales is difficult for various reasons. Degradation is a complex concept that is difficult to define. As such, and in addition, it is difficult, and expensive, to measure. What little information is available is often inadequate, lacking in detail, richness and consistency, particularly across jurisdictional boundaries. Non-productive aspects such as biodiversity tend to be particularly poorly described.

Satellite observations provide a promising approach to gathering information. The availability and technical quality of satellite images are improving steadily, while the price is decreasing. Satellite imagery makes it possible to assess large, and even inaccessible, landscapes at a low cost, relatively rapidly. Moreover, suitable historical satellite images (Landsat) dating back to approximately 1980 are available in public archives, making it possible to assess change over time.

This article describes the result of an attempt to use satellite images to assess forest degradation. The method described was originally developed to map intact forest landscapes, or IFLs (Yaroshenko, Potapov and Turubanova, 2001; Aksenov *et al*., 2002; Lee *et al*., 2002; Strittholt *et al*., 2006; Potapov *et al*., 2008). It is therefore referred to as the *IFL Method*. The method and its definitions were designed specifically to work with satellite imagery and are therefore different from what would be used for ground-based observations. The results are replicable and consistent in

V. KANTOR

A forest landscape is dominated by forests but may include naturally occurring treeless areas such as these wetlands in the northern European part of the Russian Federation. The IFL Method identifies visible changes in a forest landscape resulting from human influence

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both time and space – that is, for a country, a continent, or the world, at the same point in time.

DEFINING FOREST ALTERATION

The concept of a *forest landscape*, as it is used here, is a mosaic of naturally interspersed land cover types. A forest landscape is dominated by forests but may also include naturally occurring treeless areas, such as small lakes, wetlands, rivers and rocky outcroppings.

Forest degradation is an ambiguous concept. One person's degradation may be another person's improvement; it all depends on one's perspective. For the purposes of this article, the more neutral term *forest alteration* is used. *Forest alteration* is used here to indicate a visible change in a forest landscape resulting from human influence.

THE IFL METHOD

The IFL Method consists of two mutually dependent components: the method itself and a set of definitions and criteria. Well-defined criteria are used to prove that an area is not intact (see Box). These rules have been designed to be globally applicable and easily replicable, allowing for repeated assessments over time as well as independent verification.

The assessment logic has three major characteristics:

The landscape is classified as being either altered or not altered (intact). Although the IFL Method can be adapted to assess different types and degrees of alteration, this article takes a very simple view on alteration: a landscape is either intact, or it is altered.

An IFL is an unbroken expanse of natural ecosystems that shows no signs of significant human activity and is large enough to maintain all native biodiversity, including viable populations of wide-ranging species. In this assessment, an intact area had to be at least 50 000 hectares (ha) in size to be considered an IFL.

Criteria

A. Alteration

Portions of the study area with evidence of *significant* human-caused alteration are considered disturbed and not eligible for inclusion in an IFL. Such evidence includes:

1. Settlements (including a buffer zone of 1 km);
2. Infrastructure used for transportation between settlements or for industrial development of natural resources. Evidence would include roads (except unpaved trails), railways, navigable waterways (including seashore), pipelines and power transmission lines (including, in all cases, a buffer zone of 1 km on either side);
3. Agriculture and forest plantations;
4. Industrial activities during the past 30–70 years, such as logging, mining, oil and gas exploration and extraction, peat extraction;
5. Areas affected by stand-replacing wildfires during the past 30–70 years, if they are located in the vicinity of infrastructure or developed areas.

Human influence that either took place in the distant past or is of low intensity is considered *insignificant*. Portions with such "background" influence remain eligible for inclusion in an IFL. Sources of background influence might include diffuse grazing by domestic animals, low-intensity selective logging, and hunting.

B. Fragmentation

Portions of the study area that remain eligible for inclusion in an IFL are then assessed for fragmentation. Portions considered otherwise eligible, but that are too small, or too narrow, are eliminated. An IFL must satisfy the following criteria:

1. Larger than 50 000 ha;
2. At least 10 km wide at the broadest place (measured as a diameter of the largest circle that can be fitted inside the patch);
3. At least 2 km wide in narrow parts connecting wider patches, and in appendages.

Two types of criteria are being used. Two types of criteria are used to separate intact and non-intact forest landscapes: (A) alteration, and (B) fragmentation. These criteria are used in sequence to determine if an area qualifies to be considered an IFL.

First, the level of alteration is assessed. Altered parts of the study area are rejected as being ineligible for inclusion in IFLs. Remaining parts are then assessed for their degree of fragmentation. Again, parts determined to be ineligible are rejected.

The landscape is considered intact until proven otherwise. The assessment logic works much as a court process. The initial assumption is that the entire area of study is "innocent", i.e. intact/not altered. The method then seeks to prove that areas are "guilty" by finding evidence of alteration. Once all altered areas have been eliminated, only intact areas remain. The logic is that it is easier to spot evidence of alteration and fragmentation than to prove their absence.

APPLYING THE IFL METHOD

The IFL Method was used to assess the ecological integrity of the world's *forest landscape zone*. The forest landscape zone is different from what FAO calls the *forest zone* in that it includes treeless areas that occur naturally within the broader ecosystem that we call a forest landscape. Assessments of these two types of areas are, therefore, not comparable.

The boundary of the forest landscape zone was defined using a global tree canopy cover dataset – part of the Vegetation Continuous Fields MODIS 500 m product (VCF) (Hansen *et al.*, 2003). Forest was defined as an area with a tree canopy cover greater than 20 percent in the year 2000. Forest patches smaller than 4 km^2 were excluded. Forest landscape fragments smaller than 500 km^2 were not considered in the analysis.

The forest landscape zone was assessed in two steps. First, a preliminary fragmentation analysis was carried out for countries for which Geographic Information System (GIS) datasets for transportation infrastructure and settlements were available at a scale of 1:500 000, or finer. Areas in the vicinity of roads, pipelines, power lines and settlements were eliminated from the area of study, fragmenting the forest landscape zone into a mosaic. The goal was to identify landscape fragments free from major elements of infrastructure and greater than 50 000 ha in size. Areas that did not qualify were eliminated from further consideration, while other areas were retained as candidates for IFL.

Proportion of forest landscape zone that has been altered, by forest type

Forest type	Total area *(Mha)*	Altered area *(Mha)*	Proportion altered *(%)*	Intact area *(Mha)*	Proportion intact *(%)*
Closed forests	2 748.4	1 901.3	69.2	847.1	30.8
Open forests and woodlands	1 377.6	1 108.0	80.4	269.6	19.6
Naturally treeless areas	1 461.5	1 265.3	86.6	196.2	13.4
Forest landscape zone total	5 587.6	4 274.7	76.5	1 312.9	23.5

The second step was to use high spatial resolution Landsat TM (global coverage representing an average date of 1990) (Tucker, Grant and Dykstra, 2004) and ETM+ (global coverage representing an average date of 2000) imagery to assess all remaining potential IFL areas systematically for alteration and to draw precise boundaries for each IFL.

The image analysis was conducted through expert-based visual interpretation, using GIS overlays with additional thematic and topographic map layers.

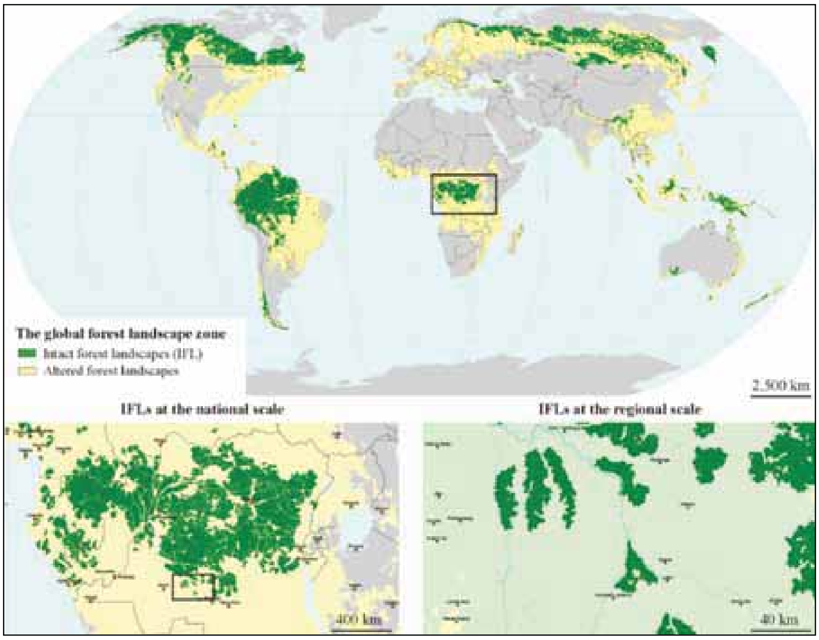
A GLOBAL ASSESSMENT OF FOREST ALTERATION

The current extent of the world's forest landscape zone, as defined above, is 5 587.6 million ha (Mha), or 37.3 percent of the Earth's total land surface. This area can be divided into three major forest ecosystem types, based on tree canopy cover (Hansen *et al.*, 2003):

1. *Closed forests* with a tree canopy cover greater than 40 percent (49.2 percent of the forest landscape zone);
2. *Open forests and woodlands* with a tree canopy cover of 20–40 percent (24.7 percent of the forest landscape zone); and
3. *Naturally treeless areas* with a tree canopy cover below 20 percent, e.g. savannahs, grasslands, wetlands, agriculture areas, mountain ecosystems, lakes (26.1 percent of the forest landscape zone).

IFLs represent 23.5 percent of the forest landscape zone (1 312.9 Mha). The balance is affected by development or fragmentation (Figure 1). In the context of the IFL Method, this part is considered altered. The extent of alteration differs among closed, open and non-forest ecosystems (Table).

Approximately two-thirds (69.2 percent) of the world's closed forests are non-intact. There are more remaining IFLs in the boreal and subtundra zones of the north than there are in the south; a long history of human activity has transformed the original woodlands and savannah-type ecosystems of the tropics and the temperate forest–steppes into croplands, pastures, or pyrogenic shrubland or grassland communities.



1
The world's intact and altered forest landscapes. The IFL Method produces maps that are relevant for planning and monitoring at the global, national and regional scales. The regional-scale map shows non-intact forests in light green and treeless areas in yellow

2
Forest alteration, expressed as the proportion of altered landscapes within the forest landscape zone of selected countries. Countries included in the analysis are shown in dark gray (62 countries total)

COUNTRY-LEVEL BASELINE

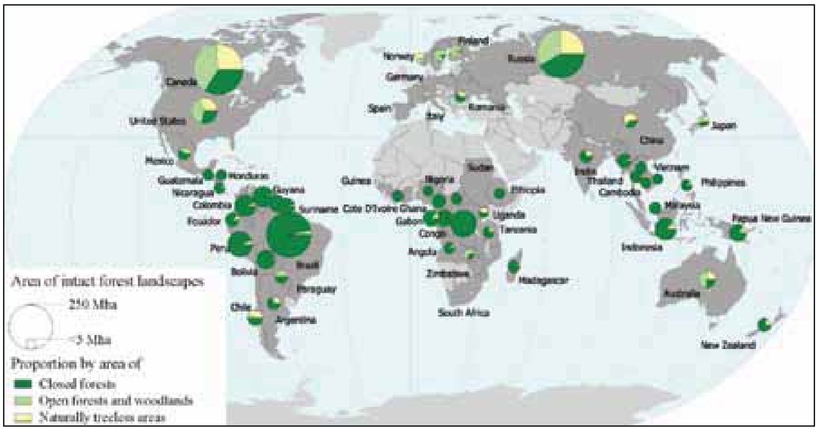
A country-level assessment was conducted that was limited to countries with at least 10 million ha of area in the forest landscape zone (Figure 2). Of these 62 countries, the forest has been almost entirely altered, i.e. less than 1 percent of the forest landscape zone remains as IFL, in 19. This group consists of European countries other than Finland, the Russian Federation and Sweden, and African countries outside the Congo Basin. Major levels of alteration, i.e. the proportion of remaining IFLs is between 1 and 10 percent of the forest landscape zone, are seen in a group of 21 countries. This group includes African countries on the edge of the humid tropical forest biome, Central American countries, countries in Southeast Asia, and Northern Europe. China and India also belong to this group. The remaining 22 countries have an IFL proportion that is greater than 10 percent of the total forest landscape zone. Only five of them, however, have an IFL proportion greater than 50 percent: Canada, French Guiana, Guyana, Peru and Suriname.

Two different groups of countries emerge when the composition of the IFLs is examined in terms of closed, open and non-forest ecosystems (see Figure 3). The first group is made up of developed countries in which there is industrial forest management. In these countries, the densest and most productive forests have been altered by management or converted to plantations. Where the natural tree canopy density is low and forests are, therefore, less attractive, in terms of forest management, most areas remain intact. Examples are mountainous regions, wetlands and the northern part of the boreal zone.

A different pattern prevails in the second group. In these areas, accessible forests have been cleared for agriculture or grazing, while inaccessible tracts of dense forests remain largely intact. The least altered dense forests are found among the countries of Central Africa, in Latin America and in Papua New Guinea. The large proportion of dense forests within the IFLs of these countries makes them important repositories of carbon, and their alteration would lead to significant carbon emissions.

ASSESSMENT OF THE IFL METHOD

The IFL Method has many advantages for assessments of large areas. It is suitable for all countries and continents. It is inexpensive to apply, and it can be applied quickly. Its data needs are fulfilled by satellite imagery, which is available in the public domain for free or at a low, and diminishing, cost. It is rigorously defined and lends itself to independent replication and verification. It is also suitable for monitoring – through replication at different points in time in order to measure change. It can be adapted and refined, for example to assess smaller landscapes. Remote and otherwise inaccessible landscapes can be assessed. The result is consistent across the entire area of study (for



3
Intact forest landscapes in selected countries and their composition, by forest type. Countries included in the analysis are shown in dark gray (62 countries total)

example, a country, or the world), and results can, therefore, be compared. Results are spatially explicit, in that they take the form of a map that is detailed enough to underpin decisions about conservation priorities and measures. Statistical information can easily be derived from the map. The method is tested and ready to use.

The resolution, and quality, of the maps has been judged sufficient for them to be used as a tool to support wood procurement and forest management in the boreal forest. For example, in Canada and the Russian Federation, and in the standard for controlled wood, the Forest Stewardship Council (FSC) is using maps produced by the IFL Method (Aksenov *et al.*, 2002; Lee *et al.*, 2002) as a proxy for large landscape-level forests, a type of forest considered by FSC to have a high conservation value (FSC Canada, 2004; FSC Russia, 2008; FSC, 2006).

The IFL Method can also be used to monitor how forest alteration expands over time. Monitoring simply involves applying the method at a different point in time than that of the baseline study and comparing results. Examples of regional monitoring in the northwestern part of the Russian Federation and Central Africa are given in FAO (2009).

There are also limitations. Skills in GIS and interpretation of remotely sensed data are required. It is suitable only for large areas (province, country, region, the world). Its consistency makes it insensitive to variations among nations in the understanding of "intactness" and "alteration". For example, in interpreting burned areas, would the cause of a fire factor in – such that they be might considered intact, if the burning is the result of natural fires, or altered, if it is the result of human-caused fires? Should the smallest allowed size of an IFL be differentiated with regard to biome (e.g. boreal vs. tropical forests) or natural disturbance regime (e.g. fire dynamics vs. gap dynamics)?

The IFL Method is biased towards overestimating the area of IFLs. This is because of its "innocent until proven guilty" logic. Human influence that is difficult to detect in satellite imagery, such as selective logging, small-scale slash-and-burn agricultural practices, and hunting (for example, poaching in Central Africa), may be overlooked, causing an altered area to be mapped as an IFL. The accuracy of the result will depend on the quality and spatial resolution of the satellite imagery.

A significant limitation of the method, as it was used for this study, is its binary nature. Landscape is classified as being either intact or altered. Neither type nor degree of alteration is differentiated. However, the method can be modified to suit different purposes. It can be made more sensitive to different types of alteration by defining additional and less strict categories, e.g. in terms of patch size and alteration within patches. It could include smaller patches as fragments of intactness to make the method more suitable for assessment of small landscapes (Lee, Gysbers and Stanojevic, 2006; Mollicone *et al.*, 2007).

The method is capable of generating useful results without adding field verification when it is applied by experienced analysts who have expert knowledge of the landscape they are assessing and who have access to Landsat TM/ETM+ images. In particular instances, field verification will improve the accuracy of the method. For example, verification could be applied in cases in which the satellite imagery is poor or in which human influence is difficult to detect, e.g. because the influence is diffuse rather than distinct, or because it is invisible from space because it is on a small scale or occurs under the canopy. There is a certain degree of subjectivity in determining IFL boundaries across transition zones from intact to disturbed areas, especially within non-forest territories, savannahs, woodlands and mountain areas. Resources for fieldwork should be focused on verifying the interpretation at important points in which there is a lack of clarity, rather than on a random or systematic sampling.

CONCLUSIONS

The IFL Method provides a cost-effective way to assess the degree of human influence across a large forest landscape, be it a country, or the world. The method is designed to use satellites as the main source of data, reducing cost and enhancing speed. Targeted ground verification of selected spots helps increase accuracy. The result is a map that shows the precise location and boundaries of intact forest landscapes, i.e. the remaining patches of un-altered land in the forest landscape zone, with sufficient accuracy to guide wood procurement, at least in the boreal forest. This map provides a guide for policy-making and priority-setting, as well as a baseline for monitoring change by recurrent application of the IFL Method to intact forest landscapes. The distinction between intact and non-intact forests used here is consistent with experience from satellite-based deforestation measurements and can be used to provide important background data for accounting of carbon loss from forest alteration.

The method can be refined to be more sensitive to the intensity or type of alteration without changing its logic or data requirements, thus enabling it to measure degrees of alteration.

The method will benefit from improvements in the quality and price of, and access to, satellite images. The effect of such improvements will be particularly strong in the humid tropics, where persistent cloudiness makes it difficult to acquire images.

The usefulness of the method can be expanded through at least three types of measures:

- *Capacity-building.* An analyst using the IFL Method must have two areas of expertise: interpretation of satellite images and GIS, and forest ecology and management. This combination of skills is rare, particularly in developing countries. Concerted training efforts can certainly help in this regard.

- *Transparency and review of results.* The results of the IFL Method are relatively easy to communicate and understand because they can be articulated on maps. These maps need to be reviewed by regional and local experts, as well as by relevant stakeholders. As such, the logistical challenges for a rigorous, paper-based review process are many, particularly for a regional or global assessment. It is possible to let reviewers access maps and provide feedback via the Internet. Development of a Web-based platform for transparency and review is, therefore, needed.
- *Funding for development and application.* The IFL Method has been developed thanks to financial contributions from corporations and foundations in the private sector. Government engagement in the further development and application of the method would be extremely beneficial.

In the case of the present study, the authors envision that the global IFL map will be periodically updated and improved to reflect further alteration. The continual improvement of satellite-borne sensors and analytical techniques will gradually reduce the necessary effort. A continuous external review process has been organized on a dedicated Web site (www.intactforests.org), which allows users to view the IFL map against a background of satellite imagery. ◆

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Remote sensing survey updates forest-loss estimates

A. Gerrand, E. Lindquist and R. D'Annunzio

A new study has improved our knowledge of changes in tree cover and forest land use over time.

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FAO led remote sensing studies focused on tropical forests for Global Forest Resources Assessment (FRA) reports for 1980, 1990 and 2000. A new study, carried out as part of FRA 2010, was more comprehensive, with satellite images collected globally. The objective was to improve our knowledge of changes in tree cover and forest land use over time. A key driver of the study was the increasing importance of climate change, which has heightened the need for better information because forest and related land-use changes are estimated to be responsible for approximately 17 percent of human-induced carbon emissions.[1]

Satellite data enable consistent information to be collected globally, information that can, in turn, be analysed in the same way for different points in time to derive better estimates of change. Remote sensing does not replace the need for good field data, but combining both methods provides better results than does either method alone.

The outcomes of the FRA 2010 Remote Sensing Survey were:

- improved knowledge on land cover and land-use changes related to forests, especially deforestation, afforestation and natural expansion of forests;
- information on the rate of change between 1990 and 2005 at global, biome and regional levels;
- a global framework and method for monitoring forest change;
- easy access to satellite imagery through an Internet-based data portal; and
- enhanced capacity in many countries for monitoring, assessing and reporting on forest area and forest-area change.

A scientific sampling design

The survey used a sampling grid design with imagery taken at each longitude and latitude intersection (approximately 100 km apart), reduced to two-degree spacing above 60 degrees North (Figure 1). There were approximately 13 500 samples, of which about 9 000 were outside deserts and permanent ice (Antarctica was excluded). Each sample site was 10 km by 10 km, giving a total sampling area equivalent to about 1 percent of the Earth's land surface. This grid was compatible with that used for many national forest assessments, including those supported by FAO.

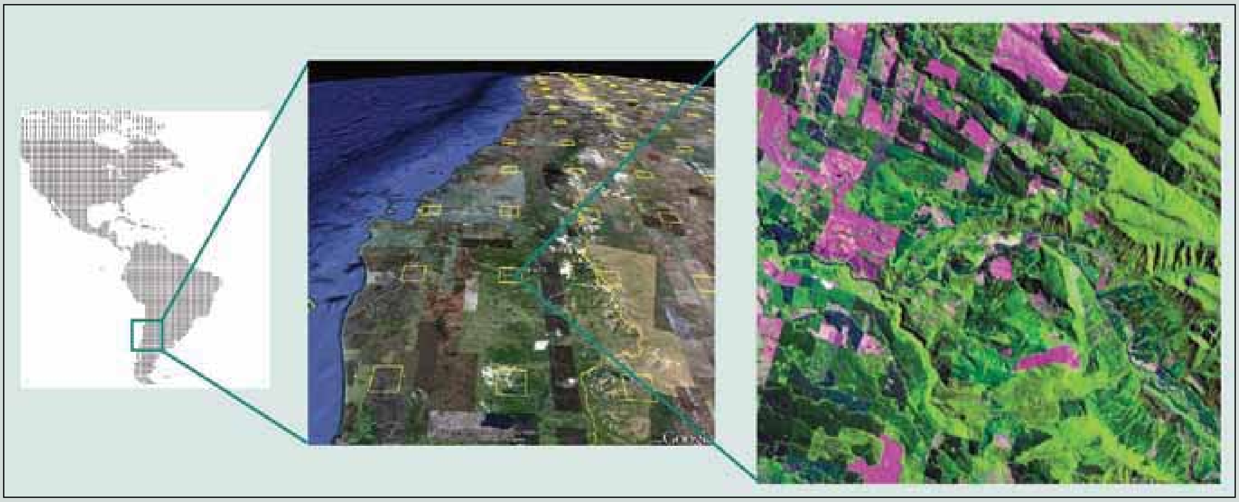
Easy access to tools and satellite images

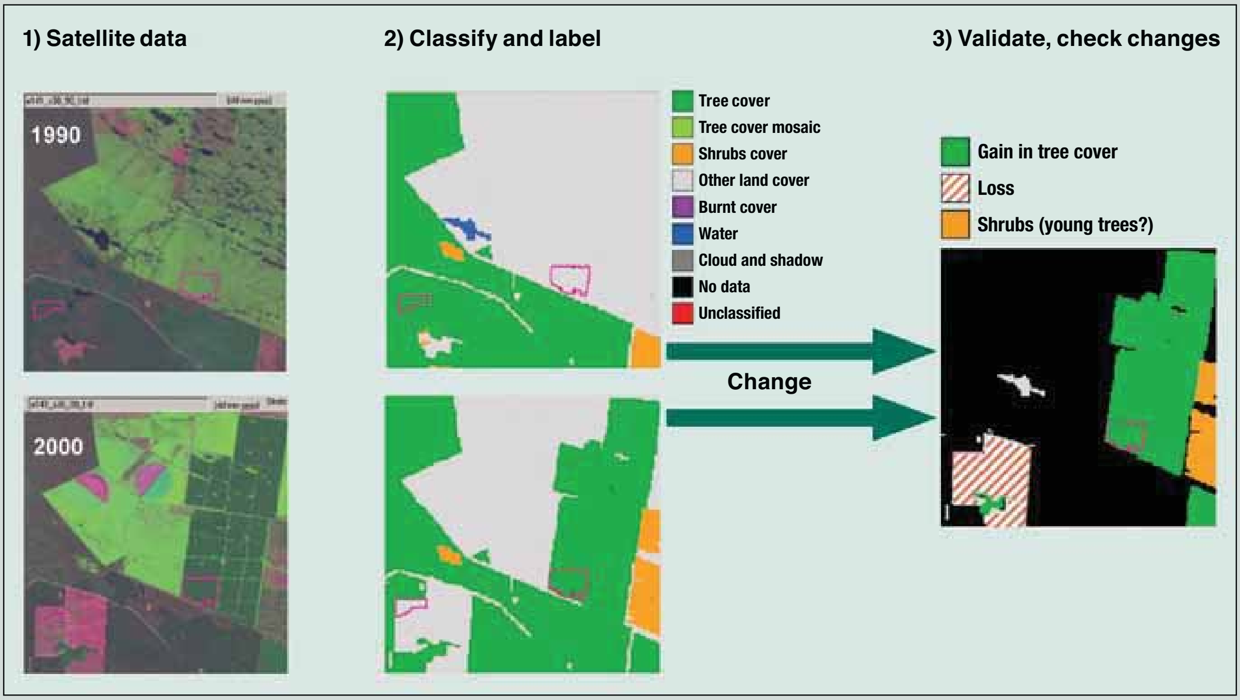
FAO and its partner organizations made preprocessed imagery for the sample areas easily available through the Internet.[2] Access to free remote sensing data and specialized

[1] IPCC. 2007. *Climate change 2007. The physical science basis: Contribution of Working Group I to the Fourth Assessment Report of the IPCC*. Cambridge, UK, Cambridge University Press.

