Forestry Department
Food and Agriculture Organization of the United Nations

FRA 2000

ASSESSING STATE AND CHANGE IN GLOBAL FOREST COVER: 2000 AND BEYOND

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The Forest Resources Assessment Programme

Forests are crucial for the well-being of humanity. They provide foundations for life on earth through ecological functions, by regulating the climate and water resources, and by serving as habitats for plants and animals. Forests also furnish a wide range of essential goods such as wood, food, fodder and medicines, in addition to opportunities for recreation, spiritual renewal and other services.

Today, forests are under pressure from expanding human populations, which frequently leads to the conversion or degradation of forests into unsustainable forms of land use. When forests are lost or severely degraded, their capacity to function as regulators of the environment is also lost, increasing flood and erosion hazards, reducing soil fertility, and contributing to the loss of plant and animal life. As a result, the sustainable provision of goods and services from forests is jeopardized.

FAO, at the request of the member nations and the world community, regularly monitors the world's forests through the Forest Resources Assessment Programme. The next report, the Global Forest Resources Assessment 2000 (FRA 2000), will review the forest situation by the end of the millennium. FRA 2000 will include country-level information based on existing forest inventory data, regional investigations of land-cover change processes, and a number of global studies focusing on the interaction between people and forests. The FRA 2000 report will be made public and distributed on the world wide web in the year 2000.

The Forest Resources Assessment Programme is organized under the Forest Resources Division (FOR) at FAO headquarters in Rome. Contact persons are:

Robert Davis	FRA Programme Coordinator	robert.davis@fao.org
Peter Holmgren	FRA Project Director	peter.holmgren@fao.org

or use the e-mail address: fra@fao.org

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Paper drafted by:
Prof. Risto Paivinen, Deputy director, European Forest Institute
Dr. Andrew J.R. Gillespie, Forest Inventory National Program Leader, US Forest Service
Mr. Robert Davis, Coordinator FAO – FRA Programme
Dr. Peter Holmgren, Project Director, FAO – FRA Programme

Editorial production: Patrizia Pugliese, FAO – FRA Programme

Abbreviations

AVHRR	Advanced Very High Resolution Radiometer
BEF	Biomass Expansion Factor
BV	Biomass of inventoried volume
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza
Cirad	Centre de coopération internationale en recherche agronomique pour le développement
EDC	Eros Data Centre
FAO	Food and Agricultural Organization of the United Nations
FORIS	Forest Resources Information System
FRA 2000	The Global Forest Resources Assessment 2000
GIS	Geographic Information System
IGBP	International Geosphere and Biosphere Programme
NDVI	Normalized Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Agency
SNU	Sub National Unit(s)
TM	Thematic Mapper
UN-ECE	United Nations Economic Commission for Europe
USGS	United States Geological Survey
VOB	Volume Over Bark
WD	Wood Density
WCMC	World Conservation Monitoring Centre

Abstract

The United National Food and Agriculture Organisation (FAO), at the request of the member nations and the world community, regularly reports on status and trends in the world's forest resources. This paper briefly describes the methods used in past surveys, describes the data and methods to be used to complete the 2000 Forest Resource Assessments, and proposes a follow-on continuous world forest survey system to enable FAO to provide the necessary information on a permanent basis. This paper is based on a background document and on the results of an Expert Advisory Meeting on FRA 2000 held in Rome, Italy on March 6-10, 2000.

Keywords: Inventory, Assessment, Monitoring, Global, Satellite, Tropical

1 Introduction

The United National Food and Agriculture Organisation (FAO), at the request of the member nations and the world community, regularly reports on the world's forest resources through its Forest Resources Assessment Programme (FRA). FRA is now executing the Global Forest Resources Assessment 2000 (FRA 2000). Reliable information on forest change (both negative and positive changes) and its trends has been widely recognised as indispensable for ensuring the sustainable management of the world's forests.

The purpose of this paper is to (a) describe the data and methods used to complete past and current Forest Resource Assessments, and (b) to propose a follow-on continuous world forest survey system to provide FRA products in future years. This paper is based on a background document (Paivinen and Gillespie 2000) and on the results of an Expert Advisory Meeting on FRA 2000 held in Rome, Italy on March 6-10, 2000.

