

IMPLEMENTATION OF REMOTE SENSING FOR DECISION SUPPORT SYSTEMS

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ABSTRACT

RESE, Remote Sensing for the Environment, is a six-year Swedish research programme, whose main objective is to help improve environmental management and research by developing methods for the operational use of information from remote sensing satellites. The scientific approach and some results have been presented at ASPRS Annual Conferences years 2000 and 2001. 2002 is the last contracted year and developed methods will be implemented by different governmental authorities, municipalities and commercial companies. It is now time to conclude the efforts to 'push out' remote sensing as a cost-effective objective and rational method for environmental management systems and decision support systems. Some examples from the forestry sector supporting national biodiversity quality objectives and the EU Habitats Directive are presented in this paper.

INTRODUCTION

The Swedish Foundation for Strategic Environmental Research - MISTRA - is the main financier of environmental research in Sweden. MISTRA supports strategic environmental research - that is, research in a long-term perspective aimed at solving major environmental problems - which

- meets the highest scientific standards,
- is guided by a vision of an environmentally sounder society,
- has as its aim system changes promoting sustainable use of resources, radically reduced environmental impacts, or essential new knowledge about environmental problems and their relative significance,
- contributes to Sweden's competitiveness, and
- has clear and measurable objectives, enabling it to be effectively evaluated.

RESE is one of 22 national programmes receiving financial support. The programme is managed by Metria Miljöanalys, the environmental analysis business division of the National Land Survey, and the research is performed at 12 different institutes all over Sweden and Estonia by a total of 60 researchers. Within the postgraduate education programme there are 18 students. The programme work includes research into terrestrial and aquatic ecosystems and also statistical and quality methods for data used in the environmental monitoring models. Information about the research approach can be found in the proceedings of the ASPRS Annual conference 2000 and 2001 and on the web site www.lantmateriet.se/rese.

REMOTE SENSING IN COMMERCIAL FORESTRY

Forestry planning is a highly complex issue, dealing with large areas, long time-perspectives, environmental constraints and forest dynamics such as growth, pests, (natural) and silviculture, cuttings (anthropogenic).

The forestry company HOLMEN participated in this RESE User Implementation project, driven by an interest to develop an advanced forestry planning system to aid the field work in its 20 Forestry Ranger Districts. HOLMEN considers the project to be an important stepping-stone into the "Remote Sensing World" and aims to incorporate RS data into the company's GIS (Arc IMS) planning system.

Finding and correcting errors in the company stand register

HOLMEN's 1 million hectares of productive forestland are divided into 200,000 compartments with a large set of individual attribute data.

There is an urgent need to maintain the register and to maintain the quality of attribute data in order to create meaningful development of more advanced planning routines.

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To detect errors, forest stand data are combined with Earth Observation data. In this study, SPOT XI data (053/222) from 3 September 1999 was used together with Landsat 5 TM (194/017) data from 9 June 1988. Change images were produced with raster matching of individual bands before subtraction. Primarily, the middle infrared channel (TM 5) was used.

Image data from 1999 and the change images were combined with stand data in a GIS and all statistics were gathered in a Neural Network. The Neural Network was trained onto and estimated the spectral response of all four spectral bands in the SPOT satellite. The estimation was compared with the actual response found in the image data. Forest stands with outliers in the near and middle infrared channels were indicated as errors. Among errors found were non-registered cuttings, and errors in timber volume or tree species composition.

The identified stands were evaluated *in situ* by a forest inventory expert and the method proved to be most useful.

Pre-commercial cleaning

Forest regeneration by planting conifers is the dominant method in northern Sweden. Natural seeding from surrounding stands occurs more or less constantly, with great variation in intensity. Very often the planted conifers soon suffer from severe competition from naturally seeded hardwoods such as birch (*Betula spp.*)

The purpose of cleaning in Swedish forestry is to regulate stem density, species composition and height distribution of a stand. Through cleaning, production is allocated to a smaller number of stems. Cleaning in a larger silvicultural context is an important measure aimed to create timber-rich forests of high quality.