[2] See www.fao.org/forestry/fra/remotesensing/portal.

1
The systematic sampling grid





2
Example of steps used in processing Landsat data to classified land cover map and resulting land cover change, 1990–2000

software has particularly benefited developing countries with limited forest-monitoring data or capacity. Authorized national experts can log in and download draft labelled polygons for checking and then upload the validated data.

Improved globally consistent estimates of forest extent and change over time

For each sample, three Landsat images – from around 1990, 2000 and 2005 – were extracted by South Dakota State University and further processed by FAO or the European Commission Joint Research Centre (JRC) to a consistent standard using an automated image-classification process. Draft land-cover labels were then prepared, and the changes in land cover over time were highlighted. National experts validated the preliminary results and then helped undertake the transformation from land-cover classes to land-use classes (Figure 2).

Strong technical partnerships and engagement with countries

The project combined the technical forest and land-cover experience in FAO, in partnership with external agencies, with funding support from the European Commission and technical expertise from their JRC. The results from this work have been reviewed and validated by over 200 national experts in 102 countries. This input has made the results some of the most detailed and widely checked global statistics on forest-cover change from satellite data.

Key findings

The findings of the survey show that the world's total forest area in 2005 was 3.69 billion hectares (ha), which is approximately 30 percent of the global land area. The findings suggest that the rate of world deforestation averaged 14.5 million ha per year between 1990 and 2005, a figure that is consistent with previous estimates. Deforestation was highest in the tropics, likely attributable to the conversion of tropical forests to agricultural land.

The survey shows that, worldwide, the net loss in forest area between 1990 and 2005 was not as great as had previously been reported, as gains in forest areas are larger than had previously been estimated.

Net loss – in which losses of forest cover are partially offset by afforestation or natural expansion – was 72.9 million ha between 1990 and 2005. The planet lost an average of 4.9 million ha of forest per year, or nearly 10 ha of forest per minute, over the 15-year period.

The new data also show that the net loss of forests increased from 4.1 million ha per year between 1990 and 2000 to 6.4 million ha between 2000 and 2005.

Although the data and analysis have not yet been applied to forest degradation, they could be reprocessed later for that purpose.

Detailed results of the survey, including information on regional losses and gains, are planned for release in early 2012. Initial results from the survey, and further information, are available at:

www.fao.org/forestry/fra/remotesensingsurvey/en.

This discussion has been adapted from the FRA 2010 report to reflect key findings of the survey.

A review of methods to measure and monitor historical carbon emissions from forest degradation

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In the absence of historical field data, developing countries can rely on consistent current ground data and remote sensing assessments.

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Disturbances that lead to forest degradation have been estimated to affect roughly 100 million hectares (ha) of forest globally per year (FAO, 2006, in Nabuurs *et al*., 2007). With respect to mitigation of climate change, forest degradation refers to a loss of carbon stock within forests that remain forests (IPCC, 2003a; UNFCCC, 2008). Degradation, therefore, implies that measured forest variables, such as canopy cover, remain above the threshold for the definition of forest. It is distinct from deforestation, which is commonly associated with a land-use change.

In 2005, the eleventh session of the Conference of Parties (COP-11) to the United Nations Framework Convention on Climate Change (UNFCCC) highlighted the role of reducing deforestation and forest degradation as tools to mitigate climate change (Reducing Emissions from Deforestation and Forest Degradation – REDD). The Conference reinforced Article 2 of the Kyoto Protocol regarding the protection and enhancement of sinks and reservoirs of greenhouse gases not controlled by the Montreal Protocol.

Developing country Parties to UNFCCC have been encouraged to take certain guidance into account when engaging in REDD and REDD+ activities (UNFCCC, 2009a), in particular, those related to establishing national forest monitoring systems. These systems need to use an appropriate combination of remote sensing and ground-based approaches to forest carbon inventory to estimate anthropogenic emissions of greenhouse gas by sources, removals by sinks, forest carbon stocks and forest area changes. All estimates should be transparent, consistent and as accurate as possible, and uncertainties should be reduced, as far as national capabilities and capacities permit.

Measuring forest degradation and related forest carbon stock changes is more complicated and more costly than measuring deforestation. Countries can measure current rates of degradation through field data and/or remote sensing data; a combination of the two types of data provides the strongest estimates. However, developing countries frequently lack consistent historical field data. Therefore, in assessing historical degradation, they are forced to rely strongly on remote sensing approaches mixed with current field assessments of carbon stock changes.

This article aims to support developing countries in the implementation of REDD+ activities by providing an overview and review of methods to measure and monitor carbon emissions from forest degradation. It focuses on historical periods in order to provide insight into the historical reference for degradation under REDD+ activities (UNFCCC, 2009b).

ESTIMATING EMISSIONS FROM FOREST DEGRADATION

IPCC Good Practice Guidance

Under the UNFCCC, countries are encouraged to use the Intergovernmental Panel on Climate Change (IPCC) *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (Good Practice Guidance) as a basis for reporting greenhouse gas emissions from deforestation and forest degradation (IPCC,

Carbon pools defined in the Good Practice Guidance

The IPCC (2003b) defines five carbon pools to be measured and monitored: aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon. Key source categories should be assessed and selected. A key source category is "an emission or sink category that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both". Key source categories should be estimated using higher tiers (Box, below), if sufficient resources are available. In the tropics, the most generalized approach is to monitor only aboveground biomass, even though soil carbon stocks in peatlands also require attention because they can contain more carbon stock than aboveground biomass.

2003b; 2006). To estimate the emissions associated with forest degradation, countries should consider:

- Areas of forest that remains forest affected by degradation, considered at the national level, ideally stratified into different disturbance or degradation types. Statistics calculated through forest inventories or through remote sensing can be used to quantify how much forest area is undergoing degradation changes, and where. Such data are referred to as *activity data*.
- Changes in forest carbon stocks that result from degradation processes, per area and time units. The carbon lost from forests and released to the atmosphere through the degradation process is commonly measured through forest field sampling and repeated forest inventories. Changes should be calculated for each of five forest carbon pools (Box, above). Measurements are reported in tonnes of carbon produced per ha per year (Mg C ha^{-1} yr^{-1}). These data are referred to as *emission factors*. (IPCC, 2003b; 2006)

The national emissions from forest degradation result from combining activity data and emission factors for each forest and degradation type, as indicated in the IPCC methodology.

The Good Practice Guidance provides the level of complexity and certainty of different reporting approaches under the UNFCCC, in terms of tiers. The higher the tier, the lower the level of uncertainty associated with the data, and therefore the better the accuracy (Box, below).

Challenges and considerations

There is not one method to monitor forest degradation. The choice of method, or a combination of methods, depends on a number of factors, including the type of degradation, available data, capacities and resources. Additionally, the potential, and limitations, of various approaches to measurement and monitoring should be considered. Challenges associated with the different methods are diverse:

- *Temporal thresholds and spatial scales*. The effect of forest degradation on forest carbon stocks depends on time. Temporal thresholds for each forest type should be established to avoid combining the effects of short-term reductions in carbon stock with the effects of long-term reductions. Sustainable forest management practices, for example, can cause temporary changes to carbon stocks that do not lead to degradation, while unsustainable practices can lead to forest degradation in the long term.
- *Integration of field and satellite data sets*. Monitoring changes in carbon stocks resulting from forest degradation relies heavily on field surveys. However, data benefit from integrating remotely sensed data with site-specific biophysical field attributes. Key issues to consider are which biophysical parameters should be measured and which time thresholds would be appropriate for relating the two approaches.

Good Practice Guidance tiers for estimates of emissions

IPCC (2003b) provides three tiers to categorize methods to estimate emissions. The higher the tier number, the more rigorous the requirements for the data, and the more complex the analysis performed. Hence, the higher the tier number, the more accurate the estimate.

- **Tier 1 uses default values for forest biomass and forest biomass mean annual increment (MAI). They are obtained from the IPCC Emission Factor Data Base (EFDB) and correspond to broad continental forest types (e.g. African tropical rainforest). Tier 1 also uses simplified assumptions to calculate emissions.**
- **Tier 2 uses country-specific data (i.e. data collected within the national boundaries). Forest biomass is resolved at finer scales through the delineation of more detailed strata.**
- **Tier 3 uses actual inventories with repeated measures of permanent plots to measure changes in forest biomass directly. In addition, or instead, well-parameterized models may be used, in combination with plot data.**

A Tier 3 approach requires a long-term commitment of resources, and therefore generally involves establishing a permanent organization to house the monitoring programme.

- *Spatial impact and intensity*. Different activities causing forest degradation are often focused on specific areas within a country. Efforts to measure and monitor must track the most important activities and their impacts to use resources most efficiently (Herold and Skutsch, 2011).
- *Identification of key forest carbon pools affected by degradation*. Methods for calculating changes in carbon stocks vary for each relevant carbon pool (Box, page 17, top), as well as for emissions of non-CO_2 greenhouse gases including methane and nitrous oxide.

Measuring historical forest degradation involves further challenges. Historical degradation is important for quantifying a country's potential reduction in emissions. *Ex ante* estimations of forest degradation may be required to estimate the reference emissions level against which emission reductions will be calculated for a given period. In addition to the general considerations relating to methodology, challenges in assessing historical forest degradation include:

- *Lack of data*. Many countries, in particular those in tropical regions, lack historical data on forest degradation and its impact on forest carbon stocks. Historical data at a national level are often limited to archives of satellite images, while remote sensing, itself, has limitations pertaining to the detection of degradation.
- *Insufficient capacity*. While many developing countries have some level of experience monitoring commercial forestry activities and have maintained some data, human resources and other capacities are often not sufficient to implement a national survey to assess historical deforestation and forest degradation.
- *Temporal considerations*. There is currently no agreement regarding a temporal threshold associated with long-term carbon stock loss. Cumulative, long-term and gradual carbon stock losses can be measured using direct methods. For carbon losses that happen more rapidly, canopy closures impede field and satellite observations.
- *Integration of different data sources*. It is rare that data sets on historical forest degradation are available. Integrating remotely sensed data with site-specific biophysical field attributes from past assessments and other sources, such as forest management data, is challenging.
- *Inconsistencies when linking historical and present data sets and methodologies*. Different systems used to acquire data through different processes are often incompatible and require harmonization and consistency.

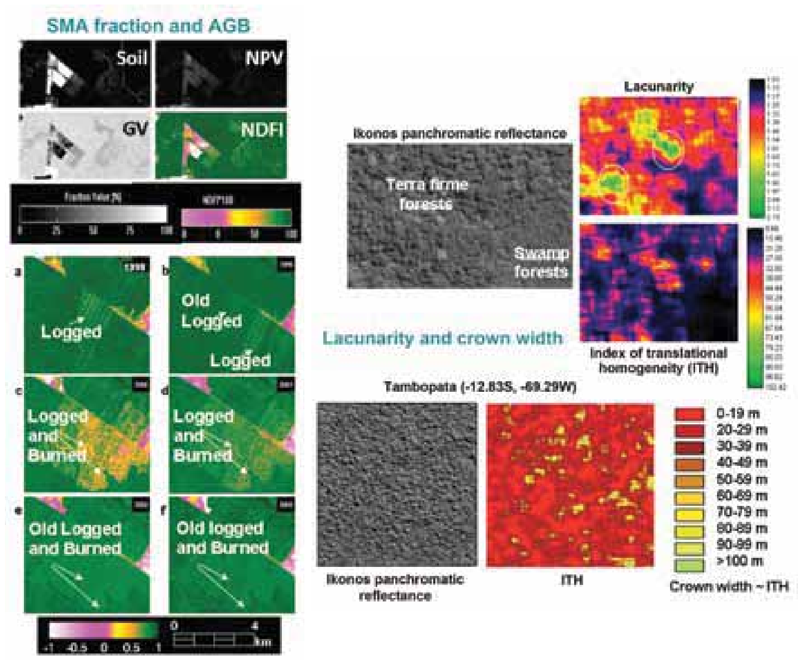
Approaches

Many developing countries have limited, or no, field data. Further, procedures for measuring carbon stock changes on a consistent basis have not been established – but they can be, given the following considerations. Historical emission factors can be derived by analysing present-day data on carbon stock losses that have resulted from similar degradation processes, and by studying and linking their chronosequences with available historical data, such as archived remote sensing images. For certain degradation activities, data might be collected from the records of companies that performed the activities. For example, records of wood volume extracted in selective logging activities could be considered.

In using such approaches to estimate historical emissions, it is important to take into account the uncertainties associated with the resulting estimates. One particular consideration is when country-specific data are used to estimate the change in carbon stocks per area and time units (e.g. through the tier 2 approach; see Box, page 17, bottom).

Selection of studies on methods used to measure forest degradation

Country	Remote sensing	Field data collection	Combination of both	Details on methodology	Source
Brazil			X	Relationship between spectral mixing analysis and aboveground biomass measured through forest transects	FAO (2009a)
Democratic Republic of the Congo	X			Field measuring of forest degradation using permanent plots	FAO (2009b)
Mexico		X		c. 25 000 1 ha plots established, of which 23 000 measured; 20 percent re-measured every year Forest disturbance: intact forest, secondary-tree dominated, secondary-shrub dominated	de Jong *et al.* (2010)
Mexico			X	Relationship between MODIS-derived normalized difference vegetation index values and areal biomass volume derived from the national forest inventory	FAO (2009c)
Nepal	X	X	X	Comparison of methodologies used in Nepal to measure degradation	FAO (2009d)



1
Examples of direct methods applied to measure forest degradation

Left: spectral mixing analysis (SMA) and estimations of aboveground biomass (AGB) used to follow the degradation dynamics of Amazonian lowland forests

Right: lacunarity analysis and the index of translational homogeneity (ITH) used to estimate crown widths in Amazonian forest landscapes. Further examples are available at claslite.ciw.edu

Sources: Left: Souza, Roberts and Cochrane, 2005. Right: Malhi and Román-Cuesta, 2008.
Note: GV is green vegetation fraction; NPV is nonphotosynthetic vegetation fraction; NDFI is normalized difference fraction index.

The estimation of country-specific values for a given parameter relies heavily on field sampling, which is frequently done through national forest inventories. However, the estimation of area affected by degradation might be performed more reliably through national wall-to-wall or sample-based remote sensing approaches (Table). Therefore, the use of remote sensing to support field data collection should be promoted, as should the use of field validation as ground truth for remote sensing.

Selected examples

Direct and indirect methods

There are two approaches to estimating forest degradation area through remote sensing, direct and indirect:

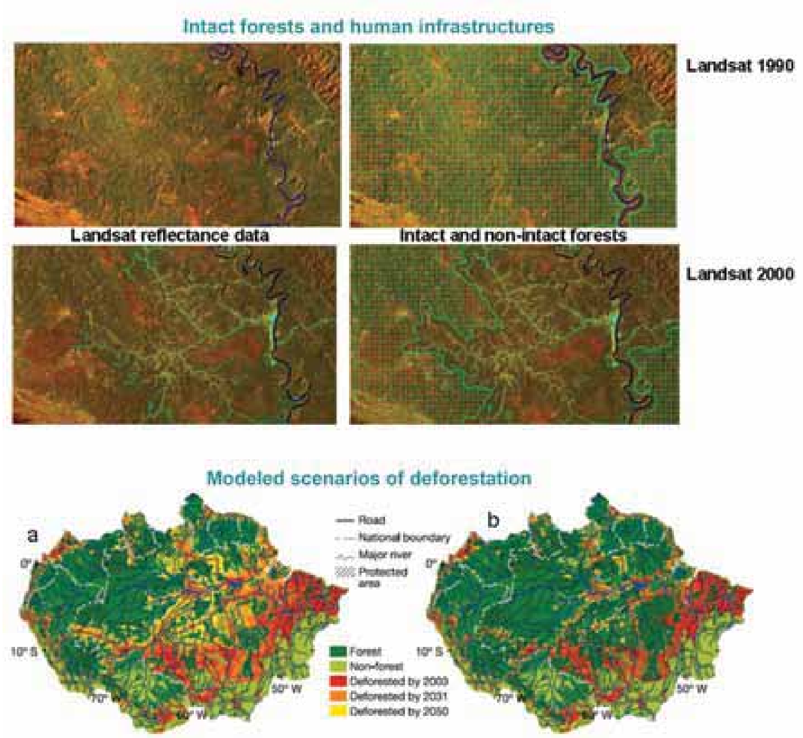
1. Direct detection of degradation processes and related area changes focuses on forest canopy damage. The features enhanced and extracted from the satellite imagery are forest canopy gaps, small clearings and the structural forest changes resulting from disturbance (Asner *et al.*, 2005; Souza, Roberts and Cochrane, 2005; Oliveira *et al.*, 2007).
2. Indirect approaches focus on the spatial distribution and evolution of human infrastructure (e.g. roads and population centres), which are used as proxies for newly degraded areas.

There are limiting factors when mapping forest degradation using direct methods. First, observations must be made frequently, such as annually or biannually, because the spatial signatures of degraded forests change when canopy gaps close. Second, not all degradation processes can be monitored with high certainty using remote sensing data. As a general rule, the more severe the degradation and the canopy damage, the easier it is to map it accurately, directly from satellite observations (Coops, Wulder and White, 2007). However, many local-scale activities that result in degradation, such as collection of fuelwood, affect only the understory and are undetectable through remote sensing analysis. Figure 1 presents two examples of direct methods.

Indirect methods prove useful when the intensity of degradation is low and the area to assess is large, when satellite imagery is not easily accessible or when the direct approach cannot be applied for any other reason. These methods work best to map newly degraded forest areas, but are less effective for repeated degradation.

One effective indirect approach is the "intact forest" approach. In this approach, the presence of human infrastructure is viewed as a proxy for degradation, and its absence is used to identify forest land without anthropogenic disturbance, or intact forest (Mollicone *et al.*, 2007; Potopov *et al.*, 2008). An intact forest is fully stocked, or any forest with tree cover between 10 and 100 percent that is undisturbed, i.e. without timber extraction. A non-intact forest is not fully stocked. Tree cover is higher than 10 percent, so that it qualifies as a forest under the Kyoto Protocol, but it is assumed that the forest has undergone timber exploitation and/or canopy degradation.

Another indirect method, which can be applied to estimate both future and historical forest degradation dynamics, is scenario modelling for forest degradation. Soares-Filho *et al.* (2006) published



Sources: Top: Mollicone *et al*., 2007. Bottom: Soares-Filho *et al*., 2006.

2
Examples of indirect methods applied to measure forest degradation

Top: estimation of intact and non-intact forests based on areas of influence (buffers) from human infrastructures. The example depicts the evolution of a forest landscape where new roads are built, reducing the total area of intact forests (green grid)

Bottom: future deforestation models for the Amazon Basin based on two possible scenarios: (a) business as usual; and (b) effective governance

an example of a "deforestation modelling" approach for the Amazon Basin that produced annual maps of simulated future deforestation under user-defined scenarios. With the right support from field data, a similar modelling approach could be used for (re)constructing historical and future scenarios of forest degradation. Figure 2 offers two examples of indirect methods to evaluate forest degradation.

Aerial photography

Aerial photography has played an important role in forest surveys (Caylor, 2000; Hall, 2003). It was the unique means to monitor canopy condition in detail until the launch, in 1999, of the first satellite to collect publicly available high-resolution imagery – IKONOS. Aerial photographs can provide information on structural changes of forest canopies over time that can be used to assess historical rates of forest degradation. The methods used to detect gaps through multi-temporal digital surface models (DSM) have been applied for long-term studies on canopy dynamics (Nakashizuka, Katsuki and Tanaka, 1995; Tanaka and Nakashizuka, 1997; Itaya, Miura and Yamamoto, 2004; Ticehurst, Phinn and Held, 2007). DSM derived from aerial photographs or light detection and ranging (LIDAR) data can also be used to estimate forest growth.

Collecting data on selective logging

ITTO (2006) estimates that 350 million ha of humid tropical forest are currently involved in timber production. The historical field data needed to assess the carbon impact of selective logging may be available from different sources:

- **data from targeted field surveys, including interviews, and from research and permanent sample plots (often implemented as local studies);**
- **data from commercial forestry, e.g. from logging concessions and harvest estimates, focused on related concession areas; and**
- **proxy data from domestic markets (charcoal, subsistence), such as timber production rates estimated from sawmill, sales and export statistics (Nepstad *et al.*, 1999).**

The use of (direct or indirect) satellite mapping of selective logging for estimating degradation at a national level is currently in an expansive research phase. Research started at the beginning of this century, with results steadily improving over time (Asner *et al.*, 2002; 2004; Souza *et al.*, 2003; Souza, Roberts and Cochrane, 2005). In the past few years, the first large-scale, high-resolution satellite maps of selective logging and degradation have been published for a large portion of the Brazilian Amazon (Asner *et al.*, 2005), throughout Africa (Laporte *et al.*, 2007), for parts of Oceania (Shearman *et al.*, 2008) and for other Amazonian countries (Oliveira *et al.*, 2007). Recently, a first global-scale direct mapping of selective logging in humid tropical forests has shown that logging activities strike deep into forest interiors, often far from deforestation fronts (Asner *et al.*, 2009).

FAO/H. HIRAOKE

Road, stream and forest area, Indonesia. Aerial photographs can provide information on structural changes of forest canopies over time

The quality of estimates of historical rates of forest degradation benefits from further analysis of images, in particular assessing carbon stock changes of individual trees. Tree height and crown areas of individual trees can be estimated from aerial photographs or LIDAR data; allometric equations, which provide for extrapolations on the basis of few measurements, can help in the estimation of their carbon stocks. However, individual allometric equations relating tree height, diameter and biomass are frequently not available for the complex structure and species composition of tropical forests.

Two other methodologies to assess individual crown areas from aerial photographs are the valley-following method (Leckie *et al*., 2003; 2004; Gougeon and Leckie, 2006), which involves following valleys of shade in a grey-level image, and the watershed method (Wang, Gong and Biging, 2004; Hirata, Sakai and Tsuboto, 2009), which views the gradient magnitude of an image as a topographic surface and creates boundaries, or "watershed lines", on the basis of the pixels of the greatest magnitude. The latter method can be useful for the identification of degradation at the canopy level.