2 FAO Forest Resources Assessment 1980-90

The 1980 FRA was essentially an expert assessment based on existing inventory information for each of 76 tropical countries. A small team of experts in FAO headquarters gathered and synthesised whatever information they could find regarding the status of forests in each of 76 tropical countries. The diversity of the information was seen in three different angles: subject, scale and reliability. The FRA 1980 study "consisted mainly in the selection, organisation, compilation and interpretation of this abundant and diverse mass of information using a single framework of classifications and concepts for the 76 tropical countries" (Lanly 1982). Although it was clearly the best available global synthesis of its time, the 1980 FRA was criticised for over reliance on country-reported data, which was feared to be biased in favour of underreporting rates of forest loss. Another criticism was that the methods used to synthesise and update data were not fully documented and made available to potential users of the data.

Partly due to this, as well as to the increased staff capacity and access to technology, the 1990 FRA incorporated a statistical sample of satellite imagery to produce regional levels of forest cover change, as a validation of the aggregated country level results produced by country data and models. This survey covered, with 10 percent intensity, all tropical forests in wet, moist and dry conditions. The survey was based on a statistical sample composed by multi-temporal satellite images over 117 sampling units. For each unit the study included the analysis of one entire Landsat image close to year 1990 and one (or more) close to year 1980.

The 1990 FRA also used a set of models to predict forest change as a function of population, based on the assumption that "the growth of human population, independently in the absence of economic development, and jointly with poorly planned and uncontrolled economic development, are the driving forces behind human activities that initiate deforestation" (Scotti 1990, Palo 1986). It was assumed that forest area reduction increases slowly at initial stages, faster in intermediate stages and slows down at final stages, following principles of biological growth processes, often described with well-known Chapman-Richards function. The mathematical connection between population density and non-forest area was created using forest cover data in a number of sub-country regions in Tropical countries. Finally, the deforestation rate was estimated assuming that the increase in the population will determine the decrease in the change of forest cover.

3 Forest Resources Assessment 2000 Data Available

The FRA 2000 continues the use of satellite image assessment for estimating rates of forest cover and change at the regional level. However, resources do not provide for extension of this approach to the country level, nor has FAO been given the mandate to conduct this level of work. Since estimates at the country level are still needed, such estimates will have to be based on other types of data. Sources of information available for completing FRA 2000 include the following:

3.1 Update of the 2000 Remote Sensing survey of tropical countries

The strategy for the Tropical 2000 Update approach is to revisit the topical FRA 1990 sampling units, and update them with a third date of TM imagery for the reference year 2000. Such a survey will provide up-to-date information on change processes, as well as new and unprecedented insights on deforestation trends over the periods 1980-1990 and 1990-2000.

The key strength of the TM change assessment approach is that it utilises advanced satellite technology in a way that provides consistent, reliable results. This approach also helps reduce program costs by allowing use of the photographic image archive already maintained by FAO. Although the method of manual interpretation does not take full advantage of current image processing technology, the method is simple to replicate, relatively inexpensive, and is readily familiar to foresters all over the world. The primary weakness of the TM change assessment as implemented by FRA is that, due to financial and time constraints, the sample intensity is designed for regional results only; few countries will have sufficient samples to support estimates at the country level. Thus, some subtle forms of forest degradation or deforestation may be missed in the stratification process, which may lead to false estimates of rates of forest loss.

3.2 Advanced Very High Resolution Radiometer (AVHRR) forest map

FRA 2000 will feature a global forest cover map produced at 1-km spatial resolution, produced at the U.S. Geological Survey (USGS) EROS Data Centre (EDC) in cooperation with FAO. This map is a complete global coverage produced with a consistent methodology and a flexible database philosophy, using AVHRR Normalized Difference Vegetation Index (NDVI) as the primary input data. Two levels of land cover are available from the database: the full classification based on seasonal definitions and the aggregated 17-category International Geosphere and Biosphere Programme (IGBP) classification. The FAO forest cover mapping effort builds on the full USGS seasonal database, refining forest classes to reflect forest density classification.

