Managing Data for the Monitoring of Tropical Forest Cover: The Global Resource Information Database Approach

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ABSTRACT: As a UN organization for the management of global resource data, GRID believes that the world community should urgently be provided with access to timely and usable data on the condition and change of tropical forest cover. The NOAA/AVHRR satellite data acquisition system, together with the recent advances in the fields of GIS and digital image analysis, have made it technically possible. GRID has developed tropical forest cover mapping methodology in two regions, West Africa and Amazonia. A digital global map is now planned to be compiled from various research organizations' recent AVHRR-LAC data classification results covering the major part of the moist tropical forest region. In this framework GRID could contribute not only its Amazonian and West African maps but, in particular, data integration and archiving capacity and capability; ancillary data layers from GRID's global database, assisting FAO's Forest Resources Assessment 1990 with the integrated datasets; and, finally, expert advice and administrative support to above functions.

INTRODUCTION

THE GLOBAL RESOURCE INFORMATION DATABASE (GRID) is an environmental data support component of the Global Environment Monitoring System (GEMS) at the United Nations Environment Program (UNEP). The mission of GRID is to provide timely and reliable georeferenced information and access to a unique international GIS service. GRID undertakes case studies with the international research community and maintains scientifically valid global or regional datasets in support of the concentration areas of UNEP. In this capacity, it has recently developed capabilities for global tropical forest cover assessment. The work is linked to UNEP's concentration area entitled "Protection and management of land resources by, *inter alia*, combating deforestation and desertification and drought." Through this work GRID plans ultimately to provide the world community access to usable data on the condition and change of tropical forest cover.

In more detail, the services GRID aims to provide include (1) results of AVHRR/LAC data analysis for selected areas of tropical forest; (2) integration and archiving in GRID database the various scientists' analysis results over tropical forest; (3) addition of ancillary data layers from GRID's global data sets; (4) assisting FAO's Forest Resources Assessment 1990 with the integrated datasets; and (5) giving expert advice and administrative support to the above functions.

METHODOLOGY DEVELOPMENT PHASE

There are currently a number of remote sensing-oriented research projects dedicated to forest monitoring and assessment at global and continental scales. GRID has formal or informal cooperative links with the following organizations:

- Food and Agriculture Organization (FAO), Rome
- Institut de la Carte International de la Végétation, France
- Instituto de Pesquisas Espaciais (INPE), Brazil
- Joint Research Centre, Italy
- National Aeronautics and Space Administration (NASA), USA
- University of Illinois, USA
- University of Joensuu, Finland
- University of New Hampshire, USA
- University of Reading, United Kingdom
- University of Zürich, Switzerland.
- Woods Hole Research Center, USA
- World Conservation Union (IUCN), Switzerland

GRID feels that there is a need for better communication among scientists and institutions on current activities and methodologies. GRID and others believe that the concerned projects should contribute in an integrated fashion to monitoring and assessment of global forest cover change, while maintaining their independence, originality, and scientific integrity. Here, GRID could play an active role by systematically archiving and integrating relevant data in the GRID database and making it available to all.

The GRID centers in Geneva and Nairobi are now equipped with powerful digital image processing and GIS systems that are capable of the full range of operations necessary to accomplish data input, processing, archiving, and distribution functions. The hardware comprises IBM mainframes, workstations, and PS/2s as well as DEC Microvax III computers with state-of-the-art peripheral equipment. Image processing and Geographic Information System (GIS) packages available at GRID include ELAS, LAS, IAX, GFIS, ARC/INFO, ERDAS, IDRISI, CHIPS, ILWIS, and SPANS.

In 1987-90, the forest-related work at GRID consisted of methodology development for (1) forest/non-forest delineation using AVHRR-satellite data over West Africa (Päivinen and Witt, 1990), and (2) assessment of deforestation using satellite data over Amazonia (Cross, 1990). Data in the form of maps and satellite imagery were acquired from a variety of sources. After being processed and georeferenced, the data were stored in GRID's digital databases. During the methodology development phase in 1987–90, the focus of data acquisition at GRID was on purchasing AVHRR-LAC data from NOAA. Landsat TM- and SPOT-scenes were acquired from EOSAT and SPOTIMAGE, respectively. Ground truth data were collected from various West African countries and from Amazonia in cooperation with local forestry authorities. The results of methodology development are encouraging enough to justify the continuation of the work at a global scale, and contributing to the development of operational systems for global tropical forest cover monitoring.

