ISSN 0041-6436

unasylva

Food and Agriculture Organization of the United Nations

An international journal of forestry and forest industries

Vol. 62 2011/2 238

MEASURING FOREST DEGRADATION

ISSN 0041-6436

unasylva

Food and Agriculture Organization of the United Nations

An international journal of forestry and forest industries

Vol. 62 2011/2

238

Unasylva is published in English, French and Spanish. Payment is no longer required. Free subscriptions can be obtained by sending an e-mail to unasylva@fao.org

Subscription requests from institutions (e.g. libraries, companies, organizations, universities) rather than individuals are preferred to make the journal accessible to more readers.

All issues of *Unasylva* are available online free of charge at www.fao.org/forestry/unasylva

Comments and queries are welcome: unasylva@fao.org

To order the FAO publications reviewed in *Unasylva*, contact the Sales and Marketing Group, Office of Knowledge Exchange, Research and Extension, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy.
Tel.: (+39) 06 57051;
Fax: (+39) 06 5705 3360;
Telex: 625852/625853/610181 FAO I;
E-mail: publications-sales@fao.org

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

Markku Simula is Adjunct Professor, Faculty of Agriculture and Forestry, University of Helsinki.
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.

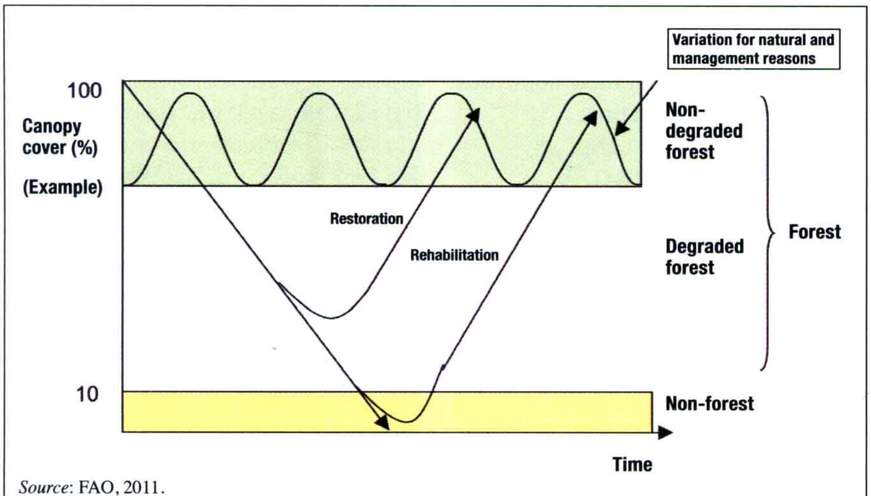
Forest degradation needs to be assessed at different spatial scales for different purposes. Assessment at the scale of a stand or site is needed for taking effective corrective action at the local level; many indicators of a forest's capacity to supply goods and services vary over time within a stand, 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. ◆

INTERNATIONAL YEAR OF FORESTS • 2011

References

CONAFOR. 2007. *Protección, restauración y conservación de suelos forestales. Manual de obras y prácticas*. Zapopan, Mexico, National Forest Commission.

FAO. 2002. *Proceedings: Second Expert Meeting on Harmonizing Forest-related Definitions for Use by Various Stakeholders, Rome, 11–13 September 2002*. Rome. Available at: www.fao.org/docrep/005/y4171e/y4171e00.htm.

FAO. 2009. *Towards defining forest degradation: comparative analysis of existing definitions*, by M. Simula. Forest Resources Assessment Working Paper No. 154. Rome (also available at ftp.fao.org/docrep/fao/012/k6217e/k6217e00.pdf).

FAO. 2011. *Assessing forest degradation: towards the development of globally applicable guidelines*. Working Paper. Rome.

Global Partnership on Forest Landscape Restoration. 2011. Web site. Available at: ideastransformlandscapes.org.

ITTO. 2002. *ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests*. ITTO Policy Development Series No. 13. Yokohama, Japan, International Tropical Timber Organization.