The primary advantage of AVHRR imagery is that the imagery is acquired for all lands (wall to wall) on a daily basis. This presents a low cost alternative to TM imagery, and the frequent availability makes it more likely that cloud free imagery will be available for any given target area close to any given target date. The primary weakness of AVHRR imagery is the lower resolution (1 km pixel size vs. 30m for TM), which leads to much coarser interpretability and less precision than interpretation TM imagery. The wider angle and interference of atmospheric effects cause problems with interpretation near to the edge of images. Thus, while AVHRR may be very suited for change assessment in large (e.g. regional) areas, it may not be so useful for assessment at the national level, particularly for small or medium sized land areas

3.3 Existing country level inventory data

Many countries have in place systems for monitoring their forests on a periodic or occasional basis. Other countries have conducted studies of subsets of their forests, or complete or partial forest inventories sponsored by a variety of donor organisations. The result is a huge set of information regarding status and trends in forest statistics at the national and sub national level. FRA 2000 professional staff have been working for years to make and keep current a metadata base describing what data exist, by country, throughout the tropical world, as well as archiving the actual data in the FORIS (Forest Resources Information System) database. Regional specialists travel to the countries in their region, gleaning available information and assembling it for potential incorporation into the FRA 2000 and future studies. FRA will make these data available, along with appropriate metadata, via the World Wide Web.

The strength of using data reported by countries is that results tend to be of higher precision than results from studies conducted at the regional scale. National forest statistics would be harmonised with other reports and analyses produced by and used in the target country, increasing consistency between FAO and National reports. Presumably, forest statistics gathered at the National level would be overseen by experts with more familiarity with the target country and with more time to spend on a single country, which should lead to improved data quality. The primary weakness with the aggregation of country level is that there is tremendous inconsistency and incompleteness in country inventory data, both within countries over time as well as between countries. Assessments are conducted with different objectives and populations of interest, using different definitions, standards, sample designs, and field methods from those used by FAO or by neighbouring countries. The results can be difficult to interpret and harmonise for comparison across countries, as FRA must do. Additionally, many countries particularly in Africa simply lack the resources to conduct forest assessments, so that data are lacking.

3.4 Models to derive forest change as a function of other attributes

The strength of the modelling approach used already in FRA1990 is that it provides a platform for generating estimates for all countries regardless of availability of country level data. Data gaps would simply be modelled by more generalised functions. Generation of models is a useful exercise in that it forces study of cause and effect relationships and can lead to insights regarding true mechanisms or drivers of forest cover change, which in turn could lead to better investment decisions by national governments seeking to manage their forests. The results of existing models are probably reasonable at the global level. However, the greatest weakness of the modelling approach continues to be inadequacy of existing models when applied to specific countries. The process of deforestation is such a complex process, involving physical, climatic, political, and socio-economic forces which are themselves very complex, that simple generalised models of forest change have so far not been developed. Current models are oversimplified and yield similar predictions of forest cover change rates for countries which are known to be very different. More complex models are yet to be developed and tested.

4 New methods

4.1 Remote sensing

The most straightforward way to intensify Remote Sensing based approach is to maximise the coverage of TM figures to cover up to 100% of the tropical belt. This, however, would require plenty of resources for purchasing the data and staff for working on it using present visual interpretation approach.

There are other potential useful sources of remote sensing imagery which may be incorporated into the final analysis. In 1999 FRA commissioned a global forest cover map to be produced by the Eros Data Center (EDC) of the US Geologic Survey (USGS). This map, based on AVHRR coverage, provides a global snapshot of forest cover at a relatively coarse scale. There are also other AVHRR –based forest cover mapping projects ongoing (see for instance http://fellini.gvm.sai.jrc.it/trees/ or http://www.geog.umd.edu/tropical/main.html.