IMPLEMENTATION PHASE

The implementation of a forest database, planned for 1990–1991, consists of the compilation and maintenance of a digital global tropical forest cover map. It is one of GRID's ambitions to support the compilation of such a map in close cooperation with the various scientific groups actively carrying out tropical forest mapping and monitoring projects.

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The GRID network is rapidly expanding. There are currently three regional GRID nodes—Nairobi, Geneva, and Bangkok. New nodes are now being established in the United States (Sioux Falls), Mexico (Mexico City), and later on in West Asia. The intention is to connect all GRID nodes with communication links in order to form an interconnected network for data management, transmission, and exchange. A new project called MERCURE, proposed by the European Space Agency (ESA), plans to connect the regional GRID nodes in Nairobi, Geneva, and Bangkok through a 64-kb satellite link via INTELSAT over the Indian Ocean. Further, 10 to 15 receive-only stations will be included in the project. It is envisaged that the MERCURE system can later be connected to the ESA/FAO project DIANA which will lead to global communication coverage. When the network is fully operational, the requests concerning georeferenced resource data can be placed through the nearest regional GRID node. As compared with today's situation, the delivery of data via high-speed communication links will be speeded up considerably.

COMPILATION OF A GLOBAL TROPICAL FOREST COVER MAP

Approach

GRID hopes to serve its partners best by assembling a Global Tropical Forest Cover Map by 1992. This will only be possible if individual investigators or research groups make available to GRID the final results of their work for inclusion in a global-scale product. To facilitate communication and cooperation between the participants, GRID supports an *ad hoc* Group of Forestry Experts which annually arranges informal technical meetings on forest cover monitoring (UNEP, 1989). The most recent meeting of the group was hosted by the Joint Research Centre at Ispra, Italy, in March 1990.

GRID Data Format

The standard format of the majority of data sets already entered in GRID's database is a raster (grid cell) format of variable resolution, georeferenced using the latitude/longitude coordinate system and stored in the Plate Carrée Projection. This projection has the equator as standard parallel, with meridians spaced at equal distances as the parallels, and a square graticule. It is a simple cylindrical projection often used for mapping and portraying global satellite data.

GRID software supports more than 20 transformations to and from other projections/coordinate systems. Many of GRID's data sets, which may have originated as maps (soils, vegetation, etc.), are also stored in vector format. GRID currently has available more than 30 different algorithms for transforming the projections of these data sets.

GRID also has a wide variety of software for reading and, if necessary, reformatting data contained on magnetic or cartridge tape, diskette, or other media. It is assumed that most of the Tropical Forest classification maps contributed to GRID for inclusion in the global database will be on magnetic tape, accompanied by suitable written documentation. Data sets/files contributed will be georeferenced or, if not, the raw (unclassified) satellite data from which the map was derived will be provided to GRID for rectification purposes. Also, a legend or land-cover classification scheme conforming to standards will have to be provided for proper integration of each data set into the overall global map product.

Data Entry Procedure for and Access to the Global Data Set

When the necessary information is supplied along with the digital map, GRID will handle the data in the following manner:

- Each contributed dataset/file will be read from tape into the GRID computer system and verified for completeness compared to documented information provided by contributors.
- The latitude/longitude coordinates of the offset pixel (northwest or upper-left corner) and spatial resolution of the data set will be stored in the file header; this references the dataset to the global grid and establishes the dimensions/extent of the dataset based on number of rows and columns.
- If necessary, the data set will be transformed into the Plate Carrée projection from its original projection. Resampling will be accomplished using a nearest neighbor technique to preserve the original data values.
- Individual data sets can then be copied into a global file representing all of the tropical zone at one-km spatial resolution, or held individually until time of final map preparation; this does not preclude the possibility of multiple map layers (i.e., different versions as opposed to one definitive map) for given areas; all datasets will also be stored offline on magnetic tape, cartridge, or optical disk.
- Once they are referenced to the global (lat./long.) coordinate system, it will be possible to overlay other thematic layers such as FAO soils, topography, NOAA Global Vegetation Index, ecoclimatic zones, etc., and other features like boundaries, hydrology, and roads from existing GRID datasets. These can then be made available as integrated datasets to the investigator(s) in various formats, scales, or projections.