There are considerable planning problems connected with cleaning, such as fast growth, high variation in site conditions and difficulties in gathering a context on landscape level in order to direct the measure in an efficient way.

To detect areas with a need for cleaning, SPOT XI data from 3 September 1999 were used, together with forest stand data. A vegetation index was calculated from the satellite data, based on the red and near-infrared channels. The index image was combined with stand ages from 5-20 years, and by thresholding the vegetation index image, areas with high vegetation index were found.

The result was presented as coloured pixels displayed on the ordinary HOLMEN forest map of digital orthophoto. The map was evaluated *in situ* by Forest Rangers and proved to be most useful.

Detecting pest attacks from the fungus *Gremmeniella Abietina*

Gremmeniella Abietina has been well known as a pest in forest seedling nurseries since the 1950's. Large areas of young (10-20 years) Lodgepole pine (*Pinus Contorta*) and Scots pine (*Pinus Silvestris*) stands in northern Sweden suffered attacks from the fungus 1987 and 1988. Another face of *Gremmeniella Abietina* occurred in 1999 and 2001 in clusters over large areas (approx 330,000 hectares), where Scots pine stands of 10-15 m in height were infected.

In practical forestry it is of great importance to identify the locus of infected areas. There is an urgent need to extract infected trees before the insect *Tomicus piniperda* uses the weakened trees for breeding.

By using Landsat ETM+ data from 7 July 2001 (after the infection) and SPOT XI from 3 September 1999 (before the infection), it was possible to map forests with heavy damage. Some forest stands with known damage were used as reference data. Change images 2001-1999 were produced in the middle infrared channel by raster matching before subtraction. By combination and thresholding of the change image and the latest image, infected areas were indicated as areas where an increase had occurred in the change image. Large increases indicate cuttings, but minor increases were either thinning cuttings or areas infected by fungus. By thresholding the latest image in the middle infrared channel, seed-tree cuttings could be removed from possibly infected areas. The spectral change 2001-1999 was divided into classes presenting the damage effect (loss of needles) by reference data.

The result was presented as coloured pixels displayed on the ordinary HOLMEN forest map of digital orthophoto. The map was evaluated *in situ* by Forest Rangers and proved to be most useful.

DECISION-MAKING FOR THE HABITATS DIRECTIVE

Long term maintenance of biodiversity has become one of the most important goals of Swedish environmental policy. Since Sweden is among most forested countries in Europe, the long-term conservation of forest biodiversity is considered here to be a priority. Simultaneously, environments traditionally treated in landscape as opposite to forest (e.g. agricultural mosaic or cities) and basically excluded from forest biodiversity

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management plans may sometimes be of crucial importance for the maintenance of forest species. So far, the integrated analyses of forest environments that extend the ownership borders are rather uncommon.

Several stakeholders operating at different scales work on strategies dealing with long-term maintenance of biodiversity. For example, all counties in Sweden are obliged to develop regional strategy dealing with this issue. Also, the National Board of Forestry and forest owners work for the long-term improvement of biodiversity conservation within their jurisdiction. At the regional and local scales, the county and municipality boards have a special opportunity to integrate efforts within long-term conservation planning among different landowners and land managers. This can be done through analysis of gaps in conservation where the entire landscape is considered. Here, the importance of remote sensing data that provide land information of similar quality independently of administrative borders is obvious.

The County Administrative Boards of Dalarna and Gävleborg have decided to use experiences from the RESE programme to analyse gaps in their nature conservation work. The gap analysis method is used and based on use of land information (both readily available and created during the project) that describe relevant spatial and temporal patterns in terrestrial environments and also on different researchers and the staff at the Boards knowledge on natural disturbance regimes and ecological demands of species being recognised as most demanding in their types of environment. The umbrella species concept was adapted and further developed by RESE-team to deal with connectivity of different habitats in the landscape. Thanks to involvement of other actors in this implementation projects (large forest companies, regional Board of Forestry) it has been possible to use their management plans to simulate the connectivity of future landscapes from the umbrella species point of view.

The method is used to developing strategies and provide a basis for decision-making for the Habitats Directive and the Water Framework Directive for catchment areas.

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