Laestadius, L., Saint-Laurent, C., Minnemeyer, S. & Potapov, P. 2011. *A world of opportunity: the world's forests from a restoration perspective*. The Global Partnership on Forest Landscape Restoration, World Resources Institute, South Dakota State University & the International Union for the Conservation of Nature. Available at: pdf.wri.org/world_of_opportunity_brochure_2011-09.pdf. ◆

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

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

V. KANTOR

Lars Laestadius is Senior Associate, World Resources Institute, Washington, D.C., United States of America.
Peter Potapov is Associate Professor, University of Maryland, College Park, Maryland, United States of America.
Alexey Yaroshenko is Forest Coordinator, Greenpeace Russia, Moscow.
Svetlana Turubanova is Research Associate, University of Maryland, College Park, Maryland, United States of America.

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.

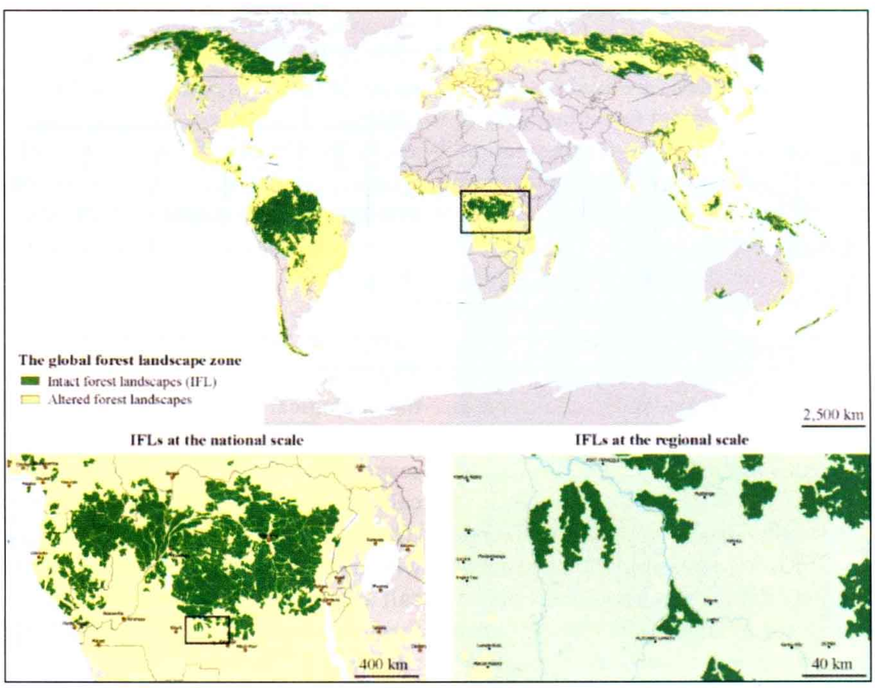
A GLOBAL ASSESSMENT OF FOREST ALTERATION

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):

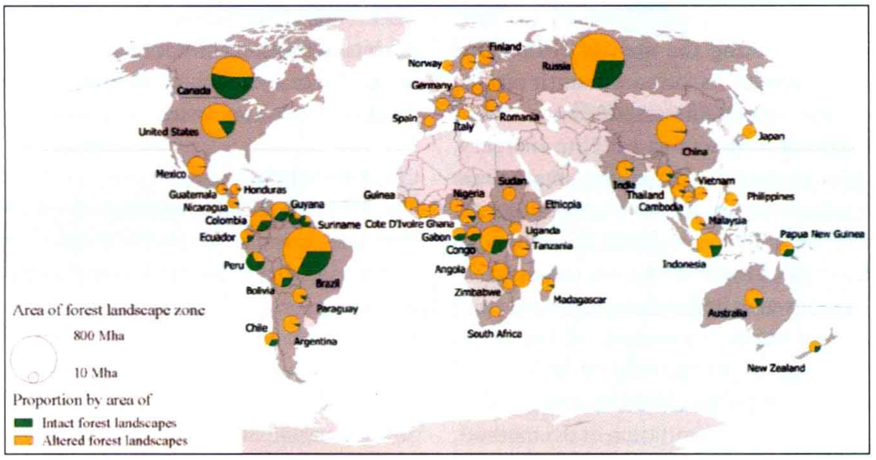
1. *Closed forests* with a tree canopy cover greater than 40 percent (49.2 percent of the forest landscape zone);
2. *Open forests and woodlands* with a tree canopy cover of 20–40 percent (24.7 percent of the forest landscape zone); and
3. *Naturally treeless areas* with a tree canopy cover below 20 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

