Natural Resources and Environmental Issues

Volume 2 *Mapping Tomorrow's Resources* Article 8

1993

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Abstract

Global assessments and monitoring are essential if we wish to be able to manage our human destiny. Periodic worldwide estimates of forest resources are the responsibility of the United Nations Food and Agricultural Organization (FAO). Other groups are also making regional estimates of forest cover. Techniques used include aggregation of national data and individual efforts. Results of either process are currently inadequate. Problems with both techniques are presented. Solutions include multiple-resource inventories, covering all lands and performed to international standards and guidelines.

INTRODUCTION

The earth's forest resources provide vital food, fuel, and fiber for an increasing world population. Forests account for about two-fifths of the world land area. In the late 1980s, the direct annual contribution to the economies of developing countries from the forestry sector was about $105 billion (Roberts, Pringle, and Nagle 1991). Forests are both carbon sources and carbon sinks. They serve as filters for the air we breath and for the water we drink. Forests provide critical habitat for diverse flora and fauna that may prove vital for human survival in the future. Forests are also places of recreation, worship, and strength for the inner body.

Forests are also the center of many national and international controversies. Social, economic, and environmental problems in one country can affect the forest resources in another. Drought and civil war in one country, such as Ethiopia, cause populations to move to other areas, such as the Sudan. In an underdeveloped country like Sudan, which cannot support its own increasing population, this emigration creates even greater demands on the land for food and fuel. These must come from the forested lands. Drought in Sudan, coupled with increased deforestation and overgrazing, has reduced the capacity of the land to support its own people much less the immigrants from Ethiopia. As a result, there is also social unrest in Sudan.

Emissions from industrial countries in the temperate areas have been blamed for forest damage in the boreal regions. Currently, the boreal regions are exporters of timber. If emissions are not reduced or if damage should become more severe, the boreal regions may have to start importing. This will put strains on other nations' forestlands.

The setting aside of large land areas in the United States for wilderness and to preserve endangered wildlife species reduces the timber-producing land base. If the U.S. population continues to increase, so will the demand for wood and wood products. To meet these demands, supplies must come from either more intensive use of our private lands or from forest resources abroad, including the tropics.

Deforestation in the tropics may cause global warming. Global warming, in turn, will affect the productivity of forested areas in other parts of the world.

Indeed, the amount and condition of the world's forests are important issues. Unfortunately, global forest resources are dwindling at unprecedented rates in the tropics and are losing diversity and productivity in other areas. The world's forestland must be assessed and monitored. We must establish what we have, determine the trends, and gather data necessary to develop sensible management plans.

Before we go further, however, we need to define some terms:

1. *Politically correct:* Subscribing to an ideological view that has become dominant. To oppose it becomes a subject not open to argument.

2. *Politically correct global monitoring system:* A system in which individual nations and international organizations work cooperatively to produce periodic estimates of the state and trend of the earth's resources. The results are acceptable to all parties involved.

3. *Inventory:* The accounting of goods on hand. Often used as a baseline for subsequent monitoring efforts.

4. *Monitoring:* The periodic measurement or observation of selected physical, chemical, and biological parameters for setting up base lines and for detecting and quantifying changes over time.

5. *Plot:* A known location on the earth's surface having defined boundaries or a point of origin. A *permanent plot* is established and documented in such a manner that one can remeasure the exact area and the same objects at a later time (Lund and Thomas 1989). A plot may not have to be located physically on the ground. One could identify an area on imagery and repeatedly observe the same area over time. Plot size may range in size from 0.1 hectare to a pixel to a Landsat scene to a whole continent, depending on what is to be monitored.

This paper examines current monitoring efforts, identifies problem areas, and offers recommendations for moving toward a politically correct global monitoring system.

CURRENT GLOBAL MONITORING

Because of the recent concerns about environmental issues such as deforestation and global warming, several groups are working to get estimates of planetary carrying capacity and change. These groups include the United Nations Food and Agricultural Organization (FAO) and the European Economic Community (EEC) working in cooperation with FAO. FAO has the mandate to conduct global forest assessments and monitoring (Singh 1992). Obtaining estimates of forest cover and production over the entire earth requires time, coordination, and funding—all of which are often in short supply.