Monitoring burning of biomass

Satellite systems have proved useful in detection and monitoring of fires for three primary purposes: identification of active fires, mapping of burned areas, post-fire (fire scars) and characterization of fires (e.g. fire severity, energy released). For the purposes of estimating emissions, the latter two uses are of particular relevance. Two main approaches – indirect and direct – have been identified (GOFC-GOLD, 2010):

1. A "bottom up", or indirect, method (Seiler and Crutzen, 1980):
   L = A × Mb × Cf × Gef,
   where the quantity of emitted gas or particulate L (g) is the product of the area affected by fire A (m^2), the fuel loading per unit area Mb ($g\ m^{-2}$), the combustion factor Cf, which is the proportion of biomass consumed as a result of fire ($g\ g^{-1}$), and the emission factor or emission ratio Gef, which is the amount of gas released for each gaseous species per unit of biomass load consumed by the fire ($g\ g^{-1}$). With this method, there is significant uncertainty associated with the area burned and the combustion factor. In particular, there is uncertainty associated with historical assessment of biomass burning events, where few data sets exist.
2. A direct method that measures the power emitted by actively burning fires and derives total biomass consumption. The radiative component of the energy released by burning vegetation can be remotely sensed at mid-infrared and thermal infrared wavelengths (Ichoku and Kaufman, 2005; Wooster *et al*., 2005; Smith and Wooster, 2005). This instantaneous measure, the fire radiative power expressed in watts (W), has been shown to be related to the rate of consumption of biomass (g/s). Direct methods, however, have yet to transition from the research domain to operational application.

FAO/C. PALMBERG-LERCHE

Satellite data can be analysed to estimate emissions from burning of biomass

CONCLUSIONS

Measuring forest degradation and related forest carbon stock changes is more complicated and more costly than measuring deforestation. Measurements are based on observing changes in the structure of the forest that do not imply a change in land use – changes that are not necessarily easily detectable through remote sensing.

Measuring all carbon stock changes within a country that are caused by forest degradation, and at consistent levels of detail and accuracy, is not likely to be possible in the near future. Focusing efforts to monitor carbon stock changes on the most important categories of carbon pools and on specific areas within the country in which activities that degrade forests are concentrated can help both to make the monitoring more targeted and efficient and to capture the most important components with priority.

Countries need to assess both carbon stock changes (emission factors) and the total area undergoing degradation (activity data) for their monitoring to be in line with the IPCC Good Practice Guidance. Measurements would ideally be taken for different types of activities resulting in carbon stock changes in forests remaining forests, including fire, logging and fuelwood harvesting.

The assessment of changes in carbon stocks requires consistent ground data. The evaluation of the total area undergoing degradation, particularly for developing countries, is more reliably measured through remote sensing for the major degradation processes of selective logging and fire. Both current and historical assessments of forest degradation will need to collect data on emission factors and activity data consistently to estimate emissions from forest degradation. ◆

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Biodiversity, ecosystem thresholds, resilience and forest degradation

I. Thompson

Following certain ecological principles in management of forests can enhance long-term forest resilience and aid adaptation to climate change.

Forests comprise multiple ecosystems associated with variance in edaphic and microclimatic conditions across broad landscapes. The composition and nature of forest ecosystems vary over time, depending on natural disturbances and changes to the climate regime. However, they remain more or less the same within the bounds of natural variation (see Figure), referred to as a stable state. In a stable state, a forest can produce a range of associated goods and services that humans value.

Biodiversity underpins most forest ecosystem goods and services, and many tropical forests, in particular, maintain high levels of biodiversity. Loss of biodiversity may have considerable negative consequences for the productive capacity of forests (e.g. Thompson *et al.*, 2009; Bridgeland *et al.*, 2010; Cardinale *et al.*, 2011) and for the provision of goods and services. Therefore, because forest degradation can be defined as the loss of the ability of a forest to produce the goods and services that are expected (e.g. FAO, 2009), the loss of biodiversity is a key criterion for measuring forest degradation. Conserving biodiversity is a cornerstone of sustainable forest management (e.g. Montreal Process, 2009) and a key to maintaining forest ecosystem functioning.

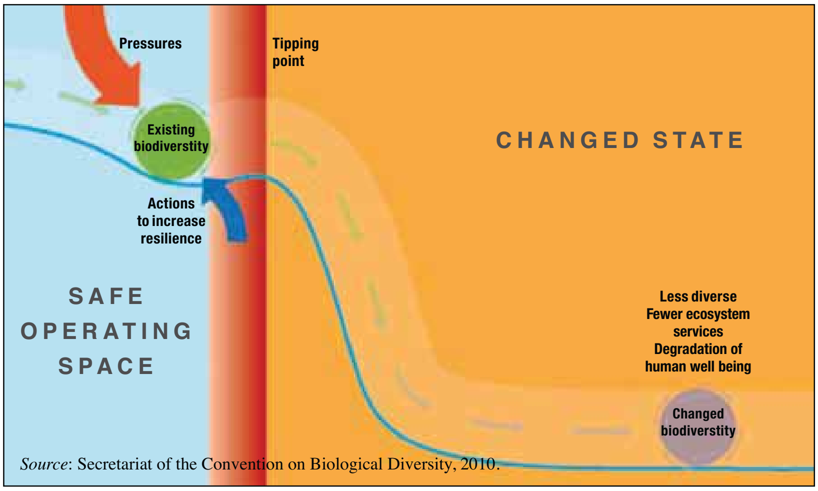
This article explores the ways in which forests maintain their stable states over time and outlines what happens when disturbances overwhelm the natural mechanisms of recovery. It describes how sustainable management of forests, including the conservation of biodiversity, is key to supporting a forest's recovery mechanisms, and presents ecological principles that can be applied to forest management.

RESILIENCE AND RESISTANCE

Definitions

An important characteristic of forests is their *resilience*, which is the capacity to recover following major disturbances

Illustration of tipping points, or thresholds, in ecosystems



Source: Secretariat of the Convention on Biological Diversity, 2010.

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(e.g. Gunderson, 2000). Under most natural disturbance regimes, forests maintain their resilience over time. Forest resilience is an emergent ecosystem property resulting from biodiversity at multiple scales, from genetic to landscape diversity (Thompson *et al*., 2009). To sustain the goods and services that humans derive from forests, forest ecosystems must recover after disturbances and not become degraded over time.

Related to the concept of resilience is *resistance*, which is the capacity of a forest to resist minor disturbances over time, such as the death of a few trees or a chronic level of herbivory by insects. Forests are generally stable and change little as a result of non-catastrophic disturbances. Minor changes are mitigated, such as when canopy gaps created by the death of individual or small groups of trees are quickly filled by new young trees. Forests may also be resistant to certain environmental changes, such as weather patterns over time, owing to redundancy among the functional species (*redundancy* refers to the overlap or duplication in ecological functions performed by a group of species; see Mechanisms) (e.g. Díaz and Cabido, 2001).

Ecosystems may be highly resilient but have low resistance to a given disturbance. For example, many boreal forests are not especially resistant to fire, but they are highly resilient to it and usually recover fully over a number of years. Generally, most natural forests, especially primary old forests, are both resilient and resistant to various kinds of changes. Loss of resilience may be caused by the loss of functional groups (see Mechanisms and Tipping points) resulting from environmental changes such as large-scale climate change, poor forest management or a sufficiently large or continual alteration of natural disturbance regimes (Folke *et al*., 2004).

Mechanisms

There is strong evidence that forest resilience is tied to the biodiversity that normally occurs in the ecosystem (e.g. Folke *et al*., 2004; Thompson *et al*., 2009). In particular, certain species and groups of species perform key functions in forests and so are essential for the forest to maintain all of its functional processes (Díaz and Cabido, 2001). For example, bird predation can maintain low abundances of insects in a forest, reducing the possibility of catastrophic levels of insect herbivory of trees, and thus increasing tree productivity (e.g. Bridgeland *et al*., 2010). Pollinators, including some insects, bats and birds, are also excellent examples of highly functional species in ecosystems, and without them, many plants could not reproduce. Forest resilience depends, in large part, on these key species and the functions that they perform redeveloping as a forest recovers following disturbances, including forest management interventions.

At a genetic level, the capacity for resilience comes from the ability of a species to persist over a range of environmental variability, such as by tolerating a range of temperatures or a certain level of drought. At the species level, there are various behavioural and functional responses that can assist a species to repopulate a disturbed area or respond to environmental changes. Further, ecosystem assembly processes very much reflect the landscape pool of available species (e.g. Tylianakis *et al*., 2008), as well as landscape connectivity. At the landscape scale, heterogeneity among forest patches can provide a measure of redundancy among species and a source for colonizers that, as a forest begins to redevelop or recover after disturbance, should enable communities to converge on the original forest types. Hence, the consideration of resilience necessarily involves thinking from small to large scales.

FAO/A. YANCHUK

Hardwood forest composed primarily of trembling aspen in the boreal forest of northern Canada. Forests may not be particularly resistant to certain disturbances to which they are resilient

Degraded juniper (Juniperus thurifera) *forest in the High Atlas, Morocco*

Loss of resilience and forest degradation

An ecosystem state is defined by the dominant floristic (tree) composition and stand structure expected for a given stand. A change in forest state results from a loss of resilience, with a partial or complete shift to a different ecosystem type from what is expected for that area. Such changes in state result in a reduction in the production of goods and services. Therefore, "change in ecosystem state" can be used as an indicator of degradation. For example, if a forest is expected to be of mixed species but is instead dominated by only a few species, or if it should be a closed canopy forest but is actually open or savannah, then the state has changed. These would be considered negative changes in state, as they degrade the forest, from a biodiversity perspective and from a production perspective, and would generally affect the level of goods and services available.

Often, the degradation of forests results from the use of poor harvesting techniques over a period of time. However, forests can also become degraded for many reasons not involving logging. For example, forests may appear intact but be missing most large animal species as a result of over-hunting (e.g. Redford, 1992). As a result, there could be long-term consequences for forest health because of increased insect herbivory resulting from a lack of control by predators, or reduced seed dispersal, functions that the missing animals might have performed. Another example of degradation might be the successful establishment of an invasive species that out-competed endemic species, thereby constraining the goods available from the ecosystem.

In any of the cases described, if changes are severe enough to cause a change in state, the extent to which the forest has been degraded can be determined through remote sensing. Using satellite data, Souza *et al*. (2003) mapped forest in the Amazon region of Brazil that had been excessively burned or heavily logged and burned, and Strand *et al*. (2007) reported on several cases in which remote sensing was used for monitoring forests affected by invasive tree species and insects from several regions of the world.

TIPPING POINTS

Forests may not always recover after severe and protracted disturbances. Thresholds exist for populations of individual species and for individual processes within ecosystems, and ultimately for the ecosystems themselves. The point at which the ecosystem loses its capacity to recover, or at which its resilience and integrity are lost, is referred to as a *tipping point*, or an *ecological threshold*. If there is too much disturbance, a cascade of effects with marked changes to the forest ecosystem will result, ultimately moving the forest to a new state. For example, severe drought and fire can convert a dry forest type to a savannah or even into grassland. Most often, the new state will provide a lower level of products and services to humans.

Tipping points can be reached rapidly or as a result of chronic change that wears away the capacity of an ecosystem to recover, such as through the gradual attrition of species over time. For example, forest fragmentation is a process that opens up continuous forests through multiple disturbances. A forest can readily tolerate some loss of spatial continuity and still maintain its species and functions, but studies suggest that certain levels of fragmentation are actually tipping points, with a resulting loss of forest biodiversity and function and a reduced capacity to produce goods and services (e.g. Andrén, 1994; Arroyo-Rodríguez *et al*., 2007).

Ecosystems can be used and harvested for services, but the derivation of those services cannot exceed sustainable levels, nor can goods be removed in a manner that destroys ecosystem processes (Figure). Once a tipping point is reached, changes to the ecosystem are large and nonlinear, often unpredictable, and usually dramatic (e.g. Scheffer and Carpenter, 2003). For example, parts of northern Africa underwent a rather spectacular change from dry forest to desert as a result of past climate change (Kröpelin *et al*., 2008). Unfortunately, we often only recognize a tipping point once it has already been

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Eastern Himalaya mountains, India. Biodiversity underpins forest resilience and is a key consideration for forest managers

reached and the generally negative consequences to the ecosystem have become obvious. Therefore, to manage a forest sustainably requires learning to identify possible tipping points in advance.

Climate change considerations

Superimposed on many other human-caused impacts on forest ecosystems is global climate change, which adds uncertainty to the identification of tipping points. Climate has a major influence on rates of respiration, production and other forest processes, acting through temperature, radiative forcing (increase in energy remaining in the atmosphere) and moisture regimes, over medium and long time periods. Climate and weather conditions also directly influence shorter-term processes in forests, such as wildfires, herbivory and species migration.

As the global climate changes, forest ecosystems will change because the physiological tolerances of some species may be exceeded and the rates of many biophysical forest processes will be altered (e.g. Scholze *et al*., 2006). Most studies suggest that many tropical forests may not be resilient to climate change over the long term, if the current and predicted trend continues, with reduced rainfall and increased drought (e.g. Betts, Sanderson and Woodward, 2008; Malhi *et al*., 2008).

Forest ecosystems are composed of distinct assemblages of species. Across regions, the ranges of individual species reflect their physiological and ecological niches, which, in turn, reflect where environmental conditions are advantageous. Species with broad physiological tolerances may be highly resilient to even significant global climate change. Likewise, species with apparently narrow ecological niches might be more resilient than they appear, if changed conditions provide them with an advantage at the expense of competitors. In either of these two potential situations, this capacity would apply to species that have large and variable enough gene pools to adapt and the ability to migrate. However, for many species this is not the case. Where population size and/or genetic diversity have been reduced, or the mobility of species is restricted through habitat loss and fragmentation or is naturally low, successful autonomous adaptation to environmental change becomes less likely. Populations may be doomed to extinction if exposed to a rate of environmental change exceeding the rate at which they can adapt, or the rate at which individuals can disperse (e.g. Schwartz *et al*., 2006).

Most of the emphasis in negotiations on global climate change concerning forests has been on how to manage forests to mitigate climate change. Adaptation to climate change has received less attention. Adaptation of forests to climate change is primarily about maintaining forest resilience even if the ecosystem type may change. If ecosystems do change, there must be an understanding of how to respond through forest management. In most cases, some forms of active management will be necessary to enable forests to adapt to climate change. Maintaining forest resilience can be an important mechanism both to mitigate and to adapt to climate change.

MANAGING FORESTS TO AVOID TIPPING POINTS

Sustainable forest management is ecosystem management of forests that, in large part, has an underlying objective to enable the natural resilience to continue. One of a forest manager's main tasks is to help forests recover after harvesting of timber or other products, through sustaining the properties of the ecosystem over the long term. In recent years this task has become more complicated through the additional stress of climate change on terrestrial ecosystems. While proper, biologically sound sustainable forest management is a major part of maintaining forest resilience, response to climate change requires additional planning and actions. If we understand ecosystems better and can accurately predict at what level of use thresholds might exist, the management of forest goods and services can be more benign.

Maintaining biodiversity

Maintaining biodiversity is a key to maintaining forest resilience and avoiding tipping points. The biological diversity of a forest is linked to and underpins the ecosystem's productivity, resilience, resistance, and its stability over time and space. A reduction in biodiversity in forest systems has clear, often negative, implications for the functioning of the systems and the amounts of goods and services that these systems are able to produce.

Understanding how biodiversity supports local forest resilience and resistance provides important clues to improve forest management. For example, while it is relatively simple to plant trees and produce a short-term wood crop, it is much more difficult to recover a forest ecosystem. The lack of diversity at all levels (gene, species of flora and fauna, and landscape) in simple plantation forests reduces resilience and resistance to disturbances, degrades the provision of services and many goods that the system can provide and renders it vulnerable to catastrophic disturbance. Through the application of ecological forest management principles, forest plantations can provide much more than just a wood crop, and forest ecosystems can be restored at the same time that the productive capacities of the forest for the chosen product are improved (e.g. Parrotta and Knowles, 1999; Brockerhoff *et al*., 2008).

Understanding thresholds

Forest ecosystems change continuously in response to short- and long-term environmental pressures, resulting in inherent variance over time. As a result, measures of function, such as production of given goods, also fluctuate over time. Therefore, thresholds should be perceived as a range in values to accommodate both this fluctuation and the statistical uncertainty associated with insufficient understanding of ecosystem functioning. To avoid forest ecosystem degradation, forest managers require some basic understanding of how local biodiversity is related to productivity and the levels of disturbance that their ecosystems can tolerate.

Suggested actions

As forests change after logging or insect attack, or because of climate change or extreme weather events, managers need to be concerned with bringing the forest back to a condition that will supply the goods and services that were desired from that forest. A key aspect of any plan to maintain a flow of forest goods and services is an understanding of local forest ecology on which to base sustainable forest management, and how the forest may change in response to changes in climate. The following suggested actions were developed from ecological principles that can be employed to maintain and enhance long-term forest resilience, and especially to aid adaptation of forests to climate change:

1. Plan ahead to maintain biodiversity at all forest scales (stand, landscape, region) and of all elements (genes, species, communities) based on an understanding of thresholds and of expected future climate conditions. This means basing actions on ecological principles and expert knowledge to conserve biodiversity during and after forest harvesting.
2. Maintain genetic diversity in forests through management practices that do not select only certain trees for harvesting based on site type, growth rate and superior form.
3. Do not reduce the landscape-scale populations of any tree species to the extent that self-replacement is not possible.
4. Maintain stand and landscape structural complexity using natural forests as models and benchmarks. When managing forests, managers should try to emulate the processes and composition in natural stands, in terms of species composition and stand structure, by using silvicultural methods that relate to the major natural disturbance types.
5. Maintain connectivity across forest landscapes by reducing fragmentation, recovering lost habitats (forest types), and expanding protected area networks. Intact forests are more resilient than fragmented forests to disturbances including climate change.
6. Maintain functional diversity (and species redundancy) and minimize the conversion of diverse natural forests to monotypic or reduced-species plantations.
7. Reduce non-natural competition by controlling invasive species (and entry pathways), and reduce reliance on non-native tree crop species for plantation, afforestation, or reforestation projects.
8. Reduce the possibility of negative outcomes by apportioning some areas of assisted regeneration with trees from provenances and from climates of the same region that approximate expected conditions in the future. For example, in areas projected to become more dry, consider also planting tree species or provenances that may be more drought-resistant than local species and provenances, with special consideration to regional species.
9. Protect isolated or disjunct populations of species, such as populations at the margins of their natural distribution ranges, as possible future source habitats. These populations may represent pre-adapted gene pools for responding to climate change and could form core populations as conditions change.
10. Ensure that there are national and regional networks of comprehensive and representative protected areas that have been established based on scientifically sound principles. Incorporate these networks into national and regional planning for large-scale landscape connectivity.
11. Develop an effectiveness monitoring plan that provides data on natural disturbances, climate conditions and consequences of post-harvest silvicultural and forest management actions. Adapt future planning and implementation practices as necessary.

The capacity to conserve, sustainably use, and restore forests rests on our understanding and interpretation of patterns and processes at several scales, the recognition of thresholds, and the ability to translate knowledge into appropriate forest management actions in an adaptive manner. ◆

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Understanding forest degradation in Nepal

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A rich experience in ground-based inventory provides a solid basis for a multi-method approach to measuring forest degradation.


FAO/P. DURST

Forests play an integral role in the farming system of Nepal

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Forests provide a wide range of regulating, cultural and supporting services for human well-being collectively known as ecosystem services. The sustainability of forest ecosystems requires careful management, efficient utilization and effective protection measures against deforestation and forest degradation. In a mountainous country such as Nepal, forests are important for the protection of water catchments, the conservation of soil and the maintenance of biodiversity, as well as for their contributions to sustainable rural livelihoods and the maintenance of the environment. It is imperative to develop common understanding of the effects of forest degradation among the users of forests, forest managers, policy-makers and politicians so that appropriate public policy to address it can be developed.

This article reviews past forest resources assessments, methodologies and findings on forest degradation in order to identify a way forward in understanding and addressing forest degradation. It proposes that using satellite images in conjunction with field surveys could be a suitable approach for assessing forest degradation in Nepal. It includes discussion on major drivers of degradation and methods of their detection, and proposes using a participatory valuation approach applying the ecosystem services index to quantify forest degradation.

ROLE OF FORESTS IN NEPAL

The widespread forest degradation in developing countries remains poorly understood and quantified (Niles *et al.*, 2001). It has been argued that a single major cause of degradation is that forest resources are grossly underpriced and are, therefore, undervalued by society (Richards, 1994). In countries in which the primary sector – the use of raw materials from the earth – is the mainstay of the national economy, and, in particular, in countries in which the resources are land-based natural resources, such as forests, these resources are both an important source of national revenue and a staple of rural livelihoods.

In Nepal, the role of forests is particularly evident in rural communities that rely on forests for securing assets such as energy, employment, supplementary foods, safe drinking water and good health to sustain and improve their livelihoods. In these communities, forests are also an integral part of the farming system. For example, it has been estimated that, in the high-altitude area of Nepal, to maintain one hectare (ha) of paddy land requires up to 50 ha of forest and grazing land (FAO, 1980), whereas, in the Middle Hills, an area of 3.5 ha of forest is required (Wyatt-Smith, 1982).

National Forest Inventory data have estimated forest and shrub, in combination, to cover 39.6 percent of the country area, and the average annual rate of deforestation to be 1.7 percent (DFRS, 1999; 2008); degradation of forests represents a serious threat to livelihoods. A common understanding of forest degradation must be developed among all stakeholders so that appropriate public policy can be formed and implemented.

FOREST RESOURCES ASSESSMENTS UNDERTAKEN

Historical assessments

Forest degradation has been understood, among the assessments over the past fifty years, as a reduction in capacity to produce timber, or timber volume, tree canopy cover, tree density and regeneration. Assessments have been focused on investigating the association of canopy cover with commercial timber volume. This approach recognizes neither ongoing degradation within dense canopy forests nor degradation of the understory. Further, the trade-off of different kinds of ecosystem services has not been considered.

In order to provide a common way to view results of the studies conducted over the past fifty years, this section provides a brief description of each major assessment of Nepal's forest resources that has been undertaken. Further sections and accompanying tables analyse the data gathered on the basis of thematic elements of sustainable forest management, methodology used for data collection, land cover, and forest degradation as a function of increase in shrub land. The section concludes with a table comparing the different methods used for assessment.

Forest Resources Survey, 1963/64

The Forest Resources Survey Office conducted the first forest inventory during the period 1963–1967. Using aerial photography from 1953–1958 and 1963–1964, the inventory involved visual interpretation of aerial photographs and mapping, combined with field inventory. The land categories included forest, crop, grass, urban, water, badly eroded and barren. The forest land was subdivided into commercial and non-commercial forest (HMG, 1968; 1969; 1973). The inventory focused on assessing extent of forest area and growing stock per ha that was up to 10 cm in top diameter.

Land Resource Mapping Project, 1978/79

The Land Resource Mapping Project (LRMP) was implemented with financial support from the Government of Canada. The objective was to develop appropriate forest land-use maps based on forest types, composition, structure and status of land degradation. The project was implemented during the period 1977 to 1984 (LRMP, 1986a; 1986b). The forest resources assessment was prepared through the combined use of aerial photographs (1977–79) and extensive ground-truth checks, land surveys and topographic maps.

Master Plan for the Forestry Sector, 1986

The Master Plan for the Forestry Sector (MPFS) Project was implemented by the Ministry of Forests and Soil Conservation. The data were based on LRMP information and forest inventory data from the Department of Forest Research and Survey (MPFSP, 1989a; 1989b). The aim was to update resource information with changes that had occurred during the intervening period since LRMP.

National Forest Inventory, 1994

The National Forest Inventory (NFI) was started in the early 1990s and completed in 1998, with a base year of 1994 (DFRS, 1999). The programme was implemented with support from the Government of Finland. The NFI involved satellite image analysis – using Landsat (an Earth-observing satellite programme currently managed jointly by the National Aeronautics and Space Administration of the United States of America and the United States Geological Survey), aerial photographs and field measurements.