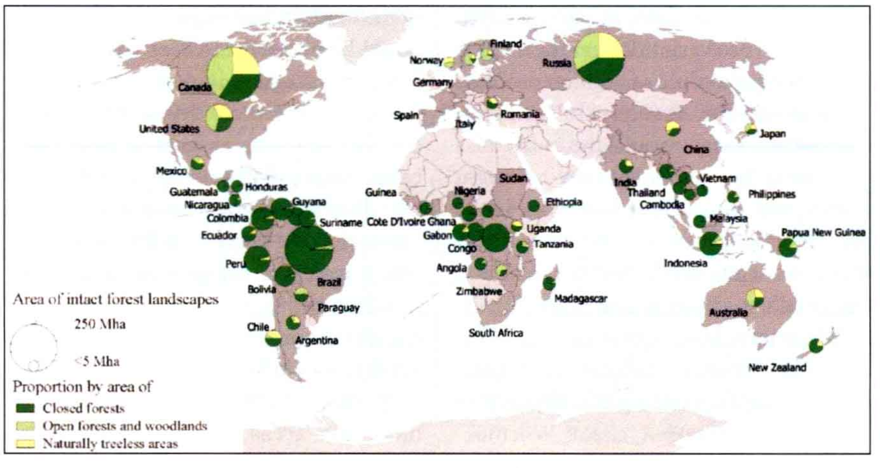
A country-level assessment was conducted that was limited to countries with at least 10 million ha of area in the forest landscape zone (Figure 2). Of these 62 countries, the forest has been almost entirely altered, i.e. less than 1 percent of the forest landscape zone remains as IFL, in 19. This group 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. ◆

References

Aksenov, D., Dobrynin, D., Dubinin, M., Egorov, A., Isaev, A., Karpachevskiy, M., Laestadius, L., Potapov, P., Purekhovskiy, A., Turubanova, S. & Yaroshenko, A. 2002. *Atlas of Russia's intact forest landscapes.* Moscow, Global Forest Watch Russia (also available at www.globalforestwatch.org/common/russia/Atlas_report_pdfs/Cover-032.pdf).

FAO. 2009. *Global mapping and monitoring the extent of forest alteration: the Intact Forest Landscapes Method,* by P. Potapov, L. Laestadius, A. Yaroshenko and S. Turubanova. Forest Resources Assessment Working Paper No. 166. Rome (also available at: www.fao.org/docrep/012/k7611e/k7611e00.pdf).

FSC. 2006. *Standard for company evaluation of FSC controlled wood.* FSC-STD-40-005 (Version 2-1) EN. Bonn, Forest Stewardship Council (also available at www.fsc.org/fileadmin/web-data/public/document_center/international_FSC_policies/standards/FSC_STD_40_005_V2_1_EN_Company_Evaluation_of_Controlled_Wood.pdf).

FSC Canada. 2004. *National boreal standard.* Toronto, Canada, Forest Stewardship Council Canada Working Group (also available at www.fsccanada.org/docs/boreal%20standard.pdf).

FSC Russia. 2008. *Russian national Forest Stewardship Council standard.* FSC-STD-RUS-01 2008-11 Russian national standard ENG. Moscow, Russian Forest Stewardship Council National Initiative (also available at www.fsc.ru/pdf/rnsen1.pdf).

Hansen, M.C., DeFries, R.S., Townshend, J.R.G., Carroll, M., Dimiceli, C. & Sohlberg, R.A. 2003. Global percent tree cover at a spatial resolution of 500 meters: first results of the MODIS vegetation continuous fields algorithm. *Earth Interactions,* 7:1–15. DOI: 10.1175/1087-3562(2003)007<0001:GPTCAA>2.0.CO;2.

Lee, P., Aksenov, D., Laestadius, L., Nogueron, R. & Smith, W. 2002. *Canada's large intact forest landscapes (a report by Global Forest Watch Canada).* Edmonton, Global Forest Watch Canada (also available at www.globalforestwatch.org/english/canada/pdf/Canada_LIFL-Text_Section.pdf).

Lee, P., Gysbers, J.D. & Stanojevic, Z. 2006. *Canada's forest landscape fragments: a first approximation (a Global Forest Watch Canada Report).* Edmonton, Global Forest Watch Canada (also available at www.globalforestwatch.ca/FLFs/GFWC-FLFs-firstapprox-150dpi.pdf).