Other groups, such as the European Community TREES project, Conservation International, the United Nations Environment Program, Woods Hole Research Institute, and International Space Year's World Forest Watch, are conducting regional assessments and monitoring programs to speed up the availability of information. In addition, most, if not all, nations conduct their own inventory and monitoring programs. Unfortunately, many of these activities are not coordinated with FAO and contribute little to the total knowledge base needed.

MONITORING APPROACHES

All monitoring efforts involve comparing data from two or more points in time. The comparison data may be in the form of statistical summaries, maps, or remote sensing products. In the past, data were stored in tables and reports. Lately, the trend is to store data spatially in a geographic information system.

The source of baseline information and later assessments may result from aggregation of existing national information in a participatory mode or from a single data collection effort covering many nations.

AGGREGATION

Aggregation of existing information or subinventories is by far the most common monitoring approach for forest assessments of large countries like the United States and Canada and for developing global assessments like those of FAO. A central unit specifies the information needed in the form of tables cooperators must complete. Participating elements collect the data for their areas of responsibility and provide summary information to the coordinating unit. Baltaxe (1992) refers to this method as a bottom-up approach. Even though forests occupy two-fifths of the world's land area, the forestry sector receives only about 4.5 percent of the total FAO budget (Roberts, Pringle, and Nagle 1991). Only a portion of that is allocated to global monitoring. As a result, FAO must rely on cooperation with other countries for forest assessments.

If the collaborating units belong to the same organization as the central unit, there can be strong control. The directing organization specifies end product, sample designs, and data collection techniques and standards. If the participating elements belong to different organizations, such as those found in Canada and Tanzania, the control is less stringent. The accumulating organization specifies data required and indicates when they are required. Participating elements are free to use whatever data collection method they wish, as long as they can provide the necessary data to the required standards needed by the head organization. This is the technique EEC/FAO uses for global assessments of the temperate zones, and it is the most politically acceptable form of global monitoring.

Through the aggregation process, there are

1. Fewer effects on the cooperators. They are free to use whatever techniques are suitable for the environmental, physical, and economic situations they face.

2. Fewer opportunities for conflicting data as the cooperating units provide the data for their lands.

3. Lower costs to the central unit as most of the expense is borne by the participating units.

Aggregation and participatory assessments and monitoring are the most politically acceptable to all parties involved. However, there are some disadvantages:

1. Collaborating elements or the head unit may have to do considerable manipulation of the data before they can be combined and used for national reporting.

2. Data may not be truly additive because of the different standards and techniques used.

3. The quality of the final report is only as good as the weakest participating group.

4. Data from participatory nations are not spatially located. The use of the information in a geographic information system (GIS) is limited.

From a national perspective, aggregation is the most desirable method. Some nations, however, may not take part for several reasons. The country may feel that it already has adequate statistics and that a new effort is not warranted. The country may not have the technology, people, funding, or time to carry out a new initiative; or the country may have statistics that it has been using as a basis for planning, funding, and reporting. New information, contrary to what has been previously reported, may be politically embarrassing to those in power.

Single Effort

Nationwide inventories conducted in one single effort are common in relatively small countries such as Taiwan and Morocco. Lately, the individual effort has become very popular to speed up the effort for collecting multicountry data and to provide maps and spatial databases of the forest resources. Groups using the single effort include the European Community TREES program, United Nations Environment Program (UNEP), Woods Hole Research Institute, Conservation International, and others. Baltaxe (1992) calls this the top-down approach.

Mapping-based inventories rely on remote sensing (aerial photography or satellite-based imagery) to produce type maps or digital databases of forest cover. At a minimum, image interpreters use ground truth to help with the classification. In this case, the primary products of the inventory are the type map or digital database and estimates of forest area. More sophisticated designs use the mapping in poststratification of randomly selected field plots, yielding both maps and the more traditional biomass statistics.

The advantages of the single effort are that the process is fast and that all data are collected within the same time frame and to the same standards. Control is simple and the processing is cost-effective. In addition most data are spatially located, providing direct input to GIS.

Many single-effort, regional-monitoring projects involve wall-to-wall mapping of the forest vegetation. Most statistics developed from aggregation of existing data rely on statistical samples for area estimates. Everything else being equal, one would anticipate better area estimates from the mapping effort than from the sampling method.

