Design of a Global Tropical Forest Resources Assessment

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ABSTRACT: An outline of the survey design proposed for The FAO Forest Resources Assessment 1990 Project, intended to assess the current status of forest resources in the tropical countries, estimate changes during 1981–1990, and build alternative scenarios about the forest resources situation by the year 2000, is presented. The following aspects of the project are discussed: objectives, output, and survey design. The statistical design, data collection, and analytical procedures are described in detail with a view to obtaining feedback from the research community.

INTRODUCTION

CONCERN ABOUT THE DEPLETION AND DEGRADATION of the world's tropical forests and woodlands led to the FAO/UNEP Tropical Forest Resources Assessment Project, which was carried out from 1979 to 1981. The project covered 76 tropical countries and provided a set of statistical data in a standard format on the present situation and observed trends.

The need for updating the baseline information, in order to keep governments and the international community informed of the current state of tropical forest resources and the nature of their changes, was discussed at the fourth and fifth meetings of the Tropical Forestry Action Plan Advisers (Rome, May 1987, and Brussels, December 1987). As a follow-up to these recommendations and those of its Statutory Bodies, FAO initiated planning of the current project.

To prepare the project concepts, an expert consultation was organized at Kotka, Finland, 26–30 October 1987. This meeting was attended by 40 experts, representing a cross section of specialists from the tropical and temperate countries, national and international organizations, and governmental and non-governmental bodies. It resulted in a set of recommendations covering various aspects of the present assessment, *viz.*, classification system, definitions, procedure, and output.

Following the recommendations of the Kotka Meeting, FAO prepared a project document for the Forest Resources Assessment 1990 Project, which formally started in March 1989.

OBJECTIVES

The project is formulated within the framework of the Tropical Forestry Action Plan with the following general objectives in view:

- Assisting member countries and the world community in reviewing policies, promoting cooperation, and taking appropriate action for conservation, development, and management of tropical forest resources;
- Supporting studies of regional and international nature requiring country level forest resources information in a common format; and
- Developing national capabilities for periodic assessment and monitoring of tropical forest resources.

Keeping the above long-term objectives in view, the project is expected to carry out the following specific tasks:

- Based on the existing reliable data, make a statistical assessment of the forest resources of the tropical countries for the reference year 1990 and estimate changes that have taken place since 1980;
- Using low resolution satellite data, make an estimate of forest cover area by the end of 1990;
- Using multi-date high resolution satellite data, make an estimate of changes that have taken place during 1981–1990;
- In a common statistical frame, combine the remote sensing based estimates of forest cover area and changes with those obtained from existing reliably collected data;
- Computerize the data collected for easy storage, retrieval, analysis, and processing; and
- Disseminate the methodology of assessment and the database to the international community.

EXPECTED OUTPUT

Main output of the Project will be the following:

- a statistically reliable, up-to-date, and comprehensive database on the state of forests and forest management in the tropics to assist member countries and the world community in reviewing policies, promoting cooperation, and taking appropriate action for conservation, development, and management of forest resources;
- interpreted remote sensing images and observed permanent sample plot data to assist a time series analysis of forest changes;
- provision of computerized vegetation and eco-floristic zone maps to localize forest cover and forest disturbance areas and integration of this information with other databases for the study of environmental impact on a location specific basis in the tropics;
- detailed data on forest changes (deforestation and forest degradation) on a sample basis for correlating this information with socio-economic factors, and planning action to control deforestation and degradation;
- a package of appropriate methodology for varying ecological and economic conditions to undertake *Global Continuous Forest Resources Monitoring* and *National Continuous Forest Resources Monitoring;* and
- national capabilities strengthened for undertaking *National Continuous Forest Resources Monitoring* in the developing countries.

SURVEY DESIGN

The Forest Resources Assessment 1990 Project includes three inter-related modules:

(a) Satellite remote sensing study of recent changes;
(b) Historical forest change study; and
(c) Study of forest change correlated with other related factors.

These modules mutually reinforce each other and constitute parts of a holistic design to understand the process of deforestation in the tropics in a comprehensive manner.

SURVEY OBJECTIVES

The primary objectives of the remote sensing study are to make reliable estimates of forest cover area in the tropical zone of the world for the year 1990 and of the rate of changes in the forest cover area during 1981–1990. To achieve these objectives in a cost-effective manner, use will be made of the following types of satellite data: (a) coarse resolution satellite data (CRSD: NOAA AVHRR) and (b) high resolution satellite data (HRSD: Landsat MSS/TM, SPOT).