Mollicone, D., Achard, F., Federici, S., Eva, H.D., Grassi, G., Belward, A., Raes, F., Seufert, G., Stibig, H.-J., Matteucci, G. & Schulze, E.-D. 2007. An incentive mechanism for reducing emissions from conversion of intact and non-intact forests. *Climatic Change,* 83: 477–493. DOI: 10.1007/s10584-006-9231-2.

Potapov, P., Yaroshenko, A., Turubanova, S., Dubinin, M., Laestadius, L., Thies, C., Aksenov, D., Egorov, A., Yesipova, Y., Glushkov, I., Karpachevskiy, M., Kostikova, A., Manisha, A., Tsybikova, E. & Zhuravleva, I. 2008. Mapping the world's intact forest landscapes by remote sensing. *Ecology and Society,* 13(2). Available at: www.ecologyandsociety.org/vol13/iss2/art51/.

Strittholt, J., Noguerón, R., Bergquist, J. & Álvarez, M. 2006. *Mapping undisturbed landscapes in Alaska: an overview report.* Washington, D.C., World Resources Institute (also available at www.wri.org/publication/mapping-undisturbed-landscapes-alaska-overview-report).

Tucker, C.J., Grant, D.M. & Dykstra, J.D. 2004. NASA's global orthorectified Landsat data set. *Photogrammetric Engineering and Remote Sensing,* 70: 313–322.

Yaroshenko, A.Y., Potapov, P.V. & Turubanova, S.A. 2001. *The last intact forest landscapes of northern European Russia.* Moscow, Greenpeace Russia and Global Forest Watch (also available at www.globalforestwatch.org/english/russia/pdf/GFW_Russia_Report_en.pdf). ◆

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.

Forestry Officers **Adam Gerrand, Erik Lindquist** and **Remi D'Annunzio** are the FRA Remote Sensing Team, FAO Forestry Department, Rome.

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.

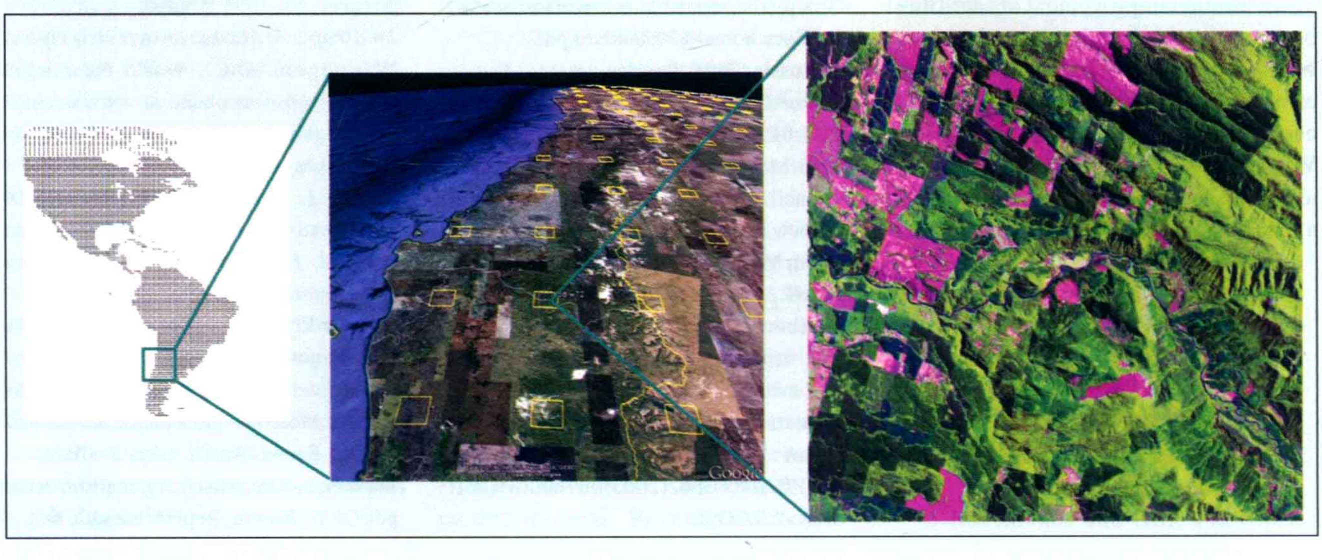
Easy access to tools and satellite images

