FOREMMS – a system prototype for large scale environmental forest monitoring

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ABSTRACT

The principal goal of the FOREMMS project is to develop and demonstrate an advanced forest environmental monitoring and management system prototype that uses both remote sensing data, ground measurements and ancillary data. This article presents the FOREMMS prototype on a conceptual level, including a system overview and a high-level description of the data collection and information extraction.

***Keywords and phrases*:** remote sensing, forest mapping, environment, system prototype

1.0 INTRODUCTION

The forest resources in Europe are again increasing, after centuries of decline. This is mainly due to the replacement of wood as raw material and source of energy, afforestation of former agricultural land, the forest management regimes implemented after the Second World War, and restrictions on heavy industry. However, pollution is still a problem in many regions, and forestry practices have often led to reduced biodiversity and loss of unique eco-systems. The global climate change put additional stress on the forests and may imply significant changes in the years to come.

Healthy, well-functioning forest eco-systems with rich biodiversity are now agreed to be essential goals. Knowledge about the status and development of the forest is crucial to reach these goals. Continuous monitoring of environmental parameters is required, and the data collection must be standardized. Manual measurements in the field and data from airborne and satellite sensors can be combined to ensure the required accuracy and coverage. It is equally important that the handling and analysis of the collected data are done in a consistent way, and that the extracted information is made available to a wide range of users.

The main goal of the FOREMMS (Forest Environmental Monitoring and Management System) project is to develop and demonstrate an advanced forest environmental monitoring and management system prototype. It collects remote sensing data, ground measurements and ancillary data, in order to extract precise and coherent information about the state and evolution of the forest environment in Europe. The information is made available on the Internet and can be visualised with a standard web browser.

The FOREMMS project is carried out by 11 partners from 8 European countries. The European Commission supports the project in the framework of the Information Society Technologies (IST) program. The project is a contribution from the IST program to the EU-ESA joint venture on Global Monitoring for Environment and Security (GMES).

The project was initiated by carrying out a survey (Maguire, 2001) to identify user needs for the FOREMMS system. Initially, three classes of user communities were considered: people in a range of professional roles relating to forests, teachers of forestry and environmental topics in schools and universities, and members of the public. However, it was seen as useful to narrow down the target range of users to avoid spreading project resources too thinly. Thus it was decided to concentrate principally upon public administrators. Such users require suitable information to help them form policies to help preserve forests. It was also decided that consideration should be given to educationalists and members of the public in order to help promote people's knowledge and appreciation of the forest environment. The survey of user needs has helped generate a wide range of end user requirements that have been fed into the process of developing the FOREMMS prototype (Skretting, 2001).

This article gives a high-level description of the overall prototype system (Fjørtoft, 2002), the data collection, the forest parameter extraction and the spatio-temporal statistical analysis, the demonstration of the prototype, and the roles of the different project partners.

2.0 SYSTEM OVERVIEW

Fig. 1 illustrates the FOREMMS concept. Data are collected from remote sensing satellites and airborne sensors, as well as automatic field measurement stations and field PCs. Ancillary data, such as elevation maps and large-scale meteorological data, are also used. The collected data are preprocessed, forest parameters are extracted by means of automatic image analysis, and statistical analysis is performed to reveal the spatial and temporal trends.

The extracted forest parameter rasters and the statistical estimates are stored in a special database system that can handle huge quantities of raster data. In fact, there is a network of nodes that share the data, each of them having data collection, data processing and data storage facilities. In a future operational system there should be one or more nodes in each European country.

The forest information stored in the node databases is made available to external users via a web user interface. A special web map server makes it possible to transfer raster and vector data over the Internet, so that users interactively can request forest information and visualize it in several ways (as a map, graph or animation) using a standard web browser.

