Earth Observation for Sustainable Development of Forests (EOSD) – A National Project

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Abstract - A group of forested nations agreed upon a set of criteria and indicators to measure the sustainable development of forests. Of the 83 indicators, remote sensing could measure in whole or in part about 25 indicators. Moreover, such measurements could also support elements of Canada's national forest inventory and reporting requirements for the Kyoto protocol on reforestation, afforestation, and deforestation (RAD). We have commenced a new project, EOSD, to monitor the sustainable development of Canada's forests from space. Two federal partners, the Canadian Forest Service and the Canadian Space Agency, are creating the ten-year project in cooperation with the provinces and territories. The project will support, with space based technology, Canada's priorities and international commitments for monitoring the sustainable development of its forests and for meeting core forest information needs of the Kyoto Protocol. The status and major changes in the composition, distribution, structure and function of forests over time will be quantified. The remote sensing observations will also form part of a three-stage new national forest inventory. It is intended that products and data will be widely available via intelligent information systems. This paper will describe the products to be produced, and outline the project implementation.

Introduction

"Sustainable development" has been defined as a process of using resources, such as forests, in a manner that meets the needs of the present generation without compromising the ability of future generations to meet their needs [1]. Close to half of Canada is forested, totaling some 418 million hectares, which is 10% of the world's forests. The vast majority of forest lands in Canada are in the public domain. Canada is the largest trader of forest products, with over 20% of the world's forest trade. The forest sector contributes more than $70 billion to Canada's GDP. Forests contribute more to Canada's balance of trade than agriculture, fisheries, mining and energy combined. Approximately 850,000 Canadians work in the forest industry or for companies that support it, and almost 350 communities are forestry-dependent.

At the 1992 United Nations Conference on Environment and Development, Canada, and most other countries, endorsed the concept of sustainable development as the guiding principle for human activities in the future. Through international conventions such as the Convention on Biological Diversity, the Framework Convention on Climate Change, and the Montreal Process, Canada has agreed upon criteria and indicators and other properties for the measurement of sustainable forest development and the protection of the environment. Because of the reporting aspects of many of these initiatives, national reporting has become an important aspect of Canada's international agenda for forestry. For example, in the Kyoto Protocol of 1997, Canada agreed to reduce greenhouse gas emissions by 6% of 1990 levels within 11 years. There are three separate reporting requirements in the Kyoto Protocol as it relates to forests: 1) reforestation, afforestation and deforestation; 2) carbon stocks since 1990; and 3) land use change and forest inventory. Under the Protocol, nations are expected to modify their national forest inventories to include measurements to meet the reporting needs of the Protocol.

In response to the concerns about sustainable development and climate and the increasing information needs for national reporting, we are beginning a project, Earth Observation for Sustainable Development of Forests (EOSD) [2], in cooperation with the Canadian Space Agency as part of their next 10-year space plan. The EOSD project focuses directly on using space-based earth observation technology to develop key information that Canada needs for sustainable development.

As the second largest country in the world and with most of the territory being very sparsely populated, Canadian governments must rely on satellite observations as the principal data acquisition tool. Earth observations and associated technology are essential for providing: 1) timely and consistent information for national, regional or provincial planning and strategic decision making; 2) information at the national level on the current state of the Canadian forests and environment in response to the national and international reporting requirements; 3) data for resource monitoring, for assessing the magnitude and impact of environmental change, and for research; and 4) strategic

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data for developing and delivering the government's environmental information and prediction strategy.

The EOSD project will be conducted in close partnership with other federal departments, the provinces and territories. There will also be academic involvement in research tasks and industrial involvement in product development and research. The EOSD project is led by CFS and is one component of the National Forest Information System (NFIS, [3]). NFIS combines EOSD, the new national forest inventory, the national forest database, and national forest and landscape modeling systems.

EOSD OBJECTIVES

The EOSD project will use space based remote sensing technology. It will integrate remote sensing and geographic information to create products to support Canada's priorities and international commitments for monitoring sustainable development of its forests and to quantify major changes in the composition, distribution, structure and function of forests over time. These data and products will be used by other CFS scientists to estimate above-ground forest carbon stocks.

The EOSD project will also develop and apply operational intelligent information systems ([4], [5]) for providing government, industry, academic and public access to accurate and timely spatial knowledge of Canada's forest resources in support of forest management in Canada. Earth observation data sets from EOSD and derived products will be accessible over the web and via high speed transfers using Canada's information super highway. In an era when nation monitors nation with remote sensing to assess compliance with international agreements, the EOSD project is intended to provide the Canadian and worldwide public with an unbiased, trustworthy picture of the current status and changes to Canada's forests.