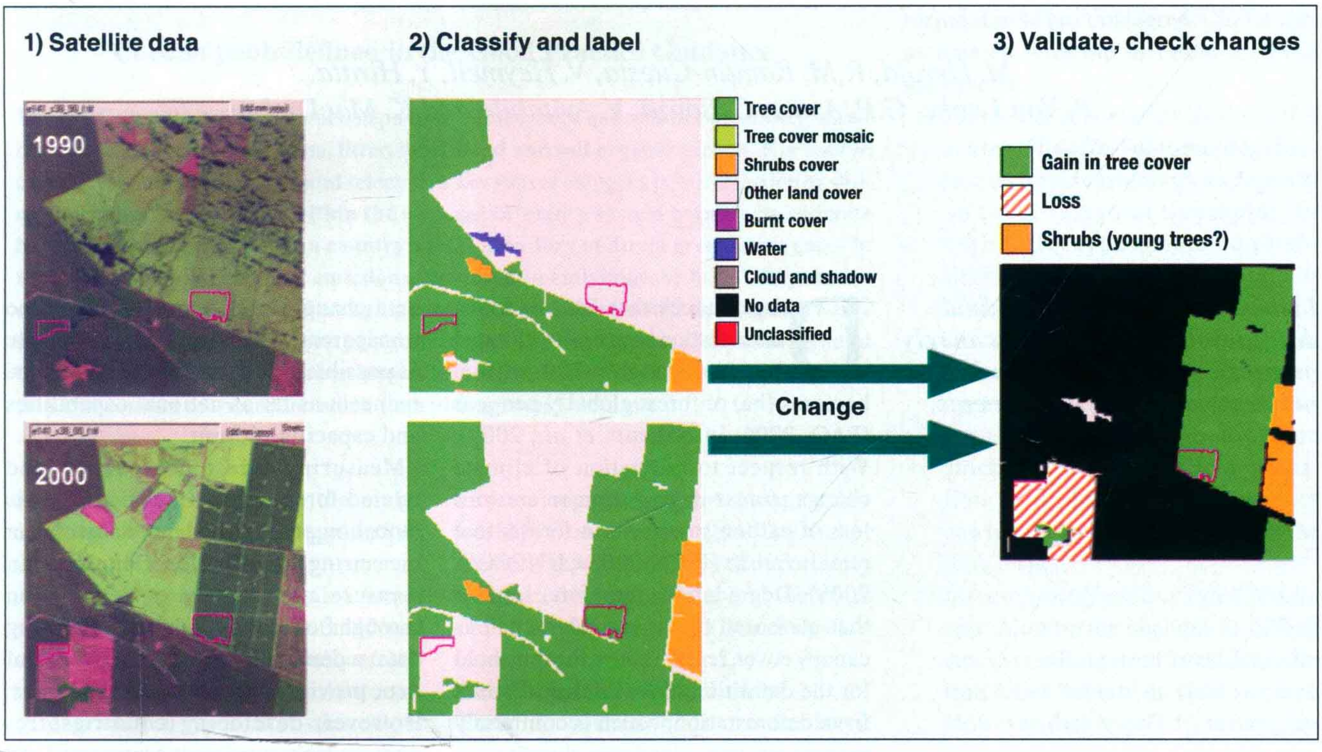
FAO and its partner organizations made pre-processed imagery for the sample areas easily available through the Internet.[2] Access to free remote sensing data and specialized

[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/remotesensing survey/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

M. Herold, R.M. Román-Cuesta, V. Heymell, Y. Hirata, P. Van Laake, G.P. Asner, C. Souza, V. Avitabile and K. MacDicken

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

Martin Herold is Professor of Remote Sensing, Center for Geoinformation, Wageningen University, the Netherlands.
Rosa María Román-Cuesta is working on the design and implementation of MRV systems for REDD+ within the UN-REDD Programme, FAO.
Victoria Heymell is a consultant in the Forestry Department, FAO.
Yasumasa Hirata is head of the Climate Change Office, Forestry and Forest Products Research Institute, Tsukuba, Japan.
Patrick Van Laake is the Technical Specialist on the UN-REDD Viet Nam Programme, Hanoi.
Gregory P. Asner is a Professor of Ecology and Remote Sensing, Department of Global Ecology, Carnegie Institution for Science, United States of America.
Carlos Souza is Senior Scientist at IMAZON, Belem, Brazil.
Valerio Avitabile is a postdoctoral researcher, Center for Geoinformation, Wageningen University, The Netherlands.
Kenneth MacDicken is Senior Forestry Officer, Global Forest Reporting and Assessment, FAO.

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,