Forest cover change analysis of the Terai districts, 1990/91–2000/01

The Terai districts are near or bordering the Siwalik Hills, the lowest outer foothills of the Himalaya. This study,

Forest infested by* Mikania micrantha *("American rope", "Chinese creeper", "mile-a-minute weed"), central Nepal. Forest health and vitality, and biodiversity, have not often been a focus of forest resources assessments

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TABLE 1. National-level forest assessments in Nepal and linkages to sustainable forest management

Study	Thematic element of sustainable forest management
Forest Resources Survey	1, 5
Land Resource Mapping Project	1, 5
Master Plan for the Forestry Sector	1, 5, 7
National Forest Inventory	1, 5
Forest cover change analysis of the Terai districts	1
Economic valuation of ecological goods and services	2, 4, 5, 6, 7
Contribution of forestry sector to gross domestic product in Nepal	2, 4, 5, 6, 7

Note: The thematic elements of sustainable forest management are. 1. Extent of forest resources; 2. Contribution to the carbon cycle, forests and climate change; 3. Forest health and vitality; 4. Biological diversity; 5. Productive functions of forests; 6. Protective functions of forests; and 7. Socio-economic functions of forests (FAO, 2011).

commissioned by the Department of Forests, estimated the extent of forest cover and the annual rate of change of 20 Terai districts. The forest cover change was estimated by analysing satellite images, supported by ground verification (Department of Forests, 2005).

Economic valuation of ecological goods and services, 2005

This study, commissioned by the Ministry of Forests and Soil Conservation, aimed to estimate the value of goods and services of forest ecosystems representing different ecological zones and management regimes (MoFSC, 2005).

Contribution of forestry sector to gross domestic product in Nepal, 2008

This study aimed to estimate the actual contribution of the forestry sector to national gross domestic product (GDP). Both "use" and "non-use" values were taken into consideration in estimating the contribution. The use values included consumptive goods such as timber, fuelwood, grass/fodder/bedding materials, non-timber forest products, sand and boulders. Non-use values included recreation, ecotourism, soil conservation and carbon sequestration (DFRS, 2008).

Linkages with thematic elements of sustainable forest management

FAO (2011) has defined the thematic elements of sustainable forest management to be: extent of forest resources; contribution to the carbon cycle, forests and climate change; forest health and vitality; biological diversity; productive functions of forests; protective functions of forests; and socio-economic functions of forests.

Thematic elements of sustainable forest management covered in each assessment undertaken are described in Table 1. By the standards of the FAO framework, not all elements are covered in the assessments. Resource assessments are focused on the extent of forest area and standing timber volume. None incorporates the elements of carbon stocks, biodiversity, forest health and vitality and protective functions of the forests in the assessment report.

Methodology

There is consensus that measuring forest degradation is more complex and difficult than measuring deforestation (Panta, Kyehyun and Joshi, 2008; Lambin, 1999; Souza *et al*., 2003). Table 2 summarizes the criteria and methods used by each study in defining and assessing forest degradation.

TABLE 2. Review of methodology of forest assessment studies

Study	Degradation criteria	Methods
Forest Resources Survey	• Stocking class (crown cover < 10 percent is a non-forest area) and density class • Scrub and shrub • Encroached forest	• Means estimator • Visual interpretation of aerial photographs • 1:12 000 to 1:60 000 aerial photographs • Dot counting • Area rectification and adjustment • Field inventory, in commercial forests
Land Resource Mapping Project	• Stand stocking • Soil surface erosion	• Visual interpretation of aerial photographs (black and white, scale 1:20 000 to 1:50 000) • Ground-truth checks by helicopter • Land surveys • Topographic maps
Master Plan for the Forestry Sector	• Crown closure • Regeneration	• Desk review • Visual interpretation of aerial photographs and field verification
National Forest Inventory	• Crown cover–stand density	• Satellite images, Geographic Information System (GIS), topographic maps, vector data boundary • Ground-based inventory • Visual interpretation of aerial photographs, scale 1:50 000
Forest cover change analysis of the Terai districts	• Crown cover	• GIS, satellite image analysis and ground verification
Economic valuation of ecological goods and services	• Crown cover • Use value of ecosystem services	• Forest inventory • Questionnaires • Market price/substitutes • Benefits transfer • Total net stock
Contribution of forestry sector to gross domestic product in Nepal	• Crown cover	• Ground-based forest inventory • Questionnaire • Market price • Market price of substitutes • Benefits transfer • Total net stock

The tree canopy stocking level is the main criterion used in assessments. Therefore, it seems accepted among them that forest degradation is the reduction in timber volume, or perhaps changes in species, sizes, structure, or in the capacity of a forest to produce timber.

The stocking level (stems/ha) is linked to forest productivity or growth and yield potential. Proxies used include canopy closure, number of mature trees, number of preferred trees, density, cut stumps, growing stock, regeneration capacity, stand maturity, lopping, species composition, grazing and soil surface erosion. The level of canopy cover at which land is described as "forest area" is 10 percent. Among the studies, there is a lack of clarity among the definitions of forest and shrub land, shrub and scrub land, and forest and degraded forest.

Results: shrub, scrub and degradation

The extent of land falling into the forest and shrub categories, respectively, is shown in Table 3. The Forest Resources Survey recognizes the quality differentiation primarily based on stand size, density classes, crown closure and merchantable volume.

There is neither clear national definition nor clear national assessment of forest degradation. Rather, degradation is characterized by fewer trees, lopped trees, unwanted species, heavy grazing pressure, unpalatable species and bushy species. The study does identify encroached forest as a kind of degraded forest.

Total forest area has not changed very much, through the various studies (Table 3), although forest cover is recorded as having been degrading (Table 4). Taking into account the Department of Forest Research and Survey definition of shrub land (DFRS, 1999), and the data from the studies (Tables 3 and 4), one can assume that shrub lands are those forest areas from which tree stems have been removed but that maintain woody vegetative cover.

TABLE 3. Extent of forest and shrub land cover in Nepal

Study	Forest *'000 ha*	Forest *%*	Shrub *'000 ha*	Shrub *%*	Forest and shrub total *'000 ha*	Forest and shrub total *%*
Forest Resources Survey	6 402	45.5	–	–	6 402	45.5
Land Resource Mapping Project	5 616	38.1	689	4.7	6 285	42.8
Master Plan for the Forestry Sector	5 424	37.4	706	4.8	6 210	42.2
National Forest Inventory	4 268	29	1 560	10.6	5 828	39.6

TABLE 4. Estimation of forest degradation rate in terms of increase in shrub land

Study	Shrub land *'000 ha*	Shrub land *%*	Forest degradation (1978/79 to 1994) *% per year*
Land Resource Mapping Project	689	4.7	5.57
National Forest Inventory	1 560	10.6	

Therefore, shrub land can be viewed as an outcome of forest degradation or as a kind of degraded forest.

A comparison of the NFI study with the LRMP shows that the area classified as shrub land increased by 126 percent between 1978/79 and 1994, at an annual rate of 5.57 percent (Table 4). There is no substantial change in total forest and shrub land area. However, the estimate of degradation does not include degradation that remains within the category of "forest", i.e. above 10 percent crown cover.

The Department of Forests (2005) definition of a degraded forest includes shrub land. However, other elements among the different inventories cannot readily be compared across the inventories because the definitions used and coverage are too varied.

Degradation assessment methods

The different assessment methodologies used in the various surveys can be grouped into aerial photography, field survey, satellite image and ecosystem service valuation. Table 5 compares strengths and weaknesses among these methodologies. This analysis would lead to the conclusion that accuracy of the assessment of forest degradation increases if methods are combined, and, in particular, if remote sensing methodologies are supported by the ground-based information.

DISCUSSION

Definition

For the period of 1978/79 to 1994, the average rate of forest conversion to shrub land (5.57 percent per year) was significantly higher than the rate of deforestation (1.7 percent per year). This statistic would indicate that forest degradation may be a more important issue to consider in efforts to reduce carbon emissions or boost the resilience capacity of forest ecosystems.

But there is no global definition for forest degradation. Classical forestry literature assumes that degrading forests are characterized by such attributes as loss of canopy cover, declining population of tree species, loss of reproductive potential, poor regeneration and loss of capacity to produce various consumptive forest products. More recent literature adds the loss of potential to sequester carbon, conserve biodiversity, harvest water, realize recreational value, and others. These environmental attributes have also been considered as important indicators of forest degradation.

The lack of a uniform definition also applies to the differentiation between shrub land and forest. The NFI defines shrub land as forest area without well-defined stems, whereas the assessment by the Department of Forests defines sparsely distributed trees or forest land with less than 10 percent crown cover – including shrub lands – as degraded forests. Neither assessment offers a clear, simple and consistent definition of degraded forests and shrub lands.

Context of the studies adds yet more variables to the definition of degradation. Forest degradation in one context may not necessarily hold the same meaning in another context. The scale and scope of its measurement may vary along with change in management objectives and expected outcome for the forests.

Drivers

Though no consensus has been reached on what constitutes degradation, policy does need to attempt to address it, and particularly at the source of the degradation. Regulatory and market instruments generally work if appropriate policy, institutions and legal frameworks are in place. But there are limitations to the influence that policy can have. For example, the cause of forest degradation can be loosely divided into the categories of anthropogenic and natural, although there is no clear demarcation between them. But natural causes would be considered exogenous and uncontrollable, and policy instruments would not help to control them.

The sources of degradation are commonly referred to as "drivers" of degradation. Drivers of degradation usually correlated to the anthropogenic category can be viewed as direct or indirect. Direct drivers could include, but are not limited to, over-extraction, intentional fire, free grazing, targeting of high-quality commercial tree species, illegal logging, encroachment, shifting cultivation and forest fragmentation. Indirect drivers might include market failure, unplanned development, policy failure, weak tenure rights and capacity gaps.

The vulnerability of a particular forest to such drivers depends on intensity and magnitude of individual drivers,

TABLE 5. Relevance of different forest degradation assessment methodologies in Nepal[a]

Methodology	Advantages	Disadvantages	Accuracy level	Costs	Implications for Nepal
Aerial photography	• Easily understood by local community • Easy to demonstrate forest degradation such as crown cover change, shifting cultivation, forest fragmentation • Long experience • Infrastructure exits • Requires low input on technology	• Difficulty in mountain area • High costs • Long time requirement • Nearly abandoned and replaced by new technologies • No latest aerial photographs available • Degradation elements such as grazing, fire damage, non-timber forest products (NTFPs) and understory damage, encroachment are not completely detectable	High	High	No recent aerial photographs available – less useful
Field surveys	• Data available for comparison • More accurate • Widely understood • Cheap labour • Considerable experience • Simple technology • Capture all kinds of ecosystem services • Local to national scale possible • Case study and research data available	• More resources • Time-consuming • Difficult in mountain terrain • No recent data available	High (standard error for the top 4 volume ranged from 2.61–6.66 percent)	Medium	Considerable experience exists; labour is cheap; community involvement is available – a good option
Satellite image analysis and GIS	• Global uniformity • Rapidly advancing technology • Easy interpretation in high-resolution images • High-resolution images usable as a map for demonstration • Requires low forest inventory	• Technical capacity and infrastructure demanding • Cloud, shadow and slope in hilly areas • Few control plots for ground verification • Seasonal images availability • Limited data to replace ground inventory • Difficult to assess understory, including NTFPs	Medium to high (67– 98 percent to distinguish in different stocking class)	Low or medium (i.e. free to moderately expensive – Landsat to IKONOS)	Difficult terrains support it; needs capacity development – if combined with field survey, is one of the best options
Ecosystem service valuation	• Recognizes broader value of forest ecosystem	• Technically demanding • Outside forestry discipline	Medium to high	Low to moderate	Community participation, true valuation of forest services

[a] Based on photographs 1:12 000 to 1:60 000 and Landsat TM images.

as well as the scale of their interaction with other factors. Methods to detect degradation may not be inclusive of all factors. Understanding the direct and indirect drivers of degradation assists in estimating the extent of degradation. The key is detecting the degradation through appropriate means of measure (Table 6). Although the drivers of forest degradation are complex, direct drivers are often detectable through observation or image analysis. Indirect drivers are more difficult to understand, and, therefore, to measure discretely.

Forest encroachment and invasion of alien species have emerged as important drivers of forest degradation, and in Nepal, particularly in the Terai plains. Illegal settlement drives forest degradation, and may lead to the permanent conversion of forests to non-forest land uses. Invasion and colonization by alien species can slowly reduce growth and potential for restoration of forests, and infestations can ultimately affect entire forests. Another important driver is forest fire. Additionally, high-altitude forests suffer degradation as a direct result of the stocking of livestock units in quantities up to nine times greater than their carrying capacities (MoEST, 2008; MoFSC, 2002).

Indicators

Past assessments based on spatial and temporal mapping of forest conditions suggest that forest degradation is causing changes in the forest structure, function and other attributes. Sharma and Suoheimo (1995) found that about 45 percent of trees in the Makawanpur and Rautahat districts are affected by rot diseases. Acharya (2000) found that there is degradation of existing forest stock resulting from repeated logging practices, which has resulted in a change of forest type. An illustration is made of conversion of Sal forest (> 60 percent of basal area) to Sal Terai hardwood, and finally to Terai hardwood (Sal basal area < 20 percent).

Crown cover is often taken as a proxy indicator to detect forest degradation. It may, however, not be a sufficient indicator to determine forest degradation. Canopy reduction will reduce carbon sink potential, but it may enhance watershed conservation and biodiversity. The understory may remain intact. Conversely, loss of ground vegetation or understory, which may not be detected, could also be key degradation element, as it affects ecosystem resilience (Table 6). Therefore, crown-cover-based assessment alone is not sufficient to detect the drivers of degradation. Field-survey-based assessment in combination with remote sensing techniques produces more technically robust information that better captures the key degradation elements and their consequences.

Value

Forest degradation can be understood on the basis of the reduction in the capacity of forests to produce all ecosystem services. Therefore, a comprehensive methodology should include understanding and valuing forest degradation on the basis of provision of ecosystem services. An effective approach to measuring degradation would use satellite images combined with field survey. To value services, and therefore degradation, a participatory ecosystem services valuation approach (PESVA) would be recommended. Such an approach captures a "degradation factor" by valuing ecosystem services comprehensively (Table 7).

The PESVA is based on the concept of the forest ecosystem services index (ESI). ESI is a summary index of ecosystem services of a forest. It measures the average performances of use values of the forest. The ESI is estimated against ecosystem services as defined by

TABLE 6. Anthropogenic drivers of degradation and their detection potentiality

Drivers of degradation	Level of significance	Key degradation element	Detectability (1 = low; 3 = high)		
			Field survey	Aerial photographs	Images
Overexploitation of wood products	High	Crown cover, biomass, understory	3	2	1
Overexploitation of non-wood products	High	Green biomass, crown density, species diversity, understory	3	1	1
Forest encroachment (illegal settlement or occupancy)	High	Crown cover, habitat, biomass, understory	3	2	2
Overgrazing	High	Surface soil, natural regeneration, habitat	3	1	1
Unplanned development: road, hydropower, etc.	High	Crown cover, habitat, commercial species, biomass, fragmentation	3	3	3
Wildfire	Medium	Understory, biomass, soil, biodiversity	2	1	2
Invasion and colonization of alien species	Medium	Biomass, understory, habitat, biodiversity	3	1	1
Pests and diseases	Low	Biomass	3	1	1

TABLE 7. Survey and measurement methods for selected variables

Key parameters observed	Indicators of degradation	Data source	Detection or measurement techniques
Biological attributes			
Canopy cover	Decreasing	NFI/DFSP/ CFOP	Image analysis/field inventory for data validation
Growing stock level	Declining	NFI/DFSP/ CFOP	Image analysis/field inventory for data validation
Forest structure	Poor regeneration and missing young stands	NFI/DFSP/ CFOP/FGD	Image analysis/field inventory for data validation
Species composition	Abundance of inferior tree species	NFI/DFSP/ CFOP/FGD	Forest inventory Field observation
Invasion and alien species	Invasion by exotic species	CFOP/FGD	Field observation
Environmental attributes			
Watershed conservation	Increasing surface erosion	NFI/DFSP/ CFOP	Participatory observation
Carbon sequestration	Increased forest fire and reduced carbon stocks	FRA/DFSP/ CFOP	Forest carbon inventory
Biodiversity	Loss of species abundance	FRA/DFSP/ CFOP	Field inventory
Water harvesting	Polluted water	FGD	Participatory observation Field survey
Resilience capacity	Poor forest restoration	FGD	Participatory observation
Wildlife conservation	Disturbed habitat	FGD/ observation	Participatory observation Field survey

Note: NFI is National Forest Inventory; DFSP is District Forestry Sector Plan, an integrated approach to forest resource management planning at the district level; CFOP is Community Forest Operational Plan, a management plan for community forests for a given period of time; FGD is focus group discussion; and FRA is Global Forest Resources Assessment.

the Millennium Ecosystem Assessment (2005). Periodic monitoring and comparison of indices with a base-line index will provide information about the extent of forest degradation or enhancement.

The PESVA requires expert inputs to develop ranking matrices and procedures for acquisition of information, to set default values and to interpret results. However, if implemented properly, it should be simple and manageable for community institutions so that local people can actively participate in the process of detection and measurement of forest degradation.

CONCLUSIONS

In Nepal, forest degradation has had adverse, and overlapping, ecological, environmental and social implications. Ecological outcomes have included a reduction in canopy cover, a decline in forest quality, structure and composition, a decrease in the productive capacity of forests, an increase in invasive species and a loss of biodiversity. The environment has undergone soil erosion, fragmentation of habitats and shifts in wildlife movement resulting from new obstacles. The combination of these factors has had broad and damaging implications on society and livelihoods, as the number of natural disasters has increased, and the production of forest products and services has declined.

Nepal has substantial experience in ground-based forest inventory, and the inventories conducted over the past half century have established considerable data sources on forest stock. The methods used have been aerial photographs, field inventories and satellite image analysis. The further development of methodologies to assess forest degradation will largely depend on establishing a consensus definition of degradation that includes full ranges of biophysical and socio-economic conditions and, in particular, forest ecosystem services. In Nepal, for example, a clear distinction between shrub land and degraded forest, and methods to assess shrub lands, are required. In addition, a robust methodology that can capture a range of drivers causing forest degradation is necessary.

The methodologies currently in use can be improved in two ways. First, measurement should use satellite images supported by ground-based inventory, to combine the strengths of both methods. Second, the PESVA should be adopted to provide information about the extent of forest degradation or enhancement.

There is a need for capacity and data-management development at national and local levels. Pilot studies should be conducted to test methodology and gather information on forest degradation. A better understanding of forest degradation needs commitments at a political level, and national strategy that understands both the drivers of degradation and methods to detect them, and the resources required. Then, the need to establish an effective degradation monitoring system can be met. ◆

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NDVI as indicator of degradation

C.L. Meneses-Tovar

A method to interpret remote sensing images is applied to observe change in forest health over time.

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Forest degradation has become a serious problem, especially in developing countries. In 2000, the total area of degraded forest in 77 countries was estimated at 800 million hectares (ha), 500 million ha of which had changed from primary to secondary vegetation (ITTO, 2002). Among other impacts, the process of forest degradation represents a significant proportion of greenhouse gas emissions. There is an urgent need to measure and analyse it, in order to design action to reverse the process.

This article describes how one method of analysing remote sensing data in conjunction with field data to monitor forest degradation was put into practice. It presents a study carried out to identify relationships between indicators of forest functions and the normalized difference vegetation index (NDVI), which is estimated through analysis of satellite images to give an indication of "greenness". The premise is that NDVI is an indicator of vegetation health, because degradation of ecosystem vegetation, or a decrease in green, would be reflected in a decrease in NDVI value. Therefore, if a relationship between the quantity of an indicator – aerial biomass – in various forest ecosystems and the NDVI can be identified, processes of degradation can be monitored.

Natural vegetation, Mexico

FAO/C. PALMBERG-LERCHE

MEASURING CHANGE

Remote sensing and phenology

One of the most important applications of remote sensing is the monitoring of processes occurring on Earth.

Images can be used for the analysis of short-term processes, for example monitoring the growth cycle of crops to evaluate the yields of one harvest. Satellite images taken at various stages in the cropping cycle for a single year are evaluated, including: soil preparation, sowing, establishment of seedlings, active growth, flowering, fruiting and translocation of nutrients or ripening of fruit and harvesting.

They can also be for the analysis of medium- or long-term processes. Analyses of forest degradation and change in land use are major examples of applications of this approach. Images from different years can be compared. These images must be captured during the same time of year so as to minimize the expression of variations in such factors as light quality, the geometry of the observation and differences in the behaviour of a community over the course of the year, in the case of plant ecosystems (Singh, 1986; Mouat *et al.*, cited by Chuvieco, 1998).

Both are *phenological* approaches. Phenology involves studying the timing of life cycle events of plants and animals, and in particular, in relation to changes in season and climate. In the case of annual crops, observing change in images is relatively easy. Changes in reflectance of light over the course of crop growth are evident and occur over short periods of time. In the case of forest ecosystems, the natural processes, and the approaches to observing them, are protracted. Behaviour in an individual takes place over a longer period (5 to 25 years), which also applies to forest plantations that are "pure ecosystems" (i.e. same-age stands). Over this period of time, the phases of planting, establishment of seedlings and active growth up to the time of commercial maturity can be distinguished, encompassing the more complex dynamics of flowering, fruiting, change of leaves and branches, and thickening of the trunk, in a constant process of change in the above-ground living matter, or aerial biomass.

Observation of phenological processes is more complicated in a primary or natural stand containing individuals of different ages and species, in which each exemplar has its own rhythm or phenological behaviour: flowering, fruiting, loss of leaves and regrowth, and survival strategy in terms of competition for light, nutrients and water.

NDVI and phenology

There are various methodologies for studying seasonal changes in vegetation through satellite images, one method of which is to apply vegetation indices relating to the quantity of greenness (Chuvieco, 1998). The NDVI is a measurement of the balance between energy received and energy emitted by objects on Earth. When applied to plant communities, this index establishes a value for how green the area is, that is, the quantity of vegetation present in a given area and its state of health or vigour of growth. The NDVI is a dimensionless index, so its values range from –1 to +1.

In a practical sense, the values that are below 0.1 correspond to bodies of water and bare ground, while higher values are indicators of high photosynthetic activity linked to scrub land, temperate forest, rain forest and agricultural activity.

THE STUDY

Background, data sets

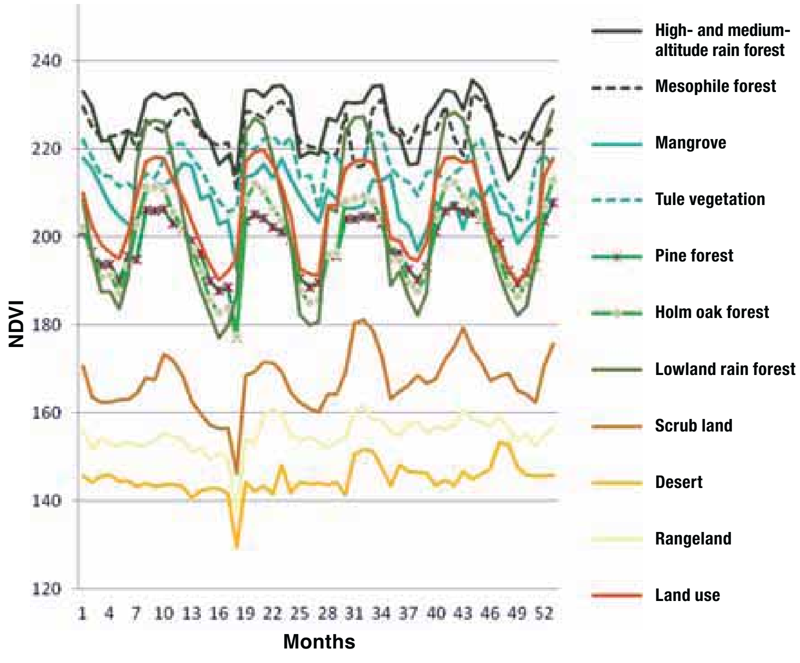
Drawing on remote sensing imagery and field surveys, the study sought to establish a relationship between NDVI and aerial biomass. First, images had to be collected. Then NDVI values had to be established through analysis of the imagery. Then, these values had to be applied to different vegetation communities both to validate the method and to establish a baseline for observations. They were then observed over time. Finally, NDVI could be correlated to aerial biomass, an indicator of forest health, through field-survey data, in order to establish the validity of the method and to make it applicable to monitoring forest use.