The primary advantage of increased use of satellite imagery is that it provides a tool for objectively filling in existing data gaps by use of an information source which is universally available. Linking TM and AVHRR data - using multi-stage or multi-phase sampling or ratio estimates - would be objective and simple to implement once the data and methods were available. The primary weakness of this approach is the lack of existing strong relationships between TM and AVHRR. Significant amounts of research have sought such correlations, with mixed results. Correlations may not be universally strong enough to act as a reliable source for filling in data gaps.

4.2 Formalizing Expert Opinions

Given the lack of globally consistent forest inventory data, some kind of synthesis based on partial data plus expert opinion is not an unreasonable way to arrive at answers. Certainly expert opinion can be subject to bias and imprecision; yet it will generally be better than no information at all. Two of these methods are the Delphi Technique and Convergence of Evidence.

4.2.1 Delphi Technique

The Delphi Technique applies elementary statistics to a sample of expert opinions in an iterative fashion, with the intention of eliminating outliers, providing feedback, and converging to a level of consensus. The technique was originally developed for making forecasts of socio-economic trends and has since been generalized for use in a variety of estimation or problem solving situations (Sackman 1975).

The original Delphi Technique had several distinguishing characteristics. A pool of experts was chosen to make predictions on some topic. However, rather than assembling the group together, each group member was asked to submit their estimates anonymously, to avoid the chance that more prestigious or dominant group members would unduly influence the estimates made by other group members. The set of estimates was then averaged, and individual estimates which were outside some range of standard error were returned to the expert who had submitted it along with a request for justification or for a new estimate. The process would iterate several times until all there were no further changes in individual estimates, at which time a consensus estimated would be adopted.

Advantages of the Delphi Technique are that it will always provide an answer in the time available, and that it takes advantage of expertise and experience which may be relevant but non quantitative. Disadvantages are that the method may lack repeatability, and that the quality of the answers depends heavily on the quality of the experts. In our case, it may be difficult to find a qualified pool of experts for each of the many countries for which we wish to derive estimates.

4.2.2 Convergence of Evidence

A second qualitative technique called Convergence of Evidence is currently used by the Foreign Agriculture Service of the US to produce annual assessments of agriculture crops in major producing or consuming countries of the world. Whereas the Delphi Technique relies on a group of experts arriving at consensus based on their (somewhat different) experience, Convergence of Evidence instead relies on a single expert who has at their disposal a variety of independent or quasi-independent information sources regarding the parameter of interest (Roke 1999, www.fas.usda.gov/pecad/who_what.htm).

For example, for estimating future wheat harvest in country X, an analyst has at their disposal historical records of past crop yields, recent weather data affecting the current year's crop, short term future weather forecasts, historical land ownership and farming data, agricultural statistics and forecasts produced by country X, and satellite data at different points over the current growing season showing potential areas and biomass accumulation of the target crop. The analyst synthesizes this information internally, using their experience and knowledge for assigning more weight to information that they feel is more reliable and arriving at a final answer. Ideally, over time, the expert has a chance to validate their estimate against a future measurement, allowing for learning over time.

This technique most closely resembles the methods used in the 1980 Assessment, where a small group of individuals immersed themselves in various available data sources. This trend continues to some extent in the current FRA 2000 where a small group of regional analysts are compiling, interpreting, and preparing to analyse regional and country level data. Clearly, the quality of the estimates for each country relies heavily upon the expertise and experience of the analyst.

One advantage of this method is flexibility in that estimates can be derived when the data sources vary in availability and quality from country to country. Like the Delphi technique, an estimate can be generated for every country and can be completed within a finite time window, recognizing that lack of time can limit the depth of the analysis. Disadvantages of this approach are dependence upon the skill of a single expert which can readily lead to bias, imprecision, and lack of repeatability.

5 Recommended Methodology for FRA 2000

An international panel of experts in forest assessment met in March 2000 to review progress and plans for completing FRA 2000, and to make recommendations for how the final results could be completed by the deadline of December 31 2000. The group reviewed the available sources of data and the proposed methods for combining the data, proposed additional data sources and analysis methods, and evaluated several alternatives for both scientific rigor and for practicality within the time and resource constraints. Criteria used to evaluate the alternatives included (1) statistical accuracy and precision of estimates, (2) ability to be used within available time, resource, and data availability constraints, (3) degree of general scientific acceptance of methods, (4) degree of transparency in methods, (5) ability to yield estimates for all countries of interest regardless of data constraints, and (6) simplicity.