Another advantage of the single method, or any method that uses remote sensing for establishing a base, is that if one can find older imagery of the same area the images may be used to detect changes and to predict trends. One may use today's technology to analyze yesterday's imagery.

To date there is no worldwide, individual monitoring activity, although it is probably just a matter of time until there is one. The technology and people having the skills are available. All that is required is time and funding.

Most current, so-called global monitoring efforts concentrate on the tropics and most are independent of one another and uncoordinated (Jaakkola 1992, Stone and Schlesinger 1992). Tschinkel (1992) reports on nine separate efforts in Central America alone. Many of these efforts cover the same area as one another and as available local (national) inventories. As a result, there are confusing and contradictory statistics and maps produced.

There are several reasons for the duplication of inventories and monitoring efforts:

1. Existing work is often out of date or does not answer the questions being asked. A new effort to provide current data is needed and warranted.

2. For one reason or another, the existing work is questionable or not trusted. There is a tendency not to trust government statistics. In reality, however, government statistics may be the most valuable data source.

3. The existing work may be unknown.

4. Researchers want to test new techniques.

5. The survey is not intended to provide objective data. Its main purpose may be to draw national and international attention to gain support for a particular cause.

Knowledge of local conditions is essential if the project is to be successful. Ground truth collected through permanent field plots is needed to determine the accuracy of the databases and to provide information not available from the remote sensing. National participation is certainly desired for these activities.

A primary disadvantage of the single effort is that statistics weaken the further one stratifies the data. For example, if a project involves several countries, the statistics for a specific country may be very poor. In addition the single effort may not make use of good existing information. The results may conflict with existing data at the local or national scale. This can place the local forestry agency at odds with the group conducting the survey. Special-interest groups can then highlight such discrepancies to promote their cause thereby fomenting further discontent.

Avoiding Conflicting Data

Conflicting data are generally not politically correct or acceptable. One may avoid conflicting data if

1. International groups do not report data at the country level

2. All parties develop and use a hierarchical classification scheme that incorporates both global and local standards

3. All parties report statistics separately and clarify any differences if data appear to conflict

COMMON PROBLEMS

There are two major problems concerning regional and global monitoring efforts regardless of whether we use aggregation or individual efforts. These include misinterpretations of data and incomplete information.

Misinterpretations of Data

In the past, most monitoring consisted of periodically comparing aggregations of country statistics over time. With the advent of satellite-based remote sensing, international organizations have been able to assess and map large areas independent of country involvement. Some recent estimates of change have resulted from a comparison of aggregated data with the more recent remote sensing-based estimates. This poses some problems because not only are we comparing data from two points in time we are also comparing data collected by different sampling methods and standards. Consequently, one should view and report the results accordingly. One must determine if the changes are due to actual changes in the resource base or to changes in the technology and standards.

Changes in Techniques

If two people independently map or randomly sample the same area at the same time using identical techniques and standards, the results will differ although the difference may not be significant. If one samples the same area at the same time and even measures the same locations, the totals for the inventory unit may vary depending on the sampling scheme used (Lund and Thomas 1989). Therefore, if we use different techniques at different points in time, we would logically assume there would be differences in the totals reported for each measurement occasion. The question then is this: Are the differences due to changes in the techniques or in the resource base? To avoid this question in the future, we should use the same sampling scheme and permanent plots on both occasions.

Changes in Definitions and Standards

If we used the same sampling design and plots on both occasions, there could be differences in the reported results due to changes in definitions and standards. For example, assume that on the first occasion we tallied trees only if they were 5 meters in height or greater. Further assume that on the second occasion we change the threshold for tallying trees to 7 meters in height or greater. Intuitively, we may expect the results from the second occasion to show less volume than the results from the first occasion.

The definition of *forestland* may also cause problems in comparison of inventories and monitoring. This is especially true where international organizations sum data from national assessments to yield global statistics. In the United States, for example, forestland is an area 1 acre in size or greater and at least 10 percent stocked by trees of any size or formerly having had such tree cover and not currently built up or developed for agricultural use. A tree is defined as a woody plant usually having one or more perennial stems at least 3 inches d.b.h. at maturity, a more or less definitely formed crown of foliage, and a height of at least 16 feet at maturity (USDA Forest Service 1989). This definition includes lands recently harvested or burned over that will be used for forest production but excludes orchards and trees in urban areas.