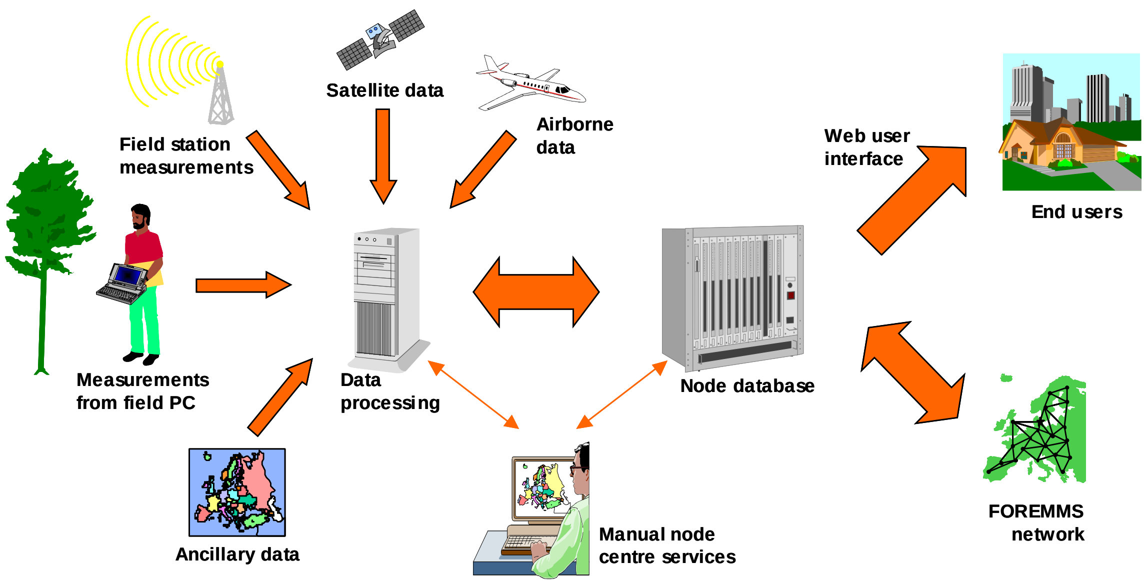

Figure 1: Conceptual overview of FOREMMS

3.0 DATA COLLECTION

Data come from satellites, airborne systems, field PCs, automatic field stations and meteorological institutes. The data sources have highly different resolution and coverage in space and time, as illustrated in Figure 2. In FOREMMS we have divided the data sources into three levels based on their spatial resolution, and all image data are resampled to a certain map projection and fixed grid prior to the analysis (Fjørtoft, 2002).

Level 1 corresponds to the finest resolution and a fixed grid with cell size 1 m. The remote sensing data on this level stem from the airborne pushbroom imaging spectrometer AISA and the helicopter-borne scatterometer HUTSCAT (Skretting, 2001). Data over test sites of limited size are collected during special campaigns that are typically performed bi-annually. The remote sensing data on Level 1 are completed by ground measurements recorded on dedicated field PCs and data from automatic field stations (wind speed, air and soil temperature, relative humidity, rainfall, solar radiation etc).

On Level 2, corresponding to fixed 30 m grid, the main data source is Landsat ETM+, which has a swath width of 185 km and 7 spectral bands plus one panchromatic band. The repeat cycle is 16 days, but due to clouds and the high cost per image, we only aim at a regular coverage of regions containing test sites (with intervals of some weeks during the growth season) and random sampling of other areas, so that all Europe is covered approximately every five years.

Level 3 corresponds to a resolution of 1 km, which is the lowest resolution level in FOREMMS. At this level, the MODIS sensor is the main source of information. MODIS images have 36 spectral bands. The swath width is 2330 km, so all Europe is covered in two passes, and images covering all Europe are available daily. MODIS data can actually be downloaded from NASA at no cost (for research purposes). Derived products, such as cloud masks and pixel positions, are also freely available. FOREMMS has therefore been designed so that the entire processing chain on Level 3 is automatic, whereas the processing is done interactively by means of a graphical user interface on Level 1 and 2, where images are acquired more rarely.

Ancillary data such as landcover maps, elevation maps and meteorological data are used to facilitate the analysis of remote sensing data.