The study focused on Mexico, which has a land area of almost two million km^2. Given its particular location and relief, the country features a diversity of

TABLE 1. Classification of field observations between 2004 and 2007 used for NDVI analysis

Vegetation community	National Statistics and Geography Institute key	Number of sites
Holm oak forest	Holm oak and holm oak-pine	20 139
Pine forest	Pine, fir, juniper, cypress, juniper and pine-holm oak with predominance of pine	6 276
Desert and dune	Microphyllous desert scrub land	199
Mangrove	*Rhizophora* spp.	980
Scrub land	Various types of scrub land	10 945
Mesophile forest	Very moist montane forest	1 526
Rangeland	Natural rangeland and through presence of sodium and chalk	235
High- and medium-altitude rain forest	High- and medium-altitude rain forest (deciduous or evergreen)	16 976
Lowland rain forest	Lowland rain forest (deciduous or evergreen)	6 470
Tule vegetation	*Thyphus* spp.	190
Without plant cover	Without plant cover	1 229

1
Average NDVI, by month, for established classes of vegetation



Note: NDVI is translated and mathematically scaled to a range of 0 to 256.

ecosystems and life zones, ranging from tropical to temperate. Data for the study included satellite images and information obtained from inventories. The satellite images were obtained from MODIS, the Moderate Resolution Imaging Spectroradiometer, launched by the United States National Aeronautics and Space Administration on board two satellites, which is designed to provide measurements in large-scale global dynamics.

The National Forest and Soil Inventory (INFyS) of Mexico, maintained by the National Forest Commission (CONAFOR), provided basic information and ground truth for the estimates. INFyS data were collected during the period 2004–2007 and updated in 2008–2009.

Establishing NDVI values

In order to estimate the phenological behaviour of wooded ecosystems, composites of images from MODIS for cloudless months, with a spatial resolution of 500 m, were analysed. These images were processed by the Maryland Institute for Advanced Computer Studies (United States of America). Fifty-three consecutive composite images of 30 days from 16 November 2000 to 13 August 2005 were used. NDVI values were calculated for the images.

Then the NDVI values had to be correlated to vegetation types present at the various sites. Field data were obtained from INFyS in a systematic stratified sampling covering all of the country's ecosystems. The vegetation community type assigned to an area indicated the vegetation most frequently observed in the field for each of the sampled sites. Labels used for this exercise were based on the classification system of the Land Use and Vegetation Map of the National Statistics and Geography Institute used in its Series II (INEGI, 2000). A total of 65 165 sites were observed and classified as seen in Table 1.

The sampled sites were superimposed on the series of 53 images that had been developed from the monthly composites of MODIS images. An average NDVI value was calculated for each type of plant community for each month in order to assess its behaviour over the course of the year.

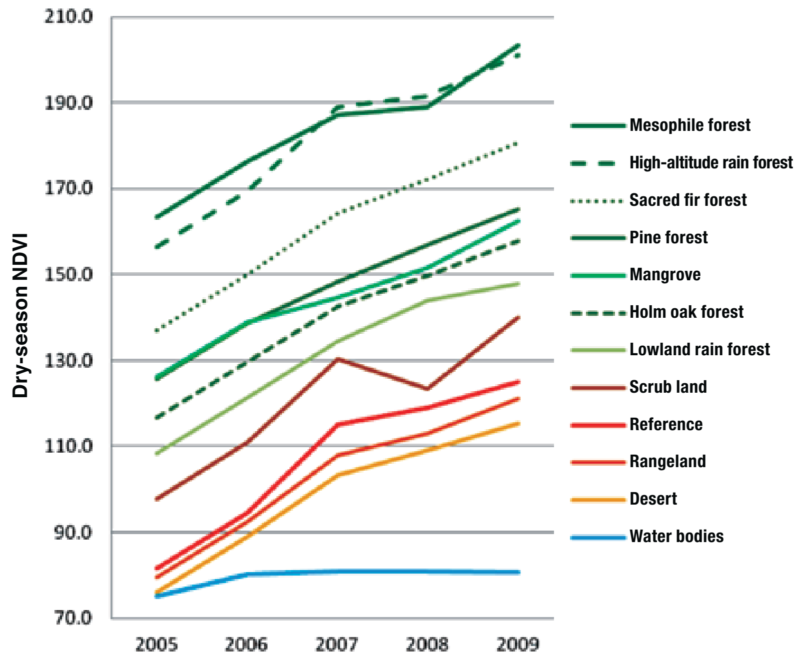
Observations

The highest NDVI values correspond to high- and medium-altitude rain forests and mesophile montane forests, which remained above the reference threshold for the quantity of greenness throughout the year (Figure 1). This threshold has a value of approximately 190 (see note, Figure 1, regarding NDVI values) and can be linked to the evergreen habit of the ecosystem or can be used to separate forests from other wooded land.

A sinusoidal trend or annual cyclical behaviour is a classic response to a regular cycle of rainfall and storage of water in the ground. The minimum NDVI values occur between February and April each year, corresponding to the driest period. The maximum NDVI values occur during July and August, which are the months with the highest rainfall. There is further variation, as the dates of the rainy season vary depending on latitude. Mexico stretches over a considerable distance from north to south.

The extreme oscillations show that lowland rain forests have the greatest range in their cycle. As with holm oak forests and pine forests, they have values below the reference threshold value of 190 between February and May in the years analysed. Dips in the NDVI value occur because the level of greenness reflected in these periods is low, as a result of falling leaves or change in their colour.

Readers should be aware that the value shown is the combined response of the whole ecosystem (soil and grassy, shrub and tree layers). Therefore, it is also possible that, during this period, part of the



Note: NDVI is translated and mathematically scaled to a range of 0 to 256.

2
Annual behaviour of the dry-season NDVI for various types of ecosystem

grassy layer dries out completely in these forests because of seasonal water stress.

The vegetation communities with the lowest NDVI values are deserts, where leaves are very sparse, followed by rangeland and scrub land. These communities show no sinusoidal trend; rather, their response is that of a region that has irregular rainfall. Analysis of degradation processes in these communities is made more complicated by such fluctuation.

Mangrove and tule ecosystems present the most complex behaviour, in terms of NDVI values. While the values are always above the reference value, they follow no regular pattern, with no clearly defined peaks. Their value is very much affected by fluctuations in water level.

The sample included a series of sites classified as "land use", a term that, for the most part, corresponds to the presence of agriculture. These areas show a sinusoidal behaviour that is slightly narrower than that of lowland rain forest. Average NDVI values of these areas never fall below the reference threshold. These consistently "green" values are difficult to explain, if mechanized annual crops are involved; one would have expected the values during the period of preparation of the soil to be close to those of bare ground. The phenomenon can perhaps be attributed to the fact that crops are being grown without any type of mechanization.

The exercise reflects the fact that, when carrying out a multitemporal analysis of processes, an important consideration is the dates on which the satellite images are taken. It is vital to compare images corresponding to the same dates, as there are differences in the vigour of growth during the different months of the year, and pronounced differences between the dry and rainy seasons – even in evergreen stands.

This type of analysis can show the natural changes to vegetation over a period of time. For it to be applied to such purposes as monitoring forest degradation, it is necessary to separate the fluctuations in greenness resulting from the natural oscillation of vegetation from those caused by other processes.

NDVI from year to year

The next step was to establish annual behaviour of NDVI for the different vegetation areas. The dry season was selected because there is less cloud cover affecting the MODIS images and because arable land is generally bare, and is, therefore, distinguishable, during this period.

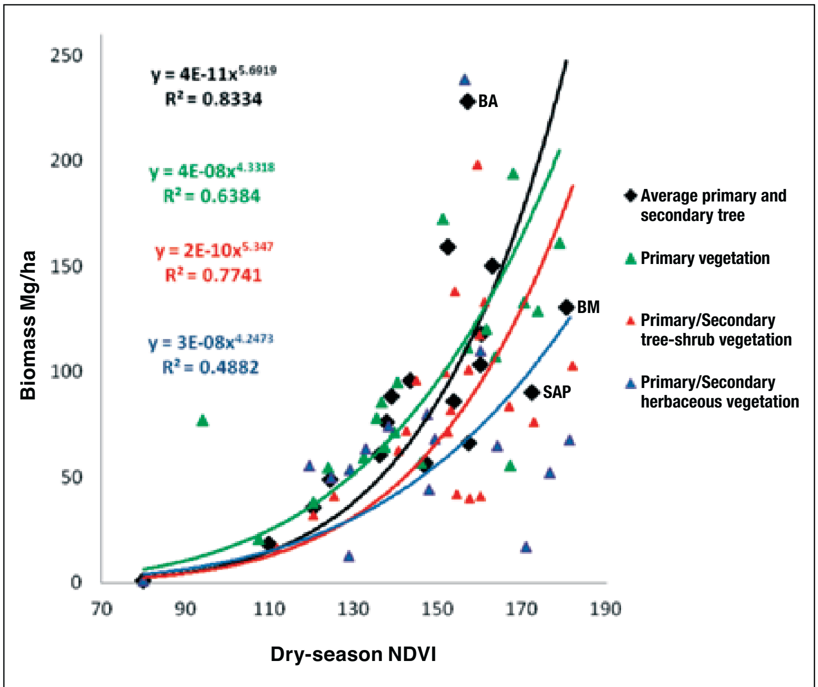
A composite of MODIS images was prepared with a spatial resolution of 250 m, using images obtained between 15 February and 15 April each year, the dry season. Average NDVI values were calculated for the period. The points observed in the previous round were superimposed, and the average behaviour was calculated for each type of plant community (Figure 2).

A definite pattern is seen relating to the biomass contents of the various ecosystems. Among the various vegetation types, an almost constant increase in NDVI is seen over the period. Exceptions are seen in mesophile montane forest, high- and medium-altitude rain forest and scrub land, which show almost no fluctuation between the 2007 and 2008 seasons.

Linkages to aerial biomass

Aerial biomass was chosen as the variable indicator of forest function to compare with the behaviour of the NDVI. A forest can experience a change in cover without necessarily a loss from its original condition, but a negative change to a structure that can diminish its capacity to provide services and products can be considered a form of degradation.

Twenty-five thousand points were measured in the field for the inventory. Each measurement point, or plot,



Note: NDVI is translated and mathematically scaled to a range of 0 to 256.

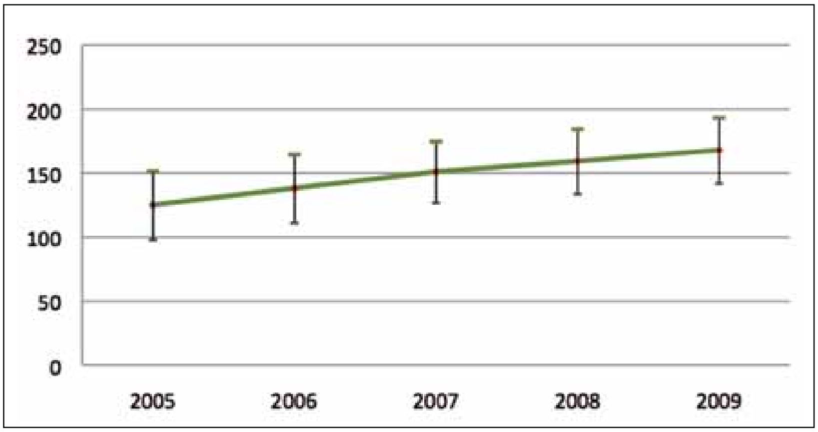
3
Comparison between dry-season NDVI and the quantity of aerial biomass per type of plant community

comprised four sites, or subplots. In each site, measurements of variables were taken for all trees with a diameter at breast height (DBH) of more than 7.5 cm. These variables included number of trees, number of species, number of live trees, number of stumps, total tree height, commercial height, clean height, DBH, diameter of the crown and basal areas, together with 21 other quantitative variables and some 45 qualitative variables connected to, for example, regrowth, impact condition, state of the topsoil and humus, and use of the resource (CONAFOR, 2011).

The quantity of aerial biomass in tonnes per ha was estimated for 16 842 plots measured in the field for INFyS (ECOSUR, 2009). Biomass equations were established for each ecosystem based on a review of the literature. Most equations were generated from materials that reflect a commercial perspective, and pertain to conifer and broadleaved ecosystems in temperate regions.

Allometric equations were developed for 120 of the almost 3 000 species listed in INFyS. Most of the models use DBH and height as independent variables. Information from the measurement of regrowth was not used to estimate biomass, arid-zone succulent species were omitted, and no equations estimating biomass or timber volume were drawn up for certain communities (thalias, savannahs, tule, palms, mangroves and some rain forests). Of the 1 305 307 trees observed, 1 230 127 individuals were taken into consideration (see Figure 4; ECOSUR, 2009). The 16 842 plots were superimposed on the NDVI images and were classified according to both type of plant community and condition (primary, primary with secondary tree vegetation and primary with secondary shrub vegetation) (Figure 3).

The relationship between aerial biomass and NDVI shows an exponential behaviour in which the origin is the NDVI value of bodies of water, for which an aerial biomass of 0 is assumed. The highest biomass values correspond to fir forest (BA), while the highest NDVI values correspond to mesophile montane forest (BM), followed by evergreen high-altitude rain forest (SAP). In estimating the aerial biomass of the latter two communities, general equations suggested by the Intergovernmental Panel on Climate Change Good Practice Guidance for Land Use, Land-Use Change and Forestry are used (IPCC, 2003). The overall relationship shows a correlation coefficient (R^2) of 0.8334.



4
General behaviour of NDVI, 2005–2009, across sample re-measured in 2009

It should be noted that the shapes that compose rain forests and mesophile montane forests are very different from those of conifers, and they are, therefore, underestimated in the model. On the other hand, there is also "overestimation", in that only trees with a DBH of more than 7.5 cm are considered in estimating biomass, while the satellite-measured NDVI encompasses the whole response of the ecosystem (tree, shrub and grassy layers).

Figure 3 shows a decline in the relationship between aerial biomass and NDVI, depending on condition or successive state. This trend indicates that in a given community there is more aerial biomass for primary ecosystems than for those affected by disturbance.

FOLLOW-UP

An initiative has been launched to re-measure the sites visited in the first round. Sites were revisited in 2009 and will be visited again in 2012. Thus, information is, and will continue to be, available on growth and changes in forest functions in 20 percent of the 25 000 established plots. Information on soil, fires and health can be estimated (INFyS database query, 2010).

In the first re-measurement, NDVI values of the 2009 INFyS field measurements were taken, and analysis was conducted for both points that had suffered some kind of disturbance and points that had not.

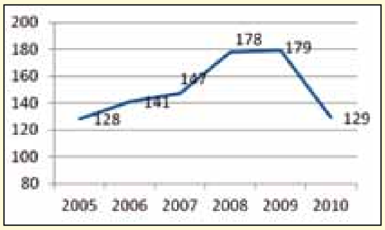
Of the total of 3 533 plots measured in 2009, 3 486 indicated an increase in NDVI over the initial measurement. The general behaviour of the NDVI is shown in Figure 4. Behaviour among specific classes of vegetation was also analysed.

The box, and its illustrative table, figure and photographs, presents the data of one point from the group – Plot 56890 – Campeche. This point was among those taken at random in order to demonstrate both the condition at the first and second field measurements and how the NDVI can vary. Further discussion (Figure 5) presents results for one grouping – land without plant cover. It should be taken into account that the field points measured evaluate only 1 600 m^2 and are representative of 1 ha, and that the whole area of the pixels is 6.25 ha.

Follow-up: Plot 56890 – Campeche

Plot 56890 presented an interesting case. Dry-season NDVI observed up to 15 April 2009 showed that the plot had recently been burned. NDVI behaviour for some years could be identified (Figure), but further analysis will have to be carried out.

In August 2005, the plot showed sub-evergreen medium-altitude rain forest, and 192 trees measured (Photo, left). The April 2009 observation shows no plant cover and 0 individuals (Photo, right; Table).



Behaviour of NDVI, 2005–2010, Plot 56890

Survey results, Plot 56890 – Campeche

Visit	No. trees	DBH *cm*	Crown diameter *m*	Cover *%*	Total height *m*	Stumps
09/08/2005	192	11.82	2.51	60.1	8.98	0
17/04/2009	0	0	0	0	0	0

5
Plots reported as "without vegetation cover" in 2009 survey, by case

Of the 3 533 plots measured in 2009, a reduction in the NDVI was detected in 47.

Plots reported as being without plant cover, from the 2009 sample, numbered 258 (Figure 5).

Among this group, four classes of case were identified:

- 129 plots were not visited in the first round because they were interpreted as "land use" and were validated by interpreting images; no reduction in NDVI was detected for any of these cases (green points, on map);
- 53 are plots that corresponded to "without plant cover" in 2004–2007 and were still without it in 2009; no reduction in NDVI was detected for any of these cases (yellow points, on map);
- 61 were incorrectly labelled in 2004–2007. Forest was indicated, but a revision of photographs and data indicated that the plots were, in fact, "without vegetation cover"; no reduction in NDVI was detected for any of these cases (red points, on map);
- For 14 plots, the 2004–2007 observation showed plant cover corresponding to some type of forest, whereas the 2009 observation showed them as being without plant cover (blue points, on map).

CONCLUSIONS

There are limitations to use of the NDVI to measure forest degradation, and areas for improvement. As phenology plays an important role in the analysis of change processes, the dates of the MODIS images used to assess those processes must be selected carefully. When processing the images, care must be taken to eliminate clouds, shadows of clouds, shadows created by the topography and saturation values in the numbers generated by the geometry of the satellite observation or by the presence of water on the leaves of trees.

Regression models can be improved. One way is by comparing two temporal measurements of a single point of INFyS. Another is by taking into account such factors as regrowth. Other measured variables are also contained in INFyS, such as standing dead trees and stumps, that could also enable a better understanding of the dynamics of the forest at each point observed, as well as the age of the sample population, in coniferous communities. Most allometric equations for estimating aerial biomass are based only on the height of the individual and the DBH; aspects such as the canopy, the diameter of branches and the basal area are not taken into account. As estimates of biomass in mesophile montane forest and rain forest ecosystems are refined, the method will prove more representative of change.

Attention should be paid to such other aspects as climate anomalies that have a major impact on the vigour of growth. For example, "wet" years associated with the la Niña/el Niño phenomena will lead to an increase in the NDVI, while "dry" years generate very low values in the change indicator.

Despite limitations pertaining to the imaging, including the resolution of the images, and limitations in the estimation of aerial biomass, the regression model of 0.83 is very good. Images generated by the MODIS sensor are suitable for analysis of changes resulting from degradation, when the impact has been sufficiently great to generate a change in radiometry, and, thus, in the NDVI. The NDVI has an anticipated behaviour and can be used as an indicator. ◆

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Mapping opportunities for forest landscape restoration

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More than two billion hectares of the world's deforested and degraded landscapes offer potential for restoration – a vast opportunity to reduce poverty, improve food security, reduce climate change and protect the environment.

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The typical response to the loss of forest cover has been to plant trees, usually, but not always, on an industrial scale, and with a limited mix of species. Indeed, planted forests now make up 7 percent of the world's forest area and contribute over 40 percent of the global industrial wood and fibre supply (FAO, 2010).

However, many planted forests have limitations in that they cannot supply the broad range of forest goods and services that society often requires. Therefore, about ten years ago, building on decades of field experience and observation, the concept of *forest landscape restoration* was introduced. Forest landscape restoration is an integrating framework that can, and should, be applied across a range of land uses to ensure that key ecosystem functions and societal requirements are maintained and strengthened.

Importantly, forest landscape restoration does not seek a return to past visions of land use. Rather, it is designed to ensure that present and future generations have key ecosystem goods and services at hand and deal effectively with the uncertainties of climatic, economic and social change.

Forest landscape restoration restores functionality and productivity to degraded lands and forests. Trees in agricultural landscapes can boost food production and resilience. Restored lands can supply clean water, reduce erosion and provide wildlife habitat. Forests and trees mitigate climate change by sequestering carbon.

Source: Minnemeyer *et al*., 2011. Visit www.wri.org/restoringforests to view a large-size version of the map.

Lands with opportunities for restoration of forests and landscapes. Forests without restoration needs and croplands on former forest lands are not shown

Opportunities for restoration

Experience shows that restoration is possible. Forests have returned to vast, formerly deforested areas in North America and Europe. Costa Rica and the Republic of Korea, among others, have embarked on successful forest restoration strategies. Restoration efforts in China, the Niger and the United Republic of Tanzania are slowing desertification and restoring woodlands with associated dramatic improvements in livelihoods and ecological health. Agroforestry systems are rapidly expanding in many parts of the world, enhancing the productivity of crop and livestock production.

Most countries that have suffered forest loss and degradation have opportunities for restoration. Yet these opportunities are often overlooked. The Global Partnership on Forest Landscape Restoration therefore asked a consortium of organizations led by the World Resources Institute to map the global opportunities for restoration (Figure; Minnemeyer *et al.*, 2011).

Method

The *potential* extent of forests and woodlands, rather than today's extent, was used as the point of departure. Apart from the obvious reason that forests can grow in these areas, potential forest extent is also a useful benchmark for assessing the historical change in forest cover.

Three categories of forests were distinguished: closed forests (canopy cover greater than 45 percent), open forests (canopy cover between 25 and 45 percent) and woodlands (canopy cover between 10 and 25 percent). Land with less tree cover was considered to be either naturally non-forested or converted to some other land use from any of the forest categories above.

Only pre-existing information was used. Definitions and data are not particular to individual countries.

We first mapped where forests and woodlands could potentially grow, if soils and climate were the only limiting conditions, i.e. where forests would grow if there were no human influence. Although trees play an important role there, dry areas such as the Sahel were not included, because of their very low potential forest density.

Next, we mapped the current extent of forests and woodlands. Forest maps were derived from global 250 m resolution satellite imagery.

We then identified restoration opportunities by comparing the maps of potential and current forest extent in light of information about current land use. Croplands on former forest land, intact forest landscapes and managed natural forests and woodlands were mapped as having no potential for restoration (although this is not always true).

Then, we considered constraints on restoration by mapping human pressure as a combination of population density and land use. Restoration opportunities in remote, unpopulated areas were also identified.

Finally, deforested and degraded forest lands were divided into four categories, resulting in a map of restoration opportunity areas and other former forest lands:

- **Wide-scale restoration** – Population density of fewer than 10 people per km^2 and potential to support closed forest.
- **Mosaic restoration** – Moderate human pressure (between 10 and 100 people per km^2). Restoration to a mix of people, trees and crops (e.g. into agroforestry parklands, small, frequent patches of woodlands, improved farm fallow and secondary forests and linear arrangements such as hedgerow, contour planting and along water courses).
- **Remote restoration opportunities** – Very low human pressure (density of less than 1 person per km^2 within a 500 km radius). Restoration may not be feasible here.
- **Agricultural and urban lands** – Converted former forest lands with intensive human pressure (density of more than 100 people per km^2), croplands and urban areas

Results

More than two billion hectares (ha) worldwide provide opportunities for restoration. Most of these lands are in tropical and temperate areas. One and a half billion ha are best suited for mosaic-type restoration, and another half a billion for wide-scale forest restoration of closed forests. However, these results must be interpreted with caution. The map is based on significant simplifications, and the underlying information is both coarse and incomplete, and sometimes also of low accuracy. Good information was available on land cover, land use, population density and other factors. Yet many important factors, such as tenure and land-use dynamics, could not be considered, for lack of data.

The map shows landscapes where restoration opportunities are more likely to be found, not the location of individual restoration sites. Many features of the landscape are not visible at the level of spatial resolution of the map (1 x 1 km), and local context could not be considered. No ground validation was conducted.

The map shows the location of land with characteristics that indicate restoration opportunities, but it does not prescribe any particular type of restoration intervention. It is intended to inform the policy-making process at the global level and should be complemented by further investigation at regional and national scales, where more detailed information is needed and available.

Conclusions

Most countries have suffered forest loss or degradation. Opportunities for restoration exist on all continents and are huge in terms of area, although the estimate of their extent is rough.