After significant debate, the Panel recommended a combination of the Delphi Technique (an iterative process using blind expert opinion to refine estimates) and a Convergence of Evidence (a method for weighing and combining different sources of information to arrive at a single country level estimate). The recommended approach uses a small group of experts to weigh the different available data sources for each country and attempt to arrive at final estimates. The experts are led in each region by the FRA Regional Coordinator. The Coordinator summarizes all available information (from TM image analysis, country reports, relevant models, other satellite imagery, etc.) and derives an initial estimate or range of estimates for each country, explaining their decision process and documenting the weight that they assigned to the various available sources of information. They then share the results with the small set of regional or country level experts to validate the results, asking the other experts to critique the reasoning or assignation of weights in the production of country level estimates and attempting to seek some consensus on final estimates. The process is illustrated schematically in Figure 1.

All available data will be used in the process. However, there were some observations and recommendations regarding the reliability of data sources. The use of AVHRR data was to be carefully considered, since the observed low correlation between FRA TM data and AVHRR map, especially on dry and semi-dry lands in the Tropics. Therefore, the panel recommended FRA2000 to consider an additional sample of TM images to complete FRA2000 change assessment in Africa where other sources of data are very limited. The change model based on population, due to its limitations mentioned earlier, was recommended to use only as ancillary data in cased of very poor quality data from other sources.

The primary strength of this combined approach is that it allows the flexibility to include a variety of information sources assessed by people familiar with the situations in the countries, while mitigating some of the disadvantages inherent in relying on a single expert to integrate the data sources. This approach makes maximal use of available information, which varies from country to country. It allows incorporation of experience and qualitative information which is relevant but is normally not considered by more objective, purely quantitative analyses. The validation procedure adds a second set of information useful for comparative purposes or for calibration.

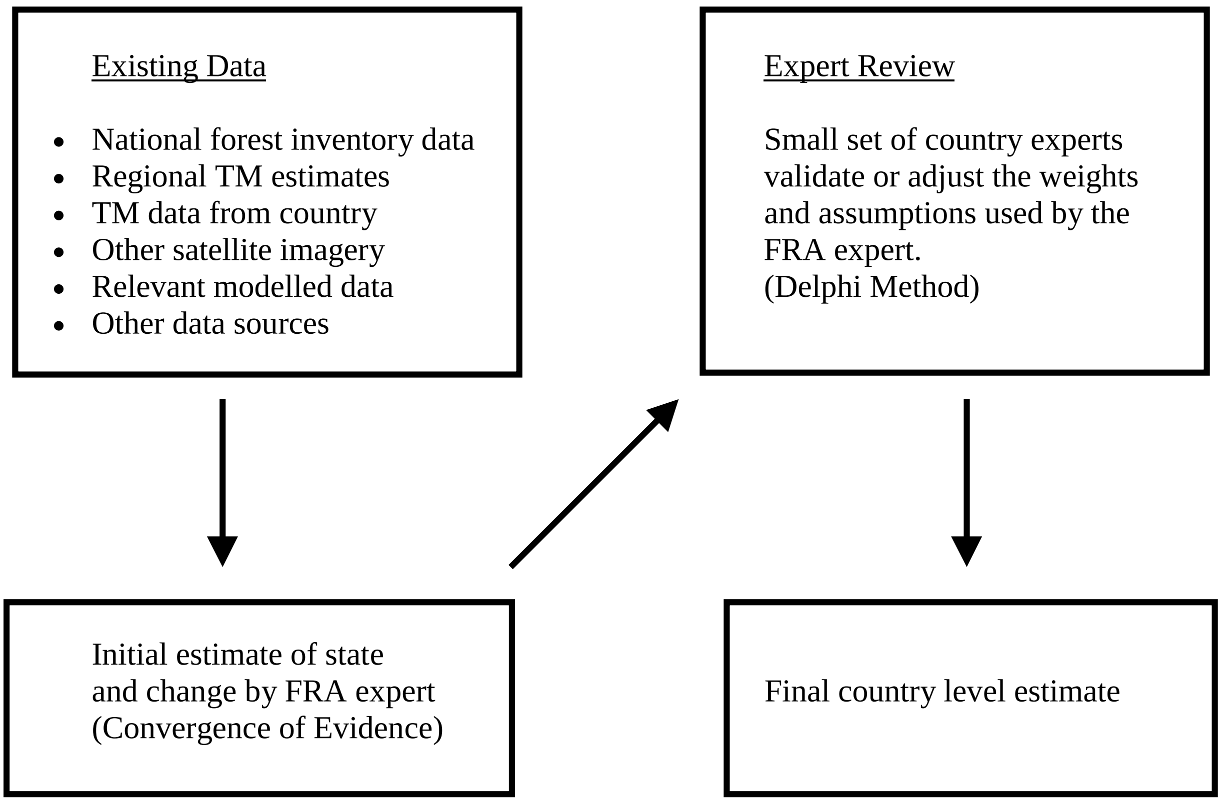
The primary weakness of this approach is the reliance on sufficiently diverse group of experts to add value in each country, and the unavoidable reliance on the availability of expertise and data. Time and resource constraints may limit the ability of FRA staff to seek sufficient input for each country. This difficulty could be partly mitigated by conducting a triage, whereby certain countries with known strong data were given less discussion, and countries with weaker data had more attention. Triage might also include stratifying countries by amount of forest cover to ensure that countries with the most forest are examined more closely, in order to minimise the chances of making relatively larger estimation errors.