Once the final global tropical forest cover map is ready for distribution, GRID through UNEP/GEMS and agency partners (like FAO) will publicize the compiled product and the work of all those who contributed to it.

As an effort to improve services related to the digital global tropical forest cover data set, GRID will maintain a meta-database which gives information about the data sets. Examples of the parameters to be included in such a data base are

- countries (and provinces) covered by the data set
- type and date of the satellite data used
- type and date of the ground truth used
- ongoing projects to fill the gaps in the global map
- ongoing projects to update the data set
- GIS products related to the data set.

The meta-database in question is the NASA Master Directory system (being installed at GRID/Geneva) which will be run on an IBM 6150 under UNIX (AIX). The system will be on the SPAN communication network and accessible in this way.

The integration of remotely sensed forest maps with other geographically referenced datasets can be performed in either raster or vector mode. At GRID, raster-based work is normally carried out on ELAS, LAS, or ERDAS, while vector work is entirely within ARC/INFO; software exists for interchange between each format.

Amazon Basin Case Study Using GIS

In the case of the Amazonia study (Cross, 1990), GIS operations are being made in both modes (raster and vector) according to the type of data and analysis involved. Initial cartographic input was from the World Boundary Database II (WBDB II). These vector data were converted to ARC/INFO format and can therefore be manipulated at will with respect to scale and projection. ARC/INFO was also used to digitize various cartographic datasets (e.g., roads, mines, protected areas). For map production on paper, ARC/INFO was preferred. Classified remotely sensed data held in ELAS were converted to ERDAS format for subsequent vectorization into ARC/INFO.

For quantitative analysis, polygon overlays were manipulated in raster mode. For example, the WBDB II data for political boundaries were rasterized in ARC/INFO in the form of filled polygons, and converted to ELAS format for overlay with classified remotely sensed data. A program for report generation was applied to the raster images and state-by-state statistics were obtained.

Vector line data were also rasterized. ARC/INFO data relating to roads were converted to ELAS, and the resulting image was

input to a distance transformation program to produce an image in which pixel values corresponded to distance from the nearest road. This was overlain with classified data for an analysis of the spatial dependence of deforestation on the transport network.

CONCLUSIONS

UNEP/GEMS/GRID feels that the world community should (quickly) be provided with access to timely and usable data on the condition and change of tropical forest cover. A digital global tropical forest cover map should be compiled, archived, and made available to all. The NOAA/AVHRR data acquisition system together with the recent advances in the fields of GIS and digital image analysis have made the task technically possible. GRID is aware of the technical and practical problems involved: The global LAC data coverage is incomplete, clouds disturb the data acquisition, and the accuracy of classification results is variable and dependent on factors like seasonality, land-use patterns, access to field data, etc. The result may not be perfect but the need is evident and immediate: today, the world community does not find much recent information on tropical forest cover at the global level.

The practical implementation of the map compilation is totally dependent on the contributions of those investigators working on country or regional level AVHRR mapping projects. GRID has neither a mandate nor the means for making anybody donate a copy of their results to its database. The map will (or will not) be born as a result of international cooperation. GRID can only offer to do its share by providing the international scientific community—and the ongoing FAO Tropical Forest Resources Assessment 1990—with its data processing, archiving, and management capacity.

The value of the global tropical forest cover data set is dependent not only on the quality of the data itself but also on the time distribution of the data included. It is only natural to plan for regular updating of such a data set. GRID intends to maintain the forest data set as up-to-date as feasible. Even if it is too early to discuss the details of the updating procedure, one aspect can be mentioned at the outset: the need for updating varies throughout the tropical region depending on the intensity of deforestation. Thus, the map data should be updated at least every 3 to 5 years in the areas of high deforestation rate and at least every 8 to 10 years elsewhere. Finally, a flexible approach to the updating problem is to update when and where new data become available.

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