The estimate of forest cover area and rates of changes and of

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their reliability will be made with help of a classical multi-phase sampling design.

Definition of Sampling Units

The tropical zone, for the purposes of the remote sensing survey, is divided into sampling units coinciding with the Earth's surface covered by nominal Landsat scenes, indexed in the Landsat Worldwide Reference Systems (WRS) by the United States Geological Survey. The location of these scenes is identified by three digit path and row numbers, which uniquely identify sampling units.

Definition of the Phases of the Study

The remote sensing study will be carried out in the following three phases:

(1) *Survey of all sampling units with help of CRSD*
CRSD is expected to provide two sets of "statistics" (or "indices") correlated with forest "cover area" and with "cover change," respectively, for all the sampling units of the survey area. These statistics will be obtained for the following two purposes: (a) Stratification of all sampling units and selection of a sub-set of them for the second phase sampling; and (b) study of the correlation between CRSD and HRSD for the selected sampling units, using ratio and regression techniques.

An essential requirement for the second phase sampling is the availability of cloud-free images. If a sampling unit selected has no two cloud-free image sets (for change assessment), an alternative sampling unit will be selected. This process will be continued until the strata have the required number of cloud-free images.

(2) *Detailed study of the selected sampling units with help of HRSD*
The second phase has two purposes: (a) estimation of forest cover area close to 1990 and (b) estimation of the forest cover area changes during 1981–90.

The first objective requires data from the most recent image only, whereas the second objective requires a multi-date analysis with one date close to 1990 and the other close to 1980. As "change" assessment is the dominant objective, all the second phase sampling units should have multi-date images.

(3) *Field studies*
The third phase will consist of field sampling. An adequate number of field samples and their distribution over various strata will be decided after review of the first and second phase results. This phase should not be seen as pure validation, but a source of statistics for correlation with the second phase.

Ultimately, all the data collected in the three phases will be combined statistically to produce forest cover area and change estimates section.

Sampling Intensity

The average annual rate of deforestation in the tropics, compared to the total forest area at a particular date, has a magnitude of the order of about 1 percent on a global basis. Generally, a very large number of samples is needed for precise estimation of any attribute that is rare in the population, such as deforestation.

As an example, for estimating an annual change of 1 percent, we must have the number of samples approximately equal to 9800 in order to achieve the standard error of ± 20 percent at the 95 percent confidence level. In case the change estimation is made not on an annual but on a periodic basis (e.g., using periodic satellite data), the number of samples required is significantly reduced. If the population is stratified, using some prior information about deforestation, further economy in sampling can be expected.

The standard error of the estimate also depends on the chosen size of the sampling units. Usually, the sampling error decreases in proportion to the square root of the area covered by a sampling unit. If change estimation is made by Landsat imagery, one scene will cover an area of approximately 3.2 million ha; a SPOT scene will cover an area of 0.36 million ha.

Assuming that the sampling will be done with the help of Landsat imagery, a 10-year time interval, and gains due to stratification, the number of samples required to make a global deforestation estimate within a standard error of ± 10 percent at the 95 percent probability level is estimated around 600. This would call for 1200 satellite scenes at the rate of two multi-date scenes per sample location to estimate changes, combined with another source of information such as NOAA AVHRR data to stratify the sampling units.

The relatively high costs involved in acquisition and interpretation of multi-date high resolution satellite data and the associated time to complete the work suggests that we keep, for the time being

- the assessment of a global mean (with confidence limits of ± 10 percent at the 95 percent confidence probability level) as our target;
- 10 years as average time interval; and
- stratification by NOAA AVHRR imagery as the main means to reduce variance.

Further consideration needs to be given to how to organize multi-date remote sensing and field sampling. This is impossible without the full cooperation of regional and national centers for remote sensing and of the concerned countries and will necessitate an early consultation with them about their participation in the monitoring at the design stage.

Involvement of the countries in monitoring would also facilitate socio-economic and ecological analysis of changes and the taking of remedial action. With their cooperation, a nucleus could be established which would continue monitoring, evaluation, and action planning activities not only in 1990 but in the future, too.

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