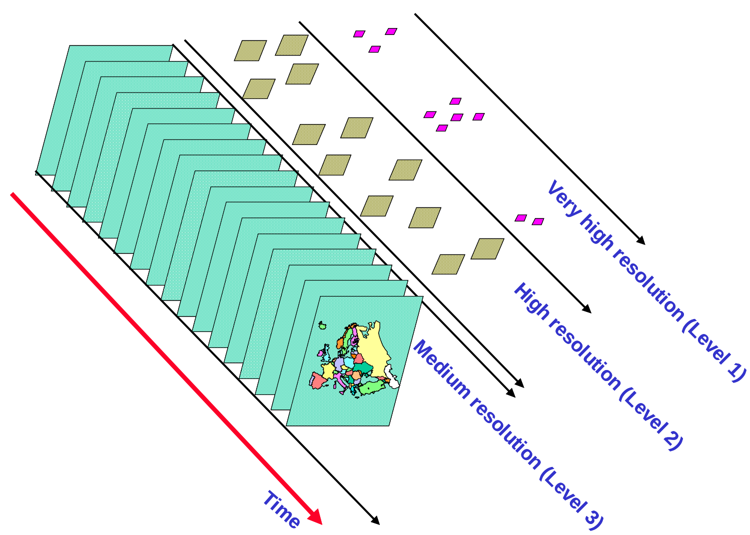

Figure 2. Multiscale and multitemporal remote sensing data.

4.0 INFORMATION EXTRACTION

Advanced algorithms are used to extract relevant forest information on each resolution level. The list of parameters currently comprises forest cover change, forest type, biomass, carbon stock, defoliation, and the biodiversity indicators dominance, contagion and complexity. (Thereto come forest cover, protected areas and forest age, which are not derived directly from remote sensing data.) The baseline algorithms for parameter extraction are pixelwise and contextual classification, and non-linear regression based on neural networks (Fjørtoft, 2002). The estimated forest parameters are exported to the FOREMMS database and thereby made available to users on the retrieval side, as illustrated in Fig. 3.

The extracted parameters are also used further on the acquisition side, as input to a statistical model that extracts informative measures for describing space-time structures and variability from multiscale and multitemporal data (Høst et al., 2001). The assessment of temporal trends is of particular interest. The systematic or slowly varying space-time components are computed in the statistical processing module on the acquisition side and stored in the database as statistical estimates (mainly raster images and temporal vectors). The computation of these decomposed space-time outputs is quite time-consuming. However, once they are estimated, the spatio-temporal evolution of a given forest parameter can be computed very quickly by the statistical analysis module on the retrieval side. We also minimize the need for data storage, since only a few slowly varying or systematic components are stored as raster images, while the high frequency variability only is stored in a descriptive summary.

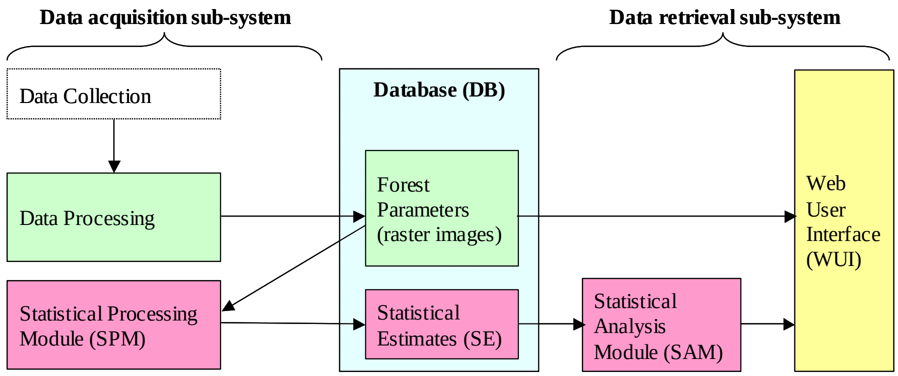

Fig. 3. The modules of the FOREMMS prototype.