To achieve the objectives of the EOSD project, it will be necessary to conduct research and development on methods for calibration, processing, data fusion, analysis, and change detection. This will be necessary in order to: identify and construct temporal and spatial databases of forest cover, fires, insect and disease disturbances for Canada; and monitor changes in forest cover and resources. The primary satellites to be used for the EOSD project are the LANDSAT and RADARSAT satellites, although complementary data from India's IRS-1C and very high resolution satellites such as IKONOS may be utilized if necessary. Experiments will be conducted on pilot areas which demonstrate the methods developed and provide estimates of accuracies to be achieved in each of the EOSD products.

The EOSD project must evolve during its ten-year life with new advances in technology. Experiments will be conducted to assess which new sensors and methods should be added to the EOSD system. For example, hyperspectral sensors can be used to improve forest species recognition, identify areas of stress, estimate some components of canopy chemistry, improve forest health measurements, estimate stems per hectare, and improve reflectance measurements of forest objects. Longer wavelength polarimetric SAR can be used to measure forest biomass and infer stand age. Very high resolution (< 1 m) sensors can be used to count individual trees and follow selective harvesting, blow downs, thinning, and forest health losses.

EOSD NATIONAL PRODUCTS

There are 25 attributes to be monitored as part of the new national forest inventory [6], 19 of which can be measured at least in part by EOSD (Table 1). The inventory involves three stages: a national plot system on a 20 km grid with approximately 2,000 ground plots; an aerial photograph covering 2 km by 2 km centered on each ground plot and providing 22,000 additional photo plots; a satellite remote sensing image. The first two stages will provide quantitative information plus serve as calibration and training sites for the satellite analyses. For areas where such calibration is not available, we will use signature extension methods to create the national products. The first national inventory will be produced for 2005.

TABLE 1. EOSD Potential Inventory Products

1	**Total forest area**
2	**Area by forest type**
4	**Forest types by protection status**
5	**Other wooded land** by protection status and type
7	**Area and percent of forest land managed primarily for protective functions**
8	**Regeneration and afforestation area by type**
9	**Area of surface water in forests**
10	**Forests undisturbed by man**
11	**Other wooded land undisturbed by man**
15	**Area available for timber production**
16	**Area converted to non-forest use**
17	**Area and severity of insect attack**
18	*Area and severity of disease infestation*
19	**Area and severity of fire damage**
20	**Area of forest depletion (harvest)**
21	*Area and percent of forest land with significant soil erosion*
22	*Total biomass by forest type, age, succession stage*
23	*Total volume of all species on timber producing land*
25	*Current volume growth of forest*

Table 1 entries in bold can substantially be met by remote sensing, whereas those in italics can only be met by remote sensing partially. It is assumed that remote sensing is combined with geographic information provided from other sources, such as our provincial partners. Remote sensing can not directly measure age. However, broad classes, such as mature and immature forest stands, can be identified by remote sensing methods.

The Canadian Council of Forest Ministers (CCFM) [1] have agreed to 83 indicators of sustainable forest management. Remote sensing can be used for 25 of these indicators which are listed in Table 2 together with their indicator number.

TABLE 2. EOSD Potential Indicator Products

1.1.1	**Percent and extent, in area, of forest types relative to historical condition and to total forest area.**
1.1.2	**Percent and extent of area by forest type and age class.**
1.1.3	**Area, percent and representativeness of forest types in protected areas.**
1.1.4	**Level of fragmentation and connectedness of forest ecosystem components.**
2.1.1	**Area and severity of insect attack.**
2.1.2	*Area and severity of disease infestation.*
2.1.3	**Area and severity of fire damage.**
2.2.1	**Percent and extent of area by forest type and age class.**
2.2.2	*Percent area successfully naturally regenerated and artificially regenerated.*
2.3.1	*Mean annual increment by forest type and age class.*
3.1.2	**Area of forest converted to non-forest land use, e.g., urbanization.**
3.2.1	**Percent of forest managed primarily for soil and water protection.**
3.2.3	**Area, percent and representativeness of forest types in protected areas.**
4.1.1	*Tree biomass volumes.*
4.1.3	**Percent canopy cover.**
4.1.4	**Percent biomass volume by general forest type.**
4.1.7	**Area of forest depletion.**
4.2.1	**Area of forest permanently converted to non-forest land use, e.g., urbanization.**
4.2.2	**Semi-permanent or temporary loss or gain of forest ecosystems, e.g., grasslands, agriculture.**
4.4.2	*Participation in the climate change conventions.*
4.5.1	**Surface area of water within forested areas.**
5.1.1	*Annual removal of forest products relative to the volume of removals determined to be sustainable.*
5.1.2	*Distribution of, and changes in, the land base available for timber production.*
5.1.5	*Availability of habitat for selected wildlife species of economic importance.*
5.4.4	*Area and percent of protected forest by degree of protection.*

Bold and italic entries have the same meaning as in Table 1. These indicators will also be measured by EOSD.