6 FRA Beyond 2000: Towards a World Forest Survey

Since 1996, FAO has worked toward the development of a continuous monitoring programme of forests at the global level, or World Forest Survey (WFS). This programme is intended to extend a statistical sample over the entire world following new stratification criteria to improve its efficiency. At present, due to several technical and financial considerations, a phase-in of the new long-term Global Continuous Monitoring Programme is being envisioned along with the implementation of the 2000 Update for the year 2000 assessment. Ultimately, the WFS will provide continuously updated country level data, with global reports and analyses published at 5 year intervals In this document, we concentrate on the tropical FRA2000, but keeping the development of a global monitoring programme in mind for after the year 2000.

The participants in the Expert Advisory meeting reviewed the current state of FAO thinking on the WFS concept and agreed that the FRA program of the FAO should take the lead in developing a proposal for a World Forest Survey. The proposal should identify the potential customers, costs and benefits of such a system. A logical first step in such a process should be to further identify potential WFS customers and their needs. It was further agreed that the FRA team should prepare a technical document on the WFS concept, to be shared with the global forest monitoring community and that a future Expert Advisory meeting should be called to help move the concept towards implementation.

Figure 1. Schematic diagram showing the steps used to take available data and arrive at a final country level estimate.



References

Lanly, J.P. 1982. *Tropical forest resources*. FAO Forestry Paper 30, Rome.

Palo, M. 1986. "Deforestation perspectives for the Tropics: provisional theory with pilot applications" In: *The global Forest Sector – an analytical perspective*. Wiley – interscience. pp. 57-90.

Päivinen, R and Gillespie, A.J.R. 2000. *Estimating Global Forest Change 1980 -1990 – 2000* A background document prepared for an international panel of experts convened to review methods to be used in completing the FAO Global Forest Resource Assessment (FRA) 2000. Rome, March 2000.

Roke, Tim. 1999. *Personal Communication - Methods used by the US Foreign Agriculture Service for predicting crop yields in foreign countries*. Information available on their web site at www.fas.usda.gov/pecad/who_what.htm

Sackman, H., *Delphi Critique*, The Rand Corporation, Lexington Books, 1975.

Scotti, 1990. *Estimating and Projecting forest area at global and local level : a step forward*. Unpublished FRA1990 Project document, November 1990. p. 22

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