In Mexico forestlands are any areas that are not in agriculture or urban.

FAO has an international definition. Forestlands are areas exceeding 0.5 hectares in extent or greater with tree crown cover more than 20 percent of area. Trees must be capable of reaching 7 meters in height or greater (Wardle and Padovani 1990). This would include plantations, orchards, etc.

If we were to use Advanced Very High Resolution Radiometer (AVHRR) imagery to classify lands, in all probability we would define forestlands as areas 1 square kilometer in size or larger and stocked with trees having at least 20 percent canopy cover. Lands recently clear-cut and not restocked with trees at the time of data collection would not qualify as forestland.

One can easily see from the above that the estimates of forestland would vary simply by changing the definitions, standards, and technology used. We can overcome some definition problems by statistically field sampling all strata with permanent plots. We use permanent plots to estimate land-cover changes between inventories, to set up a basis for long-term study of the effects of climate change, to monitor response to treatments, and to construct growth and yield predictions (USDA Forest Service 1992). International agencies may use networks of permanent plots to model biological, socioeconomic, and political factors that affect deforestation and eventually reforestation and afforestation. Global positioning systems can be used to accurately determine the location of field plots, thereby linking imagery with ground data in a GIS.

Incomplete Information

Most so-called global efforts focus on forest extent. Area information alone does not resolve issues of biodiversity and carbon storage. A network of permanent field plots will provide details that cannot be extracted from remote sensing.

Until about 1980, most national inventories of forest resources emphasized estimating the amount and extent of the timber resource. Since that time, public interest has placed increasing emphasis on the need to manage public forests for a variety of purposes and to recognize uses that have been ongoing since humans first set foot in the forests. In addition decision-makers are using national inventories for environmental monitoring both at the local scale and at the global level. New needs include information on woody and nonwoody vegetation (kind, extent, production, and condition), soil stability and productivity, water storage capabilities, and wildlife habitat extent and quality on all lands.

OUTLOOK FOR THE FUTURE

We can safely predict that the earth's population will continue to increase and that our land base will remain essentially the same. There will be more pressure on our lands to produce more goods and services. With this pressure it will become increasingly important to maintain or improve soil, water, and air quality. This is most easily achieved by maintaining or increasing world vegetation cover. Within vegetation cover it will be increasingly important to maintain or increase biological diversity and to support economic diversity of the local population. More knowledge about our resources and lands and how they react to various management activities will become increasingly important if we are to support this diversity at the local, national, and global levels. The demands for accurate, spatially located information will increase the use of geographic information systems.

We can also forecast that our technical capabilities to inventory and monitor the lands and resources will also improve. The resolution, spectral separation abilities, frequency of coverage, and overall availability of satellite-based, remote sensing systems will increase. Mapping and monitoring of our resource base will be essential. Our inventories will eventually cover all lands and resources and account for every hectare.

International organizations and cooperating nations need to be working with FAO toward a common goal—that is, to provide a complete picture of the status and trend of the world's forest resources. To do so we need to look at all functions of the forests and the relationship of forestlands to other lands and uses as well.

Multiple-Resource Inventories

Multiple-resource inventories (MRI) are data collection efforts designed specifically to meet all or part of the informational requirements for two or more functions or sectors (Lund 1986). They offer advantages over single-functional inventories in that MRI are more economical and provide more comparable data across the inventory unit.

Resource specialists have conducted multiple-resource inventories on forestlands and rangelands in the United States for some time (McClure et al. 1979). Foresters have also conducted multiple-resource inventories in Sudan (Lund et al. 1990), Tanzania (Mgeni 1990), and Australia (Vanclay 1990). Satellite-based imagery, global positioning systems, and geographic information systems have been used successfully in some of these efforts.