In March 1999, the first EOSD workshop was held in Victoria, BC. The participants reviewed the potential products list and identified the following 12 products (Table 3) as being the highest priority.

TABLE 3. EOSD High Priority Products

Num.	National Product Description
1	Forest area total and change over time
2	Forest area by type and change over time
3	Area of forest converted to non-forest use
4	Area of afforestation
5	Area of forest depletion
6	Surface area of water in forests
7	Area of forest disturbances, fire, insects, disease
8	Area of reforestation
9	Area of deforestation
10	Biomass and timber volumes
11	Above ground carbon estimates
12	Fragmentation and connectedness in forest ecosystems

In addition to the output products given in Table 3, EOSD is also expected to store and make available image products such as orthorectified imagery, enhanced imagery, and classified images. These image products and those of Table 3 will require the fusion of GIS data such as topography, forest cover, and other environmental data. In the optical domain, these products will require at least two dates of imagery corresponding to leaf-on and leaf-off conditions. To cover Canada's forests once we will require some 750 images. If it takes one week to analyze these images with the fused GIS, then it would take a single analyst 750 weeks or 14.4 years to complete one coverage of Canada's forests. Intelligent systems which automate much of the analyst's tasks are required to achieve the necessary rates of production with a factor of 10 improvement in speed.

SCHEDULE AND IMPLEMENTATION

The project proposal was developed in 1997 as part of the Earth Observation Working Group (Chair, Florian Guertin, CSA), of CSA's Long Term Space Plan III development. CFS began the project late in FY 1998/99 with major funding to commence the following year. Financial contributors are from CFS, CSA, and the provinces and territories. The project schedule is divided into three phases. The first three years involves R&D into specific procedures and algorithms for producing the 12 products. During this phase, standards for these forest products will be defined. An infrastructure for remote sensing data storage, processing communication and distributed access across Canada will be developed. Remote sensing acquisitions will begin in the first year for several long term test sites. Classification, enhancement, validation, and seamless spatial integration of several thousand satellite images and the subsequent integration and distribution of this information offer opportunities for the geomatics industry.

The second phase of the project will be dominated by production of the forest information created using remote sensing. Complete coverages of Canada are required for 1990, 2000, 2005, and 2008 to meet the international reporting needs. Major interpretations of data will begin with classification of images in combination with geographic information, such as topography, historical forest cover, and field data. In the fourth year assessment of the qualities of the products and development of refinements to methods and procedures will be done. The third phase will include analysis of the products and procedure refinement, plus assessment of sustainable development issues by integration of forest cover information with field-based plot data, information on soils, physical characteristics (soils, climate), anthropological and historic data. This period will improve remote sensing access, distribution and information systems, revise the classification methods, adjust for new sensor characteristics, and optimize overall system performance. In this phase standards and routines for change detection involving old and new sensors will be incorporated into the system and estimates of significant 5-year forest changes will be reported and distributed. At the end of the project we will have demonstrated an operational capability to monitor the sustainability of Canada's forests. We expect the EOSD technology, when acquired and transferred to the provinces, will lead to provincial use of remote sensing for forestry on a routine basis.

Throughout the project there will be technical innovation, such as the development of intelligent information systems and technology to conduct the work and distribute data and products. Also throughout there will be a R&D program into change detection techniques to be incorporated into the system. This R&D change detection component will be particularly strong in latter years in preparation for having two complete, national, satellite coverages and with the advent of new space-borne sensors, such as Radarsat 2 and hyperspectral data availability.

CONCLUSIONS

A brief outline of a new major remote sensing project, EOSD, has been given. This project will provide Canadians with powerful, timely data and information to monitor and resolve key problems of sustainable development. Detailed results expected include: timely and consistent information for national, regional or provincial planning and strategic decision-making regarding the sustainable development of forests; national level information on significant disturbances and changes in forested ecosystems; and quantification of the diversity, distribution, productive capacity, and structure of Canada's forested ecosystems. The project will add to spaced-based monitoring methodologies, such as classification and change detection algorithms for key parameters of sustainable development of forests. Distributed databases and information systems on the spatial and temporal structure of Canada's forests and earth-observation data sets and derived products will be the basis for analysis of carbon budgets for forests as required by the Kyoto Protocol. Additional information about the project can be obtained from our web site, http://www.aft.pfc.forestry.ca.

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