Mitigation of climate change is a major benefit of restoration, making it an important complement to avoiding additional deforestation and degradation, as well as an opportunity in which many countries can engage, including countries with little or no deforestation left to avoid.

Most areas that present restoration opportunities are located far from ongoing deforestation. The world does not need to wait for deforestation and degradation to cease before it embarks on the path of restoration.

The Bonn Challenge

A global restoration goal has recently been launched – to restore **150 million ha** of lost and degraded forests by 2020. This goal was launched in September 2011 at a ministerial roundtable at the Bonn Challenge on forests, climate change and biodiversity, which was hosted jointly by the International Union for the Conservation of Nature and the German Ministry of Environment on behalf of the Global Partnership on Forest and Landscape Restoration. The Bonn Challenge links the decisions on forests made under the United Nations Framework Convention on Climate Change with those of the Convention on Biological Diversity, which adopted the goal of restoring 15 percent of destroyed or degraded ecosystems by 2020.

The map helped quantify these targets.
For more information, see:
ideastransformlandscapes.org.

While this goal may sound ambitious, it can be achieved through a doubling of current rates of afforestation, forest regeneration and silvipastoral/agroforestry expansion. This effort would meet the Bonn Challenge and help turn the vision of no net forest loss within the next decade into reality.

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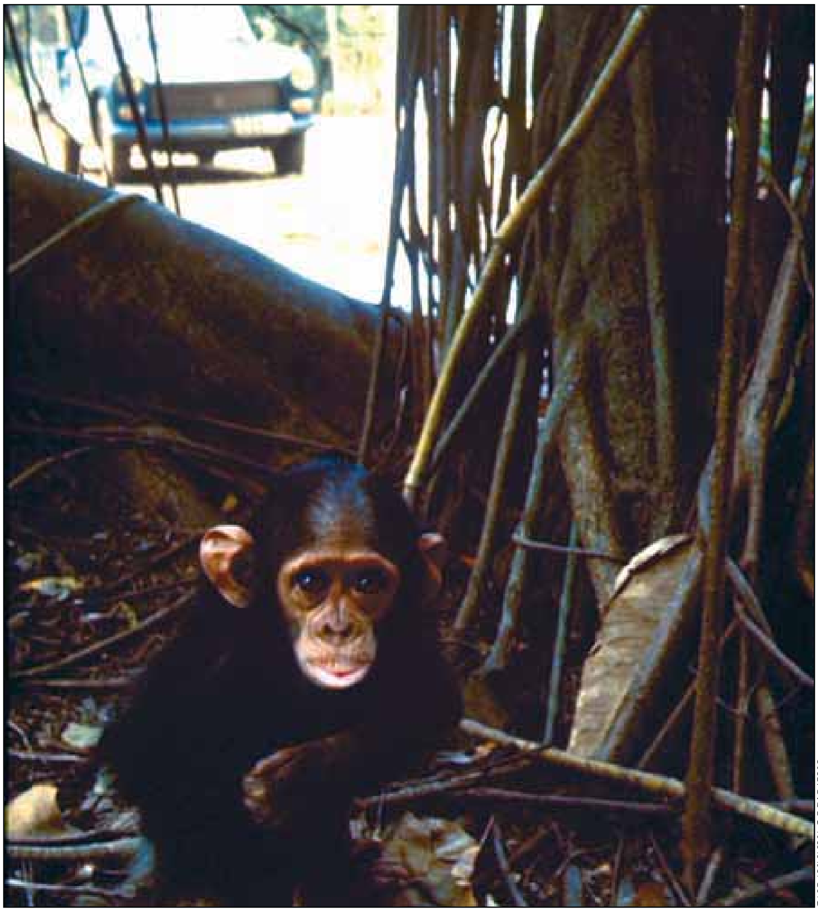
Measuring the abundance of wildlife populations in Central African logging concessions

R. Nasi and N. van Vliet

As timber concessions in Central Africa open remote areas to hunting activities, methods for monitoring and measuring wildlife populations bear review.

In Central Africa, selective logging is the most area-extensive extractive industry, with logging concessions occupying 30–45 percent of forests (Nasi, Cassagne and Billand, 2006). The presence of heavy machinery and logging teams has effects on wildlife (Johns, 1997; White, 1994; White and Tutin, 2001), through direct disturbance and modifications of the structure and composition of the habitat. Logging boosts access to remote forests by opening roads in previously inaccessible areas, providing access to markets and increasing population density. Settlements linked to forestry company infrastructures and camps attract large numbers of people, including workers, their families and traders, to areas that have been sparsely populated (Poulsen *et al.*, 2009). Access to remote areas and a rise in population increase hunting activities.



FAO/O. SOUVANNAVONG

About half of Africa's remaining forest cover is allocated to timber exploitation. Effective wildlife management in timber concessions is critical

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The blue duiker is an important source of protein in Central Africa. According to the IUCN Red List, "[T]his abundant, highly resilient species is suffering some decline in its distribution and numbers as human populations continue to grow and expand"

Hunting can, in turn, trigger numerous, yet not completely understood, effects that can alter the overall function, structure and composition of the ecosystem. In many cases, these effects are relatively straightforward and easy to predict, especially for those species directly targeted by hunting activities. However, hunting may also have indirect effects, often referred to in the literature as "cascading effects", as several steps of consequential effects may be involved (e.g. Wright, 2003). Among the various systems dependent upon the presence of fauna whose processes are potentially affected by hunting are plant regeneration (loss of pollinators, seed dispersers and seed predators), food webs (loss of top predators or of their prey) and plant diversity (change in herbivory patterns, increased pests) (see Stoner *et al*., 2007, for a review). Hunting, like other extractive activities, may therefore contribute to the degradation of forests. One potential extreme effect is degradation to the stage of quasi-total defaunation[1], in which they become "empty forests" (Redford, 1992).

Although the impact of logging activities and hunting on wildlife is well documented, the role of logging concessions as potential "wildlife reservoirs" compared with unmanaged land is also increasingly recognized (Meijaard *et al*., 2006; Clark *et al*., 2009). As about half of Africa's remaining forest cover is allocated to timber exploitation, wildlife management in timber concessions is critical, particularly as hunting activities press farther into remote areas. Because hunting is about the only source of protein, with fish, insects and grubs, for a large part of the rural population in the tropics, as well as being an important source of income, hunting activities must be managed in such way that they continue to provide protein and income to rural populations, without leading to local extinction of the most vulnerable species (Nasi *et al*., 2008).

Managing hunting activities can only be achieved if appropriate methods to monitor wildlife populations and forest degradation as an impact of hunting are available. This article presents some of the lessons learned from past and recent efforts in assessing the impact of hunting on wildlife populations.

INDICATORS AND METHODS FOR THEIR MEASURE

Indicators

The abundance and density of certain wildlife species appear the most common direct indicators, if not the easiest to measure with any precision (see van Vliet and Nasi, 2008a) of defaunation as an impact of hunting (see Azevedo-Ramos, de Carvalho and Nasi, 2005, for a review on animal indicators and logging). In Central Africa, the abundance and density of large mammals are used as indicators of forest defaunation, with a particular focus on primates and ungulates. The species usually chosen, on the basis of importance as a source of protein and income for rural and urban people living in the Congo Basin, are duikers (*Cephalophus spp*.) and bush pigs (*Potamochoerus porcus*), as well as small diurnal monkeys.

Extent and spatial distribution of roads have been particularly useful for indirect assessment of defaunation (Laurance *et al*., 2006; van Vliet and Nasi, 2008b). Indeed, the distribution of mammals within a forest concession appears influenced much more by roads and hunting than by the direct effects of logging, such as disturbance and modification of habitat (Marshall *et al*., 2006). Most indications of hunting activities are found less than 3 km from logging roads, and there is a strong correlation between hunting signs and distance from roads.

[1] In this article, the word "defaunation" describes a significant decline in animal populations ranging from decrease in numbers or diversity to almost total fauna extirpation.

Other indirect indicators used to assess hunting intensity in logging concessions are: hunters' harvesting profiles, in which data on hunting off-takes are regularly collected for a sample of hunters; hunter effort,[2] which is an economic measure of the effort invested by the hunter; household consumption of bushmeat; and quantity of bushmeat traded in nearby markets.

Survey protocols

Mammal abundance and density

Some studies have used *diachronic* approaches, or approaches in which measurements are taken at two different times at the same site; abundance of mammals is measured before and after logging activities have taken place, and the two sets of data are compared. However, in most cases, data on wildlife abundance before logging activities have not been available. In these cases, researchers have favoured *synchronic* approaches, or approaches in which measurements are taken at one moment in time at different, but related, sites. Using these approaches, data collected from neighbouring hunted and not-hunted sites are compared to assess the impact of hunting.

The most commonly used protocol to survey mammal abundance is line transects, in which data are collected along straight, parallel transects.

In surveys performed by logging companies during their forest management inventories, transects made for vegetation surveys, covering a whole concession, may be used for survey of wildlife and detection of human activity (e.g. hunting). In Central Africa, the inventory of more than 30 million hectares (ha) to comply with national forestry laws (Nasi, Cassagne and Billand, 2006), represents an invaluable data bank that could be used for the assessment of forest degradation (Mathot and Doucet, 2006; van Vliet and Nasi, 2008b).

Studies carried out by individual researchers use shorter, more localized transects of 1–2 km, seeking sites that are similar in terms of habitat and representative of unlogged areas, recently logged areas and areas logged more than a certain number of years before. Data collected during line transect survey protocols usually combine daytime visual counts, pellet counts and nest counts for primates. Transects are walked during the day, early in the morning to maximize direct sightings (from 06.30 a.m. to 10.00 a.m.), at an average speed of 1 km per hour. For duikers, the call count method (van Vliet *et al.*, 2009) and night time visual counts (Julve Larrubia, 2005) have also been used.

To obtain data on mammal densities from the line transect records, perpendicular distances of the observations are measured (or estimated). These distances are analysed using distance sampling, in which measurements of the distances of objects observed from a transect line are used to estimate the probability of observing an object (Buckland *et al.*, 1993). This method requires a minimum number of 60 direct observations for each species studied, which can be a limitation, given the elusive behaviour of many tropical forest mammals.

For shy and elusive species, dung counts have often proved to be more practical than direct sightings, as the number of observations is often much higher. If data on defecation rates and dung degradation rates are available for each species, dung observations can also be used to assess animal densities using distance sampling. While counting dung pellets is a relatively simple method, there are many possible errors associated with it. Pellet group counts are unworkable, at times, because of variable defecation rates, use of transects and latrines by the animals, variable loss of pellets by beetle attack (van Vliet, Nasi and Lumaret, 2009), extremely dense vegetation or difficulties in identifying pellets of different ungulate species living in the same zone. When the number of observations is scarce, the number of observations per km, or KAI (kilometric abundance index), can be used as a measure of abundance (Mathot and Doucet, 2006). This simple index can be used to compare mammal abundance between sites or over a long-term monitoring period.

As a substitute for line transects, some studies (e.g. Forboseh, Sunderland and Eno-Nku, 2007; Hart *et al.*, 2008) prefer census walks or *recces*, where the observer follows a path that offers the least resistance through the vegetation. Recces can be used to register diurnal direct sightings, dung piles and nests. The data obtained are not meant to estimate densities, but can easily be converted into KAI.

Other survey methods besides line transect counts are: capture-recapture methods using nets (Dubost, 1980; Koster and Hart, 1988), in which animals are captured, marked and released, with the marked animals counted, on recapture; net hunting encounters, which involves counting the number of animals seen per searched area (Noss, 2000); and estimating densities from home-range size and population structure (Feer, 1996). These methods have mainly been used for duikers and in relatively small areas because they

Duiker dung pile. Counting dung pellets may be more practical than relying on direct sightings, for certain species

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[2] E.g. number of hunting days for a given yield or game harvested for a given hunting effort (e.g. Rist *et al.*, 2008).

are time consuming and usually require the presence of big, well-trained teams.

Capture-recapture methods using non-invasive genetic sampling, for example, from collection of hair and faeces, and camera traps, which are automated cameras that take photographs of wildlife, are currently being tested for some of the Central African species, but the results are as yet unpublished.

Hunting and trading activities

Studies based on data collected at the village or household level use regular (daily, weekly or monthly) semi-structured interviews to assess harvesting profiles, hunter effort or household bushmeat consumption.

Data collected to establish harvesting profiles include species hunted and quantities, hunting technique (gun or snares), number of days allocated to hunting activities, quantities of bushmeat sold or consumed and average price and weight of each animal or piece of animal (e.g. Wilkie *et al*., 1998; Tieguhong and Zwolinski, 2009).

As an alternative to the measure of hunting off-takes, the measure of hunter effort can also be used. Hunter effort may be quantified in units of time such as the number of hours (Franzen, 2006), days (Peres and Nascimento, 2006), or months (Noss, Oetting and Cuéllar, 2005) spent hunting. Hunter effort can also be measured in a number of ways other than in units of time, such as by an index based on the frequency of encounters with hunter signs (Cullen, Bodmer and Valladares-Padua, 2001), by the number of hunters operating in an area (Naughton-Treves *et al*., 2003), in units of hunting equipment such as the number of nets used or traps set per unit time. Other measures are more spatially based, such as the distance of hunting location from human settlement (Rao *et al*., 2005) or nearest point of human access (Hill *et al*., 1997), or the distance travelled by a hunter during the hunt itself (Sirén, Hambäck and Machoa, 2004).

When assessing household consumption of bushmeat, detailed information is recorded about the composition of the principal meal of the day (or of the last few meals), including the unit price of animal protein (fish, livestock or bushmeat), the quantities consumed and the species of bushmeat, if any (Starkey, 2004; Poulsen *et al*., 2009).

Most studies using data collected in bushmeat markets to assess the impact of hunting on wildlife do not focus specifically on logging concessions, but more broadly on a catchment area at a regional scale (Fa *et al*., 1995; 2004). The catchment area is often calculated by evaluation of the total surface covered by all locations mentioned as bushmeat sources by bushmeat sellers, which usually extends beyond the logging concession area. Two main attributes of market dynamics are measured: quantity of and daily availability of each species. These measures are expressed quantitatively as daily abundance of a species and availability of each species in the market. The markets are visited on a regular basis (every day to once a week), and a sample of traders (or all, depending on the size of the market) is interviewed about species sold, quantities and whether meat is smoked or fresh.

DISCUSSION

Line transects provide the possibility to carry out multiple species surveys and have been used largely in the context of logging concessions. However, for regular monitoring, line transects are costly and time consuming. Records from line transects are often too scarce to enable calculating density estimates. These constraints limit the effectiveness of transect surveys as a tool for the monitoring of wildlife population trends. Line transects also imply collateral environmental impacts such as

C. DOUMENGE

Bush pig. Consumption of, and market for, bushmeat can indicate the impact of hunting

the degradation of the understory and the use, by hunters, of these transects to set nets or hunt with guns.

For these reasons, some researchers now prefer to use census walks, or recces. Although this survey approach is attractive when large areas need to be surveyed, as there are fewer logistic constraints, further research is needed to evaluate the quality of the data collected using recces for different mammal species and sign types (including dung, nests, direct observations). More innovative methods, such as capture-recapture methods using non-invasive genetic sampling (Petit and Valiere, 2006) and camera traps, might open new, efficient ways to carry out mammal surveys over large areas. These methods are already used in other contexts for temperate species. With development, they may prove promising for application to tropical species in Central African forests.

Rather than trying to estimate absolute values of densities (with the level of methodological caveats incurred), the aim should be to estimate trends of abundance over time. The KAI offers one simple, but efficient, method to do so. Similarly, methods based on the knowledge of local experts – for example the pooled local expert opinion, PLEO – offer a way to monitor wildlife abundance (van der Hoeven, de Boer and Prins, 2004). In contrast with classical methods, the PLEO method is inexpensive and ensures better local ownership of the results.

Indirect indicators of the role of hunting in forest defaunation are receiving increased attention, although not specifically in the context of logging. The existing literature provides some lessons learned that also apply to logging concessions. For market studies, Fa *et al*. (2004) assessed the efficiency of a number of methods for measuring the volume of bushmeat traded. They found that: useful inferences at a regional scale can be drawn only from a large sample of markets; timing and coordination of sampling may be highly influential on the costs and quality of results; and sampling in blocks of days is as efficient as random sampling in estimating species richness, but not carcass volume. One of the main limitations of market studies is that they generally underestimate the real harvest rate because only a portion of the hunting off-take is sold to markets; the rest is consumed at the village level.

In that sense, hunter interviews for the estimation of harvesting profiles can be more appropriate because they are useful to determine both the quantities kept for own consumption and the quantities sold. Estimations of harvesting profiles and of hunter effort both are time consuming and can only provide accurate results when a certain level of trust exists between the interviewers and the hunters interviewed, limiting the extent of a study to the relatively small scale. Additional challenges associated with measuring hunter effort are: total time estimations can be systematically biased, which can result in overestimation of relevant effort; quantifying trapping effort is problematic because of variable trap checking rates, variable trap group composition and species trap specificity; and economically relevant measures of catch taken from the hunter perspective underestimate the true biological impact of hunting (Rist *et al*., 2008).

CONCLUSIONS

Given the limitations of the different methods discussed in this article, a well-designed survey protocol might imply the use of a combination of approaches with both measures of mammal abundance and measures of hunting and trading activities within a logging concession. Instantaneous measures of these indicators have shown their limits in determining the effects of logging and hunting on wildlife. Instead, long-term monitoring protocols need to be established with the joint effort of governments, logging firms, conservation non-governmental organizations and forest certification bodies.

Van Vliet and Nasi (2008a) show how uncertainty is accumulated in various estimations (especially in those of wildlife populations). Results obtained in different sites are not comparable because different methods have been used to calculate parameters, and each method has different sources of error. Without evaluation of accuracy and standardization of methods, conclusions regarding harvesting sustainability and hunting impacts should be treated with caution.

Further research is needed to lower the human and financial costs of monitoring protocols. The development of innovative methods associated with new technologies, such as non-invasive genetic methods and camera traps, is to be encouraged. Priority for the coming years should be to develop more standardized protocols that would allow comparisons among sites. Until now, most of the studies carried out in different logging concessions of Central Africa have developed their own protocols for the assessment of hunting on forest wildlife populations. The result has been that there are large dissimilarities in the data obtained, and, therefore, there are not comparable results across and within sites. The existence of a more standardized protocol at national or regional levels would provide generalized results that could easily be translated into practical recommendations for more sustainable hunting practices. These recommendations could, in turn, be included in national laws or certification processes to ensure that wildlife is properly taken into account in the management of logging concessions. ◆

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INTERNATIONAL YEAR OF FORESTS SPECIAL
forests for people

INTERNATIONAL YEAR OF FORESTS • 2011

The International Year of Forests (IYF) is drawing to a close. Since its launch at the ninth session of the United Nations Forum on Forests in February, communities around the world have tasted and tested and breathed and squeezed the essence of life of our planet through events celebrating *forests for people*. *Unasylva* is pleased to present a selection of FAO's IYF activities, including a glimpse of FAO staff getting their hands dirty. IYF may be ending, but forests are on the international agenda – and **forests are for people**.

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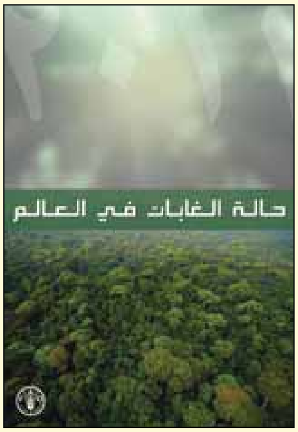
A mission to Rwanda focuses on wildlife and climate change

The year in print

At the outset of 2011, this journal encouraged its readers to **celebrate forests every day** through a photographic montage of themes pertaining to the international days celebrated throughout the year. Forests wove a thread through the International Day for Older Persons, World Teacher's Day, International Day Against Drug Abuse and Illicit Trafficking, World Creativity and Innovation Day.

The ninth biennial *State of the World's Forests 2011*, which considered the theme *changing pathways, changing lives: forests as multiple pathways to sustainable development*, was launched at the IYF inaugural event in February. A chapter on the local value of forests examined the nexus of forests and people. What role does traditional knowledge play in natural resource management? How much can small and medium forest enterprises contribute to rural livelihoods? How can policy support community-based forest management?

FAO Forestry Papers shared the Organization's technical work throughout IYF. *Guide to implementation of phytosanitary standards in forestry* provided public information and guidance on how to address burgeoning threats to forest health by exploring phytosanitary concepts and showcasing good practice. *Reforming forest tenure – issues, principles and process* provided government policy-makers and others concerned with forest tenure reform with a holistic view of key issues to consider in tenure reform and proposals to address them. *Community-based fire management – a review* presented the state of the art in a participatory approach to fire management that takes into account such issues as fire prevention, the role of traditional knowledge and climate change mitigation. *Wildlife in a changing climate* explored the effects that climate change has had, and is likely to have, on wild animals and provided information on how these changes might be addressed.



Special issues of* Unasylva *and* State of the World's Forests *were published

The year in wood

In October, Rediscovering wood: the key to a sustainable future drew together 350 participants from around the globe and more than 3 000 members of the public in Bangalore, India, to discuss the key role of wood use as part of the path to sustainability. The conference placed a particular emphasis on the aesthetics of wood and included various exhibitions and side events as well as the involvement of a broad range of speakers from a diverse array of fields.

The end of IYF featured an unusual sculpture exhibition. Some 30 large-scale works by the group of Finnish wood sculptors Puunkuokkijat were on display for FAO staff and visitors, who paused to reflect on the grand works as they crossed through FAO headquarters in Rome. The three artists in the group – Kari Kärkkäinen, Matti Kurkela and Seppo Kalliokoski – share a common mission to **reinvent wood as a modern material for sculpture**.

FAO/G. NAPOLITANO

FAO headquarters, Rome, hosts a sculpture exhibit

FAO/P. CSOKA

FAO staff plant a forest in Italy

FAO/G. NAPOLITANO

Sustainable forest management is the theme in Zimbabwe

The year in dirt

In August, FAO staff attended a tree-planting event that the Forestry Commission of Zimbabwe held to encourage local tobacco farmers to **practise sustainable forest management**. Honorable Minister of Environment and Natural Resources Management Francis Nhema was the guest of honour at the event, along with other senior government officials and representatives from NGOs and the private sector, particularly those involved in tobacco production.

October saw FAO staff planting trees in honour of IYF. The FAO Forestry Department, together with the Italian Corpo Forestale dello Stato, held an event at Castel Fusano, Italy, to which all staff from FAO headquarters were invited. Participants learned about forestry and sustainable forest management – and planted a forest.

Watch FAO staff get their hands dirty: www.youtube.com/watch?v=SxyYh95PoQ4.

The year in good will

In May, popular recording artist and FAO Goodwill Ambassador Anggun visited Jakarta, in her native Indonesia, to view a forestry site and to **discuss reforestation activities** in areas affected by the 2004 tsunami. Goodwill Ambassador Anggun's visit highlighted the protective functions of coastal forests. She stressed that IYF was an excellent opportunity to raise awareness on both the importance of forests for people and communities and the need to protect those forests.

In June, FAO Goodwill Ambassador and Olympic track legend Carl Lewis visited the Dominican Republic and Haiti to mark IYF. In Haiti, reforestation efforts were under way to help the country protect itself against flash floods and mudslides at the outset of hurricane season.

FAO Goodwill Ambassadors support IYF

To view a video of FAO Goodwill Ambassadors in support of IYF, visit www.youtube.com/watch?v=M_HF5kIYV_Y.

FAO

Assistant Director-General Eduardo Rojas-Briales participates in an Earth Day concert, Rome

The year in song

In April, less than a year after a devastating earthquake hit Chile, the Lollapalooza music festival debuted in Santiago, including headline acts from around the world. As part of the IYF activities, several musicians planted some of the first trees of a programme supported by FAO and the Government of Chile to plant 20 000 trees in Santiago.

Also in April, the fourth annual concert to **mark Earth Day** was held in Rome. The Assistant Director-General of the FAO Forestry Department, Eduardo Rojas-Briales, spoke to the audience of 30 000 young people about IYF, and, in particular, of the importance of forest ecosystems to local communities and to the planet as a whole.