5.0 PROJECT DEMONSTRATIONS

The demonstration sites of the FOREMMS project represent the three major forest types in Europe: Mediterranean forests, temperate forests and boreal forests. The Mediterranean forests are dominated by evergreen conifer and broad-leaved species. The timber volume and land area covered by Mediterranean forests are significantly smaller than those of the temperate and boreal forests. The temperate forests in central Europe are dominated by deciduous broad-leaved species mixed with conifers. Pure stands of conifers are also found. Boreal forests in the Nordic countries are dominated by conifer species mixed with deciduous broad-leaved species. The temperate and boreal forests constitute an economically significant resource.

Our Mediterranean forest sites are located in Tuscany, Italy, the temperate forest site is the Niepolomice forest near Cracow, Poland, and the boreal site is located north of the town of Joensuu in Finland. During the demonstration period, airborne campaigns will be made over these areas, and ground measurements will be used to calibrate remote sensing data and make training sets for the parameter extraction algorithms on Level 1. Validated results on Level 1 are downsampled and used as training data on Level 2 etc.

6.0 PROJECT PARTNERS

The 11 partners in the FOREMMS consortium and their main responsibilities within the project are:

- Norwegian Computing Center (NR), Norway: project coordination, parameter extraction, and statistical analysis.
- HUSAT Research Institute, Loughborough University, UK: user needs, usability, system evaluation.
- ELE International Ltd., UK: automatic field stations.
- ARTEC Group, Belgium/Italy: web user interface.
- Finnish Forest Research Institute (METLA), Finland: user partner, Joensuu test site, system verification.
- Department of Forest Ecology, Forest Faculty, Agricultural University of Cracow, Poland: user partner, Niepolomice test site, system demonstration.
- Institute of Agrometeorology and Environmental Analysis for Agriculture, National Research Council, Italy: user partner, test sites in Tuscany.

- Laboratory of Space Technology, Helsinki University of Technology (HUT), Finland: airborne campaigns, pre-processing of AISA and HUTSCAT data, training sets.

- Computer Science Department, Universitat Autònoma de Barcelona, Spain: field PC software.

- COMELTA S.A., Spain: field PC hardware.

- Active Knowledge GmbH, Germany: subcontractor to HUT, multidimensional database system RasDaMan.

7.0 FOREMMS AND GMES

In line with the European strategy for space developed by the Commission for the European Countries (EU) and the European Space Agency (ESA), the EU and ESA Councils have stressed the strategic importance for Europe of global, independent, reliable and ongoing access to information concerning environmental monitoring and management, risk monitoring, and enhance civil protection and safety (e.g. with regard to global change, environmental stress and disasters).

This information is critical for the formulation and informed conduct of policies within the EU and for their effective implementation. It is also a vital part of Europe's contribution to issues affecting the global environment and the safety of our planet.

The Global Monitoring for Environmental and Security (GMES) is an ambitious concept, which reconciles the political needs associated with environment and safety issues with the scientific and technological capacities offered by information society technologies and Earth observation technologies, e.g. observation satellites.

The goal of the GMES initiative is to establish a coherent, operational, long-term and user-dedicated information system that meets the specific needs for policy making and research in several fields such as environment, agriculture, regional development, security, and transport. The GMES initiative aims at supporting Europe's leading role in the monitoring of the global environment and provides support to policy makers in the fields of hazards and crisis management.

Developments and forerunners (resulting in particular from research work) can be used and adapted to respond to the needs of GMES. To ensure the transition to a fully operational phase within this decade, coordination at European level between providers and users and the establishment of an institutional framework ensuring the long-term supply of the services (be they public interest or commercial services) required by the users are essential.

The FOREMMS consortium believes that the prototype developed during the 3-year FOREMMS project will prove to be a first step in reaching the goal of a European-wide monitoring system for forests, and can be considered as a baseline of forest monitoring for GMES.

8.0 CONCLUDING REMARKS

A forest environmental monitoring and management system prototype that uses both remote sensing data, ground measurements and ancillary data has been developed in the framework of the FOREMMS project. It will be tested during the summer season 2002. The consortium wishes to promote the FOREMMS system to the GMES-initiative, taken by CEC and ESA.

9.0 REFERENCES

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