Holistic Needs

Not only are multiple-resource inventories needed, but today's decision-makers at the national and international level need holistic inventories of all lands and resources. This is especially true when we want to monitor changes in land use and productivity. There is too much interaction and interchange of uses between agriculture and forestlands, for example, to consider them in separate inventories or monitoring efforts. In the tropics, farmers are rapidly converting forestlands to agriculture. One way to reduce this is to improve yield from the agricultural lands. Thus, the decision-maker needs more information on existing agriculture lands. On the other hand, many of the agricultural lands in the temperate and boreal areas are being converted to forests. The decision-maker needs to know the capability of the agricultural lands to sustain given tree species.

In Sudan, for example, forestlands are defined the same as they are by FAO. However, the Sudanese foresters are equally interested in finding lands that once were forested but are no longer. These are lands where reforestation methods may be most successful. Similarly, at a recent ASEAN Seminar on Land Use Decisions (ASEAN 1992), member countries recommended the development of integrated land-use policies and examination of nonforestlands for conversion to forestlands to take pressures off natural areas. In order to carry out such recommendations, one must conduct integrated or multiple-resource inventories across all lands.

Global Connections

Because funds for such activities are limited, cooperation between national and international groups is essential if we are to get a complete picture of what is happening to the earth's limited resources and precarious environment.

If the most politically acceptable global monitoring is the aggregation or participatory method, nations must have guidance on how to design their monitoring efforts. If the single approach must be used, coordination and standardization among groups doing multicountry estimates are needed if we are to get a complete and understandable picture of the earth's resources.

At the endorsement of the Food and Agriculture Organization of the United Nations, the International Union of Forestry Research Organization (IUFRO) Working Party on Remote Sensing and World Forest Monitoring (S 4.02.05) is developing a set of Guidelines for World Forest Monitoring. The basic input for these guides was developed at the Wacharakitti International Workshop on Remote Sensing and Permanent Plot Techniques for World Forest Monitoring, sponsored by IUFRO S 4.02.05 and held in Pattaya, Thailand, January 13-17, 1992.

The objectives are to provide guidelines to yield internationally compatible data at the global level, to ensure effective use of funds through coordination and cooperation, and to promote accurate use and sensitive reporting of results.

The short-term goals are to outline the principles for data sharing for global forest resource statistics and to create data indices. The long-term goal is to set up a global network of forest resource managers to supply monitoring information.

The guides simply suggest that if a nation or group is going to collect forest information that nation or group should collect the data specified to the given standards or have the capability to convert the data to the standards and guides. Listed within the guides are minimum data requirements, land-cover classification schemes, and direction on use of remote sensing and establishment of sample plots.

The expected end product would be a network of databases, which when incorporated in its entirety will monitor forest resource estimates for the world. The final result of these guides will be a multinational network that will consistently provide reliable information to the international community.

Even with that system, there are some obstacles to overcome:

1. The standards and guides may not be known. This may be overcome by more publicity.

2. People may not see the benefits of using standards. Having local people help develop the guides and standards can build some ownership.

3. The timing for the monitoring effort may not meet local needs, or data collection costs may exceed available budgets. Forming partnerships and cost sharing may help overcome these obstacles.

RECOMMENDATIONS

Regardless of the method used for constructing global assessments, there are several things that one may do to improve estimates:

1. Statistically sample all lands for vegetation resources through permanent field plots. This network of plots will provide tools to help classify imagery, to evaluate the classification accuracy, and to yield data not available through remote sensing. This procedure will also help overcome land classification problems.

2. Record cover types according to an agreed upon vegetation-cover classification system, such as that by the United Nations Educational, Scientific and Cultural Organization (UNESCO 1973) for all lands. This will provide a common link to other monitoring efforts.

3. Record the coordinates of field plots and sample locations for use in GIS.

4. Collect and store basic data in a noninterpreted database. This will permit one to recompute estimates based upon a variety of classification or definition systems.

5. In any published report, state definitions and standards used and provide cross-references to international standards.

Our pool of existing information will increase as we expand our inventory and monitoring programs to include all resources in all lands. Our ability to access, use, manipulate, and analyze the resulting data will increase as we move toward global standards for data collection. As our global information base improves, we should become better able to manage the earth's resources.

ACKNOWLEDGMENT

My thanks to Dr. Allan Falconer, Utah State University, for his invitation to participate in the Natural Resources Week Symposium *Mapping Tomorrow's Resources* and for his kind review of this paper.

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