The year in small-scale production

Sharing products and services

On the occasion of the International Year of Forests (IYF), Germany, in close cooperation with FAO, held an international fair in Bonn on *forests for people* – the central theme of IYF. The event, International Bonn Forest Days, was convened 6–9 October 2011 at a central marketplace near the Bonn cathedral. Its concept was to showcase products and services from forests around the world. Visitors enjoyed performances about forests and their multiple roles. Dozens of exhibitors, from Germany and ten other countries representing all regions of the world, provided forest products for viewing, tasting and testing. Visitors chewed raw caoutchouc, sipped beer brewed from Black Forest waters, petted raccoons, and sampled cosmetics made from tropical forest plants. The booths of FAO-supported small producer groups from Burkina Faso, Central Africa, the Lao People's Democratic Republic and Nepal showed how local people can **generate income from sustainably managed forests**. Information was shared on the role of forests, conservation of biodiversity and emerging technologies in the production of forest-based products.

FAO/K. WAGNER

A producer from Burkina Faso exhibits at the International Bonn Forest Days

FAO/M. PERRI

IYF banners are sewn into bags by detainees at a women's prison, Italy

Harnessing opportunities

The IYF banners that have graced the south side of FAO's Rome headquarters have found a new purpose. Thanks to an initiative spearheaded by FAO staff member Sergio Ferrara, and in close cooperation with Ora d'Aria, an association concerned with offering opportunities to those who live in isolation, in particular in prisons, the banners were cut and sewn into satchels by detainees at a local women's prison. The detainees have an opportunity to earn money for their work, and to practise skills that will help them reassimilate into society in the future.

Second Mediterranean Forest Week addresses sustainable development and climate change

The Second (II) Mediterranean Forest Week, organized by the Mediterranean Regional Office of the European Forest Institute (EFIMED) and *Silva Mediterranea* (FAO), with several other key partners, was held 5–8 April 2011 in Avignon, France, with the support of the Ministry for Agriculture, Food, Fisheries, Rural Policy and Local Development of France, the Provence-Alpes-Côte d'Azur region and the Ministry of Science and Innovation of Spain.

The event was included in the agenda of the International Year of Forests 2011, and participants comprised actors involved in the management of woodland ecosystems in the Mediterranean.

Plenary and several parallel sessions addressed the role of forests for the sustainable development of Mediterranean territories and the impact of climate change on wildfire prevention strategies and key resources such as water. During these sessions, a Position Paper on Wildfire Prevention in the Mediterranean was adopted by the main stakeholders involved in management of forest fires. This position paper was presented at the Fifth International Conference on Wildfires, held in South Africa in May 2011 (see page 60). Partners also approved a precise timetable for the extension of the European System of Information on Forest Fires (EFFIS) to Algeria, Lebanon, Morocco, the Syrian Arab Republic and Tunisia.

Highlights among the sessions and meetings convened included: Forest governance in the Mediterranean region; Water and forests interactions; EFIMED annual meeting; ArcMED General Assembly; and a scientific seminar entitled Biodiversity of Mediterranean forest ecosystems: changing the paradigm of conservation.

The Secretariat of the Committee on Mediterranean Forestry Questions, *Silva Mediterranea*, organized several statutory meetings and thematic sessions. The annual meeting of the Enlarged Executive Committee of *Silva Mediterranea* was co-chaired by the Assistant Director-General of the FAO Forestry Department, Eduardo Rojas-Briales, and the President of *Silva Mediterranea*, Spas Todorov, from Bulgaria.

Three sessions on Forests, societies and territories promoted the exchange of cross-sectoral experiences of forest governance and provided the following key recommendations:

- Improving the knowledge base on the territorial context, the forest resources, the services provided by woodland ecosystems, and the risks and opportunities, by including the "climate change" factor (impact, mitigation potential, adaptation options);
- Promoting intersectoral approaches and the inclusion of forest management within local projects for the long term;
- Bringing relevant local stakeholders into projects from the outset, particularly local decision-makers (political backing) and administration (consistency with existing activities and budgets, financial support);
- Defining the project area in compliance with the social, politico-administrative, geographical and ecological contexts;
- Devoting the necessary time and human and financial resources to the learning processes offered by territorial development operations, particularly in terms of running activities and communicating;
- Assessing the benefits rendered by woodland ecosystems and associated management costs. Identifying beneficiaries. Developing sustainable funding mechanisms;
- Developing, improving and adapting tools for collective approaches (including the use of prospective approaches) in order to facilitate the emergence of joint visions, strategies and programmes of action;
- Testing, assessing and developing instruments and measures (legal and economic) for the implementation of collectively adopted programmes of action;
- Developing and running networks for the effective sharing of experience between Mediterranean areas; and
- Clarifying and enhancing the links between consultation and decision-making processes.


C. BESACIER

Second Mediterranean Forest Week, Avignon, France

Mediterranean Forest Week, which was held for the first time in Antalya, Turkey, in 2010, is a unique platform to improve dialogue among the Mediterranean forest research community, policy-makers and relevant stakeholders and to communicate to the international community and society at large the relevance and challenges related to Mediterranean forests.

The Third Mediterranean Forest Week will be hosted in 2013 in Algeria.

For further information on this event, see the newsletters of *Silva Mediterranea* at www.fao.org/forestry/silvamed/en/, or www.efimed.efi.int/portal/events/mfw2011.

Wildfire 2011 builds on global cooperation

The 5th International Wildland Fire Conference, "Wildfire 2011", was held in Sun City/Pilanesberg National Park, South Africa, 9–13 May 2011. Convened by the regional sub-Saharan Wildland Fire Network, AfriFireNet, and funded by the Government of South Africa, the conference was held under the auspices of the United Nations International Strategy for Disaster Reduction and FAO, in conjunction with the Third Session of the Global Platform for Disaster Risk Reduction in Geneva, Switzerland.

The Secretary-General of the United Nations, Mr. Ban Ki-moon, conveyed an opening statement to the 500 delegates from 61 countries. He welcomed the efforts of fire specialists from around the world to develop a spirit of global cooperation in addressing the role of fire in the global environment and its impacts on society.

The conference provided a holistic panorama of fire management through technical sessions including Community-based fire management and Fire and poverty alleviation. Participants expressed strong concern at the escalation of wildfires across the globe, many unprecedented in the modern era for the severe impact on communities, the environment and the world economy.

A highlight of the conference was an exhibition held during a field day at the Pilanesberg Game Reserve. South African wildland firefighters, men and women, from eight "Hotshot" crews from the Working on Fire programme (WoF), supported by water bomber aircraft and helicopters, demonstrated their skills in a live wildland firefighting display. WoF is funded by the Government of South Africa and is one of South Africa's most successful initiatives for the alleviation of poverty, creation of jobs and uplifting of communities.

FAO supported the development of several conference papers, among which were two plenary ones. One paper highlights the potential, and need, for REDD+ programmes

Wildfire 2011, Sun City/Pilanesberg National Park, South Africa

WILDFIRE 2011.11.22/B. SUTHERLAND

WILDFIRE 2011.11.22/B. SUTHERLAND

Wildfire 2011, Sun City/Pilanesberg National Park, South Africa

to include fire management components. Another paper explored megafires, indicating the probability of an increase in the number of megafires with climate change and expressing the need to prepare for this eventuality through forest and landscape management.

The conference concluded that international cooperation and a strengthening of wildland fire science and management skills are key to stemming the escalation of wildland fire. The recommendations of the conference call for, among others:

- An increase in fire management efforts in such areas of concern as: terrain contaminated by radioactivity, unexploded ordnance, land mines and chemical deposits, notably in regions affected by the nuclear fallout in Chernobyl (1986) and Fukushima (2011); securing peat bog/wetland ecosystems that are subjected to drainage and climate-driven desiccation (Russian Federation, 2010); and unnecessary burning on croplands, fallow and other lands;
- More involvement of civil society in fire management through participatory approaches (community-based fire management), applying controlled burning to improve livelihoods and health of local populations, and promoting volunteer groups to assist state authorities in rural fire management. It was additionally recommended that an international conference on community-based fire management be convened before the next International Wildland Fire Conference;
- Widespread application and adaptation of advanced principles in fire management under local conditions: application of the Voluntary Guidelines for Fire Management of FAO, ITTO and WHO/UNEP; global adoption of the Incident Command System (ICS) for the management of incidents; integration of forest fire management principles and tools in the REDD+ scheme; and acknowledgement that fire management should be part of land management;

- Systematic application of advanced technologies for wildland fire science and management, notably Satellite Earth Observation products, meteorological observations and forecasting, and climate modeling;
- Promotion of bilateral and multilateral/regional agreements on cooperation in wildland fire management and mutual assistance in wildland fire emergencies; and
- Further involvement of the six FAO Regional Forestry Commissions and the National Platforms for Disaster Risk Reduction in the implementation of principles as laid down in the fire management guidelines and the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters.

In response to global climate change and taking into account that global warming leads to an increasing occurrence and severity of wildland fires and intensifies their impact on society, the conference also recommended:

- Development of adaptive fire policies and strategies for mitigation, adaptation and protection at national to international levels;
- Integration of fire management in landscape management; and
- Support to countries to conduct fire management assessments, formulate legal frameworks and strategies, build sustainable fire management capabilities and institutions, and develop fire management plans and human resources.

The Republic of Korea will host the 6th International Wildland Fire Conference in 2015.

All conference papers supported by FAO and/or about FAO Fire Management activities are collected in:
FAO. 2011. *FAO at the Vth International Wildland Fire Conference*. FAO Fire Management Working Paper No. 27. Rome (also available at www.fao.org/docrep/014/am663e/am663e00.pdf).

For a complete version of the conference statement, visit www.wildfire2011.org/docs/10-Wildfire-2011-Conference-Statement.pdf.

The Gambia's Community Forest Policy wins award

WORLD FUTURE COUNCIL

2011 Future Policy Awards are announced in New York, United States of America: H.E. James Kimonyo, Ambassador of the Republic of Rwanda to the United States of America; Olympic track legend Carl Lewis, FAO Goodwill Ambassador; H.H. Jato S. Sillah, Minister of Forestry and the Environment, the Gambia

The Republic of the Gambia, with the support of FAO and other development partners, has developed and implemented the first policy and legislation in Africa to provide local populations with secure and permanent forest ownership rights. Transferring forest tenure from state ownership to management by local communities has enabled them to reduce illegal logging and forest fires, slow desertification and benefit from using the forest products. Communities have established producer groups, generating income from forest management. Over 350 villages manage 12 percent of the country's forests, and there has been a net increase in forest cover of 8.5 percent over the past two decades. A target is for nearly half the forests in the Gambia to be under community management by 2016.

The inspiring and innovative forest policy of the Gambia was recently recognized by the World Future Council, which awarded the Gambia's Community Forest Policy the Silver Award in its 2011 Future Policy Awards. The awards were announced in New York, United States of America, in September, followed by a presentation ceremony in Bonn, Germany, in October. Carl Lewis, FAO Goodwill Ambassador and Olympic track legend, who attended the awards ceremony in New York, said, "The Gambia's people-centered approach has been highly successful and represents a model to replicate in other countries with similar forestry environment."

The World Future Council is a political advocacy group that is based in Hamburg, Germany. It was created specifically to focus on policy solutions to global challenges. Information on the Future Policy Award and its 2011 winners, and the World Future Council and its activities, can be found at www.worldfuturecouncil.org/future_policy_award.html.

> *The success of the Gambia's Community Forest Policy proves that even in the world's poorest countries, with the right policies and legal framework in place, rural populations can benefit economically from forests and significantly improve their food security and environment. The Gambia's experience has shown that the challenge of sustainable forestry can be attained through the government's willingness to empower rural populations.*
>
> **Eduardo Rojas-Briales**, Assistant Director-General, FAO Forestry Department

ACPWP addresses the role of FAO Forestry in key areas

The FAO Forestry Department and the International Council of Forest and Paper Associations (ICFPA) held the 52nd FAO Advisory Committee on Paper and Wood Products (ACPWP) meeting in Montebello, Canada, 23–25 May 2011. Forty-five participants from seventeen countries convened to discuss matters pertaining to the sustainable development of forest industries, and to climate change and greenhouse gases related to wood energy.

The Committee expressed its strong support to collaboration with FAO. It requested that FAO should elaborate further work in three main areas in 2011–2012. First, FAO should continue providing information and analysis useful to the development of sound climate change policies as they relate to the forest industry. Second, in the context of preparations for RIO+20, FAO was requested to highlight the important contribution of the forest products industry to green economy. Finally, the Committee asked FAO to assess the concept of hosting a process in which industry and the conservation community could explore modalities for supporting the industry's continued commitment to improving sustainable forest management.

The ACPWP is an FAO statutory body composed of senior executives from the private industry sector worldwide. It meets yearly with the main objective of providing guidance on activities and programme of work of the FAO Forestry Department on issues relevant to the paper and forest products industry, in support of the efforts of member countries to progress towards sustainable development. The 53rd session of the ACPWP will be held in New Delhi, India, from 23–25 May 2012, in conjunction with the ICFPA Annual Meeting.


J. TISSARI

ACPWP meeting, Montebello, Canada

For more information on the ACPWP and its activities, visit: www.fao.org/forestry/industries/9530/en/.

Expert Meeting on the Governance of Forests and REDD+ gathers stakeholders in Rome

The UN-REDD Programme, Chatham House, FAO and the World Bank organized the Expert Meeting on Governance of Forests and REDD+, held on 19–20 May 2011, at FAO headquarters, Rome. The meeting drew together a variety of participants, including government officials from donor and recipient countries interested in forest and REDD+ governance; experts drawn from international institutions and academia; national and international civil society organizations; and the private sector.

The meeting aimed to encourage coordinated provision of information and assessment of REDD+ and forest governance. To this end, it launched two new guides to assist practitioners: Framework for Assessing and Monitoring Forest Governance, emerging from the 2010 Stockholm Symposium on Forest Governance Indicators, led by the World Bank and FAO, and draft Guidance for the Provision of Information on REDD+ Governance, developed by UN-REDD and Chatham House. The two guides offer consistent and complementary guidance for providing information on REDD+ and forest governance, drawing from practical experience and existing initiatives in this field.

Presentations introduced the documents themselves, and described the relationship between them and how they could be used in a complementary way. Participants were given the opportunity to comment and ask questions.

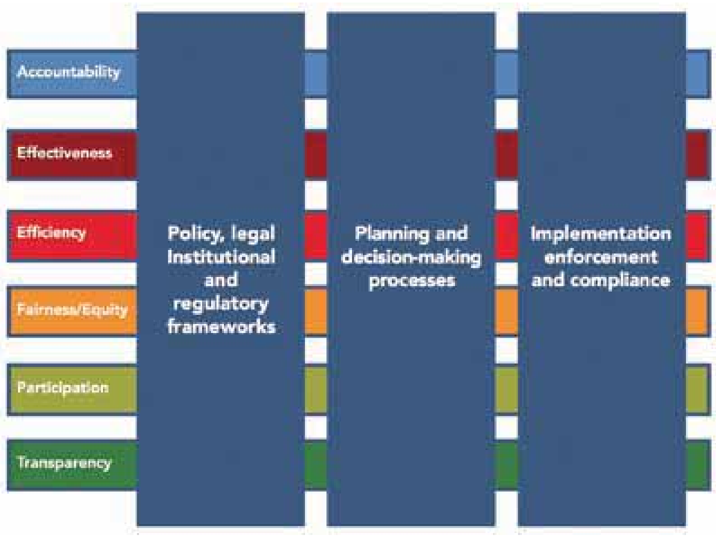
A key theme of the meeting was to consider, more generally, the governance information needs of different stakeholders, including governments, the private sector and local communities. Users' perspectives were addressed among working groups, and a separate panel discussion highlighted the work of governments and civil society organizations and explored how the documents would be useful for their activities. For example, Filippo del Gatto, from Madera Verde (Green Wood) in Ecuador and Global Witness, explained how the Framework for Assessing and Monitoring Forest Governance could help his work with the Center for International Forestry Research PRO-FORMAL project in Ecuador, most notably to find identifiable elements ("subcomponents") of local political economy and commodity chain governance, and design indicators for their analysis and measurement.

The main outcomes of the meeting were:

- A significant contribution of the documents is to propose a common language and common concepts for all those interested in assessing and providing information on governance;
- The documents have a wide range of applications, from advocacy work to government-led reforms;
- Ownership, created through participatory processes, will be key to their successful application;
- There are already several opportunities for early use of the documents: Participatory Governance Assessments for REDD+, International Development Law Organization (IDLO) e-training courses, Forest Law Enforcement, Governance and Trade of the European Union (EU FLEGT) and REDD+ Facilities, national forest programmes, and the Forest Policy and Economics Education and Research (FOPER) project of the European Forestry Institute; and
- Participants made the following recommendations to the lead agencies:
  > Further develop the documents, including their dissemination and communication (e.g. through an e-network and/or Web site);
  > Further analyse synergies among initiatives and encourage coordination between existing tools;
  > Organize a "community of practice" to collect and share information on country best practice;
  > Support in-country actions through training, capacity-building and pilot application.

Framework for Assessing and Monitoring Forest Governance: www.fao.org/docrep/014/i2227e/i2227e00.pdf

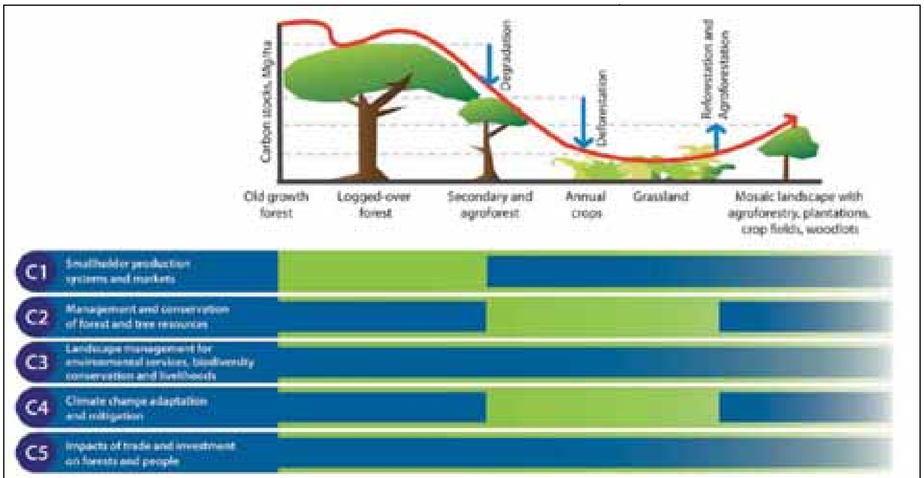
Draft Guidance for the Provision of Information on REDD+ Governance: www.unredd.net/index.php?option=com_docman&task=doc_download&gid=5336&Itemid=53



Source: Framework for Assessing and Monitoring Forest Governance.

Pillars and principles of good forest governance

CRP6 components within the forest and land use transition curve



Source: CGIAR Research Program.

Introducing CRP6, a new approach to forestry research

A new initiative is poised to influence the management of 1.8 billion hectares (ha) of forests. The Consultative Group on International Agricultural Research (CGIAR) has included forests and trees in its new research portfolio and has appointed the Center for International Forestry Research (CIFOR) to lead the area. CGIAR Research Program number 6 (CRP6) is Forests, Trees and Agroforestry: Livelihoods, Landscapes and Governance. CRP6 involves partner centres Bioversity International, the International Center for Tropical Agriculture and the World Agroforestry Centre. The programme is based on global comparative research and stands to benefit millions of the world's poorest people.

The initiative will target 46 percent of global forest cover, 1.3 billion ha of closed forests and 500 million ha of open and fragmented forests. It is expected to:

- save between 0.5 and 1.7 million ha of forest from deforestation each year;
- lead to the adoption of ecologically and socially sustainable production and management practices in 9.3–27.8 million ha of managed forests; and
- reduce carbon emissions by between 0.16 and 0.68 Gt CO_2 a year.

Research will target approximately 500 million people living in or close to forests in Africa, Latin America and Southeast Asia, and will contribute to:

- better production and management options that benefit at least 3 million producers and traders and their families;
- increased conservation of tree diversity that benefits at least 2 million producers;
- production and management technologies that raise the productivity of target groups by at least 50 percent;
- the doubling – at least – of incomes from forest and agroforestry products for target households;
- more funding for climate adaptation programmes that benefit an additional 60 million people;
- an increased supply of REDD+ credits worth between US$ 108 million and US$ 2 695 million per year; and
- a significant increase in women's access to forest benefits.

Tropical forests are the agenda at the Summit of the Three Rainforest Basins

The relevance of tropical forests in contributing to the livelihoods of people and conserving biodiversity is well known. The three rainforest basins (Amazon Basin, Congo Basin and forests of Southeast Asia) represent 80 percent of the world's tropical forests and are home to two-thirds of terrestrial biodiversity. The countries sharing these resources face similar challenges in finding an appropriate balance among conservation of forest biodiversity,

Heads of States or their representatives present at the summit

BUREAU DE BRAZZAVILLE

mitigation of climate change and achievement of economic and social development. To overcome these challenges, a sound cooperation among these countries is essential.

The first proposal in this regard was made in 2006 in Bali, Indonesia, by the Government of the Republic of the Congo, followed in 2010, also in Bali, by a proposal by the Government of the Republic of Indonesia. To put the proposals into practice – to take stock of what is happening in the tropical forests of these crucial regions and to generate momentum for their sustainable management – the Summit of the Three Rainforest Basins was held, hosted by the Republic of the Congo.

In the lead-up to the summit, three UN agencies were contacted to produce background documents for the summit. FAO and the International Tropical Timber Organization (ITTO) were asked to prepare a publication on the state of forests in the Amazon, Congo Basin and Southeast Asia, the United Nations Educational, Scientific and Cultural Organization to prepare a Draft Cooperation Agreement, and the United Nations Environment Programme to submit a Draft Declaration of the Summit. *The State of Forests in the Amazon Basin, Congo Basin and Southeast Asia* stressed that the potential value of the many goods and services provided by rainforests clearly outweighs the benefits that can be obtained from almost any alternative land use. "[T]he value of tropical forest services ...could reach many thousands of dollars per hectare," wrote Eduardo Rojas-Briales, Assistant Director-General of the FAO Forestry Department and Emmanuel Ze Meka, Executive Director of ITTO.

The summit took place in Brazzaville from 29 May to 3 June 2011. About 600 people were in attendance, including Heads of States or their representatives, ministers and media. The summit comprised three segments: the Experts segment, the Ministerial segment and the Presidential segment. Presentations were given by participating organizations on thematic issues related to forest development, including REDD+ and poverty alleviation, green economy and innovative financing for sustainable forest management. The presentations aimed to facilitate a common understanding of critical issues, opportunities and challenges facing the countries of the three rainforest basins.

A review of the Draft Declaration was conducted at the Experts segment. An updated version was submitted to the Ministerial segment, where it was reviewed and finalized. It was presented to the Presidential segment, where it was adopted by the Heads of States or their representatives.

Delegates agreed that there was a need for more consultation among the countries, prior to discussion and signature of the proposed Draft Cooperation Agreement.

Heads of States or their representatives agreed to take concrete steps to promote dialogue and cooperation among their countries and mandated their ministers in charge of forests to prepare an action plan accordingly. A follow-up committee, Bureau de Brazzaville, was set up, led by the Republic of the Congo, and including the Republic of Indonesia and the Republic of Guyana, with technical support of the United Nations agencies and WWF. The mandate of the Bureau de Brazzaville is to finalize the wording of the Draft Cooperation Agreement, taking into account the comments and remarks of the experts, and to gain the support of the countries for its adoption at the Rio+20 Summit, at the latest.

The President of the Republic of Guyana, H.E. Bharrat Jagdeo, was nominated to act as a goodwill ambassador of the three rainforest basins.

For more information on the summit and its background documents, see www.3bassinsforestiers.org/en/.

First Africa Drylands Week explores potential for development

> *[T]he trees in drylands sustain the land and have come to mean the difference between living in abject poverty and a sustainable livelihood.*
>
> **Luc Gnacadja**, Executive Secretary of the United Nations Convention to Combat Desertification

The First Africa Drylands Week was held in Dakar, 10–17 June 2011, back to back with the global observance on 17 June of the World Day to Combat Desertification. The theme was *towards a global vision and partnership on sustainable land and climate risk management for the Sahara and the Sahel Initiative*. The First Africa Drylands Week was a contribution to the International Year of Forests and to the United Nations Decade for Deserts and the Fight against Desertification.

The event was organized by the African Union Commission, the Earth Institute of Columbia University, the European Union, FAO, the Government of the Republic of Senegal, the Millennium Development Goals Centre for West and Central Africa, the Secretariat of the United Nations Convention to Combat Desertification and Wallonie-Bruxelles International. Over 17 partners and more than 200 scientists, technical specialists, development actors, NGOs, policy-makers and donors came together to explore the challenges posed by land degradation, desertification, climate change and poverty in the circum-Sahara region.

Field trips showcased desertification issues and projects on the ground. One itinerary took participants to the regions of Kébemer, Linguere and Louga to visit various project sites. Projects included the dune fixation project and its management for tourism, which is being implemented by the Forest Service (Senegal) in partnership with NGOs and private sector organizations, and the Acacia Operation project (see Box, page 66), which was implemented by FAO with such partners in Senegal as the Forest Service, local women's groups, the private sector and local communities.

***Farmer growing beans around an* Acacia senegal**

Gums, resins and livelihoods

Sahelian countries have been severely affected by drought and desertification, with an adverse impact on important production systems such as cattle-breeding, agriculture and woodlands.

Tree species producing gums generally belong to the Acacia genus, which is spread throughout the African continent, and, particularly, in arid and semi-arid areas. In addition to producing gums, fodder and firewood, Acacia species contribute to favourable conditions for agriculture by protecting crops against heavy rain and wind erosion, by buffering extreme climatic conditions and by restoring soil fertility.

FAO, in collaboration with its partners in Burkina Faso, Chad, Kenya, the Niger, Senegal and the Sudan, and the Network for Natural Gums and Resins in Africa (NGARA), and funded by the Government of Italy through the Trust Fund for Food Safety and Food Security, successfully implemented the Acacia Operation project. The goal was to support food security, alleviation of poverty, and control of soil degradation in the arid lands of these countries that produce gums and resins. The approach was to strengthen the capacity of the countries to address these problems through the improvement and restoration of Acacia agrosilvopastoral systems, and through the sustainable development of the resin and gum sectors.

Achievements of the project were many. In total, 13 240 ha of Acacia were restored. Agrosilvopastoral systems were established, and gum and resin production improved. Local people were empowered though an intensive capacity-building programme on use and application of technology; establishment of nurseries and plant production; agriculture production; and the harvesting and processing of gums and resins. Information exchange, training, technology transfer and quality control of gums and resins were improved through strengthening the organization and management of NGARA. A ten-year programme for gums and resins producer countries was elaborated.

For more information, visit www.fao.org/forestry/aridzone/62998/en/.

The week featured plenary and world café sessions, as well as working groups. Among the themes addressed were:

- rehabilitation of degraded lands and fighting sand encroachment in arid zones;
- the science and practice of re-greening the Sahel;
- small and medium enterprises – value chain of dryland products; and
- initiatives and processes for sustainable land management (contributing to the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity, the United Nations Convention to Combat Desertification).

Building on Africa's successes locally, nationally and regionally, participants reinforced, throughout the sessions, that efforts to address current and future challenges must include an Africa-wide alliance. The alliance should include poverty-reduction strategies, based on the Millennium Development Goals. Strategies should be aimed at transforming local community livelihoods and environment through such best practices as farmer-managed natural regeneration and other agroforestry systems led by local communities; rehabilitation and restoration of degraded forests and lands; integrated soil and water management; sand-dune fixation; and urban and peri-urban forestry.

> *"The combined effects of land degradation, deforestation and soil exhaustion are particularly severe in arid and semi-arid lands. They are driven by overexploitation of forests, trees, bush and grazing land, inadequate management of soil and water resource as well as poverty and limited development opportunities and exacerbated by climate change. …There are many major successes that have already been achieved providing [an] excellent basis on which to build."*
>
> From the Statement from the participants of the First Africa Drylands Week

The First Africa Drylands Week demonstrated renewed solidarity and unity throughout the circum-Saharan region. Participants recommended the organization of a Second Africa Drylands Week to maintain the momentum and commitment to transform these ecosystems during the United Nations Decade for Deserts and the Fight Against Desertification.

For more information on the First Africa Drylands Week, visit drylandsforum.wordpress.com.

Inaugural APEC Meeting of Ministers Responsible for Forestry is held in Beijing

The first Asia–Pacific Economic Cooperation (APEC) Meeting of Ministers Responsible for Forestry was convened 6–8 September 2011, in Beijing. The theme of the meeting was enhanced regional cooperation for green growth and sustainable forestry development.

Participants included all 21 APEC economies, including 9 ministers, leading international forestry organizations and representatives from industry associations and the private sector.

President Hu Jintao of the People's Republic of China opened the meeting.

The meeting included discussion on, among others, new opportunities and challenges facing forestry in Asia and the Pacific, wise use of forest resources to improve livelihoods and promote sustainable development, strengthening forest governance and management, and enhancing cooperation to achieve growth for the forest sector in the region.

Recognizing the roles of resource and energy constraints, climate change, loss of biological diversity, poverty and food insecurity, the meeting adopted the Beijing Statement on Forests and Forestry. The statement takes into account the diversity among APEC economies and development needs. Fifteen points of commitment are elaborated, supporting green growth, sustainable forest management and rehabilitation. Among the commitments are to strengthen further political commitment in support of sustainable forest management, forest conservation and forest rehabilitation; to strengthen international cooperation on sustainable forest management; to strengthen cooperation among APEC economies on forest policies and management and to encourage these economies to enhance afforestation, reforestation and tree-planting programmes; and to strengthen outreach programmes to raise public awareness about forest-related issues.

The full Beijing Statement is available at www.apec.org/Meeting-Papers/Ministerial-Statements/Forestry/2011_forestry.aspx.

APFNET

APEC forestry ministers unveil plaque commemorating formal operations of the Asia–Pacific Network for Sustainable Forest Management and Rehabilitation

Addressing threats to forest health

Guide to implementation of phytosanitary standards in forestry. 2010. FAO Forestry Paper No. 164. Rome, FAO. ISBN 978-92-5-106785-7.

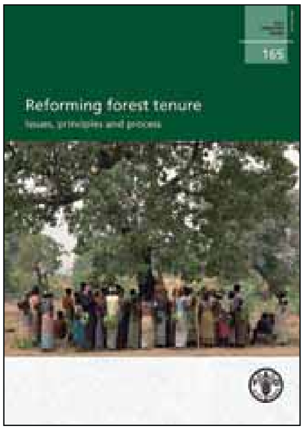
Produced by an international group of scientists, phytosanitary authorities, forest experts and industry representatives and reviewed by more than 100 specialists from 46 countries, this guide provides easy-to-understand practical information on how good forest management practices and well-implemented phytosanitary standards can minimize pest spread and facilitate safe trade.

Each chapter has been prepared as a stand-alone document allowing the reader to concentrate on specific topics that are of interest. One chapter describes how the International Standards for Phytosanitary Measures (ISPMs) affect the import and export of forest commodities. Another addresses how people in the forest sector can reduce the risk of spreading pests through effective management approaches. Preventing forest pest introduction and spread by using phytosanitary measures is explained in a further chapter. The way forward – how forest sector personnel can work together with national plant protection organizations to contribute to the development and implementation of ISPMs and national phytosanitary regulations that help reduce pest movement in a manner least restrictive to trade possible – is another chapter's focus.

Supplemental information includes examples of forest pests and their impacts, with colour photographs that illustrate the pest, symptoms/damage and possible hosts, and a glossary that clarifies the terminology used.

The guide is an essential reference for those involved in nursery activities, planting, managing, harvesting, manufacturing, trading and transporting forest products. It will also benefit forest policy-makers, planners, managers and educators, particularly in developing countries. It should be noted that this guide is for public information and guidance only and is not an official legal interpretation of the International Plant Protection Convention or its related documents.

Also available online: www.fao.org/docrep/013/i2080e/i2080e00.htm.

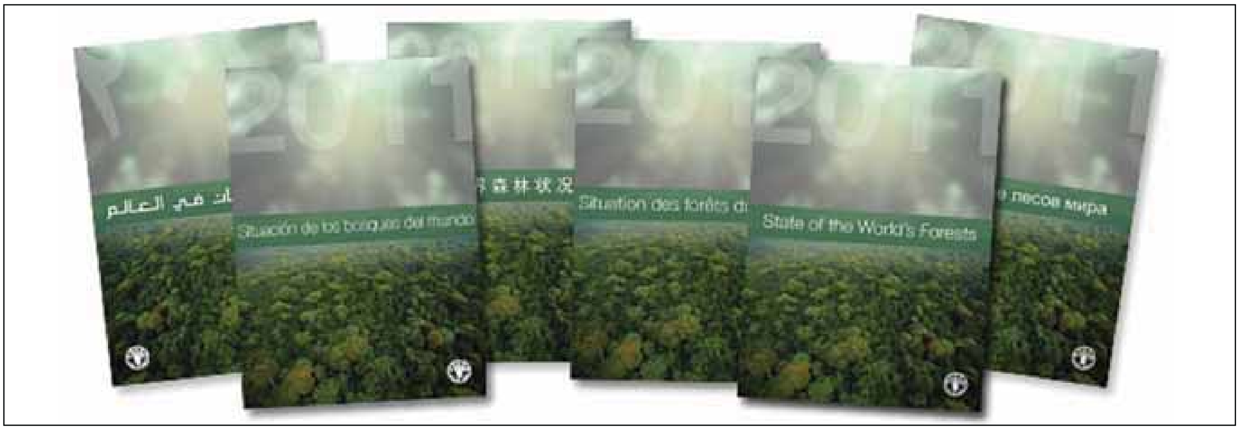


Towards secure tenure arrangements

Reforming forest tenure: issues, principles and process. 2010. FAO Forestry Paper No. 165. Rome, FAO. ISBN 978-92-5-106855-7.

Secure tenure is an important prerequisite for sustainable forest management. More diversified tenure systems could provide a basis for improving forest management and local livelihoods, particularly where the State has insufficient capacity to manage forests. In the past decade, many countries have initiated efforts to reform their tenure arrangements for forests and forest land, devolving some degree of access and management from the State to others, mainly households, private companies and communities. This publication provides practical guidance for policy-makers and others concerned with addressing forest tenure reform. Drawing from many sources, including forest tenure assessments carried out by FAO in Africa, Central Asia, Southeast Asia, and Latin America, it deduces lessons about what works and what does not, and why. It formulates a set of ten principles to guide tenure reform, and proposes an adaptive process for diversifying forest tenure in a context-appropriate way. The publication emphasizes that successful tenure reform is linked with reform in associated regulatory frameworks and governance arrangements, and must be seen in the context of a wider national development agenda.

Also available online: www.fao.org/docrep/014/i2185e/i2185e00.htm.



Forests and sustainable development

State of the World's Forests 2011. 2011. Rome, FAO. ISBN 978-92-5-106750-5.

The ninth biennial issue of the *State of the World's Forests*, published at the outset of 2011, the International Year of Forests, considers the theme *changing pathways, changing lives: forests as multiple pathways to sustainable development.* The report explores the core subjects of sustainable forest industries, climate change and local livelihoods and examines their potential to stimulate development at all levels. In addition, new regional-level analyses drawn from the Global Forest Resources Assessment 2010 are presented.

The report is divided into four thematic sections. One explores some of the key regional trends in the extent of change in forest area, the areas allocated for productive and protective functions, levels of biomass, and employment, among other topics. The discussion provides an indication of regional approaches to forest resource use and the measures that countries have taken to adapt to changes in biological systems and policies and new management techniques.

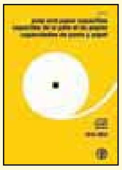
Adaptability is also a key theme in the second section, which is on developing sustainable forest industries. It reviews the extent to which the forest industry has developed, based on a number of key global drivers, and discusses how it can strategically modify its approach to the use of forests. A key message is that the forest sector continues to make a real contribution to employment and economic growth for many countries.

Climate change occupies a prominent position in international discussions, and forests have a particular role to play in the global response. The third area presents an update on the negotiations under way related to forests and climate change. In particular, the report focuses on developments in reducing emissions from deforestation and forest degradation, and in conserving and enhancing carbon stocks (REDD+). It provides a snapshot of some emerging legal guidance on forest carbon tenure and different approaches to determining ownership of the resource.

The final section highlights the importance of forests to local livelihoods, through a discussion of traditional knowledge, community-based forest management, small and medium forest enterprises and the non-cash value of forests. Considered together, these themes provide insights on the true contribution of forests to the creation of sustainable livelihoods and alleviation of poverty.

Also available online: www.fao.org/forestry/sofo/en/.

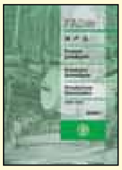
New editions of FAO statistical publications



Pulp and paper capacities: survey 2010–2015. 2011. Rome, FAO. ISBN 978-92-5-006911-1.

This annual survey presents statistics on pulp and paper capacity and production by country and by grade. It is based on information submitted by correspondents worldwide, most of them pulp and paper associations or paper companies, representing about 70 percent of the world production of paper and paperboard.

Also available online: www.fao.org/docrep/014/i2285t/i2285t00.pdf.



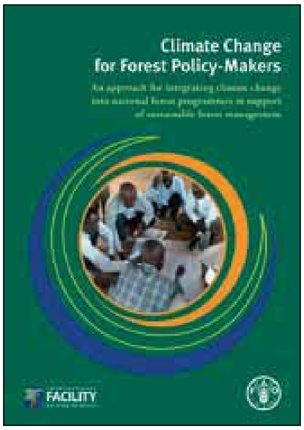
FAO Yearbook of Forest Products 2009. 2010. Rome, FAO. ISBN 978-92-5-006544-1.

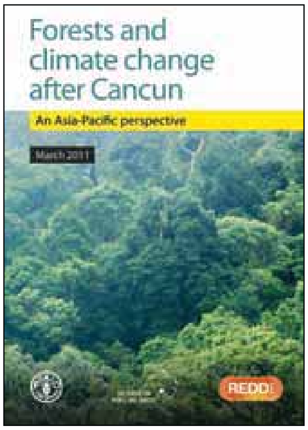
This yearbook is a multilingual compilation of statistical data on basic forest products for all countries and territories of the world. This sixty-third issue contains annual data on production and trade in forest products for the years 2005–2009 and on directions of trade in 2008 and 2009.

Also available online: www.fao.org/docrep/014/i1211m/i1211m00.htm.

A statistical heritage online

A complete collection of *FAO Yearbook of Forest Products*, 1947–, is now available on the FAO Web site: www.fao.org/forestry/62283/en/.





Forests and climate change – booklets

Climate change for forest policy-makers: an approach for integrating climate change into national forest programmes in support of sustainable forest management. 2011. FAO, Rome.

The critical role of forests in climate change mitigation and adaptation is now widely recognized. Forests contribute significantly to climate change mitigation through their carbon sink and carbon storage functions. They play an essential role in reducing vulnerabilities and enhancing adaptation of people and ecosystems to climate change and climate variability, the negative impacts of which are becoming increasingly evident in many parts of the world.

In many countries climate change issues have not been fully addressed in national forest policies, forestry mitigation and adaptation needs at national level have not been thoroughly considered in national climate change strategies, and cross-sectoral dimensions of climate change impacts and response measures have not been fully appreciated. This publication seeks to provide a practical approach to the process of integrating climate change into national forest programmes. The aim is to assist senior officials in government administrations and the representatives of other stakeholders, including civil society organizations and the private sector, to prepare the forest sector for the challenges and opportunities posed by climate change.

Also available online: www.fao.org/forestry/climatechange/64862/en/.

Forests and climate change after Cancun: an Asia–Pacific perspective. 2011. Bangkok, RECOFTC. ISBN 978-616-90183-4-6.

The 16th Conference of the Parties (COP-16) of the United Nations Framework Convention on Climate Change held in Cancun, Mexico, in 2010 changed the shape of REDD+ negotiations and global forest policies. The Cancun Agreement carries REDD+ firmly forward as a key component of the post-2012 international climate change regime by describing its main elements and implementing its initial phase.

What effect will the decisions from the talks have on forests and forest users in Asia and the Pacific? Building on the success of a similar initiative following COP-15 in Copenhagen, FAO and RECOFTC – The Center for People and Forests, Bangkok – brought together 11 regional experts, with support from the Norad-funded REDD-Net project, to reflect on these issues. This 28-page booklet summarizes their responses to 12 key questions. The questions directly address the many REDD+ issues and implications including safeguards, costs, financing, key challenges, benefits, binding commitments and future negotiations, and explore the implications of the Green Climate Fund and Land Use, Land-Use Change and Forestry methodology.

This short booklet provides succinct answers to some of the many questions arising in forestry and climate change discussions today, with particular focus on the implications for the Asia–Pacific region.

Also available online: www.fao.org/world/regional/rap/nre/about/en/.

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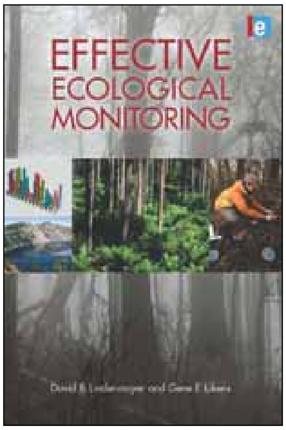


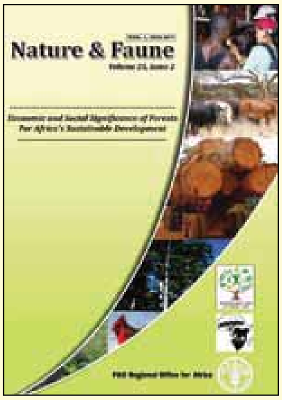
Introducing "Adaptive Monitoring"

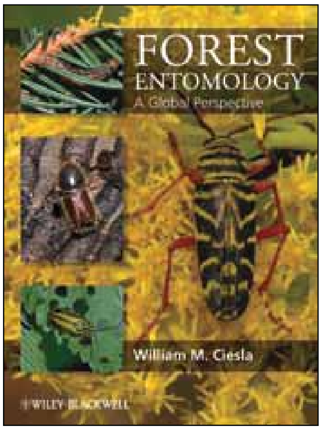
Effective ecological monitoring. D.B Lindenmayer & G.E. Likens. 2010. London, Earthscan. ISBN 978-1-84971-145-6.

Ecologists and managers of natural resources readily acknowledge the importance of long-term monitoring for improved understanding and management of complex environmental systems. Long-term data are crucially important for providing baselines for detecting and evaluating changes in ecosystem structure and function, and for evaluating responses to disturbances such as climate change or pollution. This book outlines some of the key pitfalls and deficiencies in ecological monitoring programmes. Some of the features of long-term monitoring programmes that are essential to make them viable are described, using case studies in Australia, Canada, the United Kingdom and the United States of America. The authors propose a new approach, which they call Adaptive Monitoring, which collects the key characteristics of successful long-term monitoring programmes in a logical and coherent framework. Written for the educated layperson and policy manager in an accessible style, each chapter includes a summary and a reference list.

The new issue of *Nature & Faune* is out!

Volume 25, Issue 2, considers the theme "Economic and social significance of forests for Africa's sustainable development". Visit www.fao.org/africa/publications/nature-and-faune-magazine/ to view current and past issues.





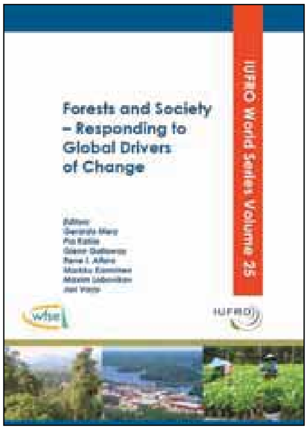
World of insects

Forest entomology: a global perspective. W.M. Ciesla. 2011. Chichester, UK, Wiley-Blackwell. ISBN 978-1-4443-3314-5.

This textbook examines forest insects in a global context and addresses the species of major concern in the world's forest ecosystems.

The first part explores the roles of insects in forests, their population dynamics and their effects on natural forests, plantations, agroforestry systems, urban woods, wood and non-wood products. Approaches to forest insect monitoring are reviewed, and alternatives for management of damaging forest insects within the framework of integrated pest management are presented. The basis for classification of forest insects into orders and families is reviewed. The second part provides 235 profiles of forest insects, worldwide, their distribution, hosts, life histories and economic, social and ecological impacts. A series of tables provides summaries of the distribution and hosts of many more species. Included are those that damage forests, others that are simply curiosities and some that are beneficial.

This book is designed as a reference for students, practising foresters and forest health specialists, especially for those who work internationally or are concerned with species that have the potential to expand their ranges via international trade, travel or environmental changes. A companion Web site with additional resources, where readers can download figures, tables and images from each chapter for their own use and teaching purposes, is available at: www.wiley.com/go/ciesla/forest.



Change, challenges and opportunities

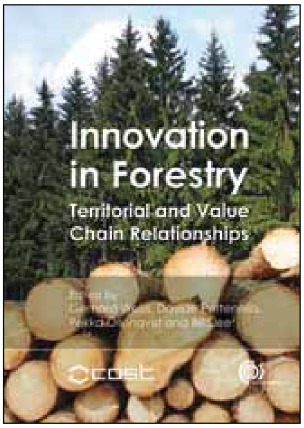
Forests and society: responding to global drivers of change. G. Mery, P. Katila, G. Galloway, R.I. Alfaro, M. Kanninen, M. Lobovikov & J. Varjo (eds.). 2010. IUFRO World Series, Vol. 25. Vienna, IUFRO. ISBN 978-3-901347-93-1.

Produced by the Special Project on World Forests, Society and Environment of the International Union of Forest Research Organizations using a multidisciplinary collaborative approach, this book identifies the main global drivers of change affecting the world's forests and forest-dependent people and the challenges and opportunities they create. It also proposes ways to reduce the adverse effects of these drivers and to take advantage of the new opportunities they may bring.

The book analyses important environmental changes such as climate change and air pollution, forest and water cycling and forest health in a changing environment. Also addressed are socio-economic changes related to markets and investments, technological development, changing social environments and human health and well-being, and the crucial role of the drivers of change that originate from outside the forest sector, such as the demand for land for agriculture and bioenergy production. Many regional examples are provided that illustrate how society and institutions strive to respond to the changes and challenges, at different scales in different parts of the world. To address the environmental, social and economic challenges facing the world's forests, the study presents recent advances in approaches to managing forests for wood and other ecosystem goods and services, and on institutional arrangements that hold most promise in fostering efforts to manage these challenges in the long term.

Suitable for a wide audience, this publication will contribute to discussions and further research related to the drivers of change, and the threats and challenges that forests, forestry and forest-dependent people are facing today and will face in the future.

A companion policy brief, developed from the main conclusions of the book, and different chapters of the book are available online at: www.iufro.org/science/special/wfse/wfse-achievements.



Innovation and European forestries

Innovation in forestry: territorial and value chain relationships. G. Weiss, D. Pettenella, P. Ollonqvist & B. Slee (eds.). 2011. Wallingford, UK, CAB International. ISBN 978-1-84593-689-1.

Innovation is increasingly recognized as a key factor in environmental protection and balanced sustainable development within the forestry sector. This volume presents the results of innovation research in European forestry and forest-based industries, spanning a broad range of forestry processes from business to institutional, and from ecosystem services to global market commodities. By understanding the full range of factors that influence innovation processes, the authors provide a comprehensive theoretical foundation for the analysis of innovation processes and policies in a traditional, rural sector as well as presenting empirical analyses of innovation processes from major innovation areas. Using case studies, territorial services of the forest sector are examined, including various types of forest ecosystem services such as carbon sequestration or recreation and wood value chains, including timber frame construction and bioenergy. This book should be of interest to researchers and policy-makers in forestry and environmental sciences.