National Level Forest Monitoring and Modeling in Canada

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Abstract

Canada is the steward of some 10% of the world's forests. Forestry is also the single largest industry in Canada's economy. The demand for verifiable, current, and credible information on a range of forest indicators is growing as the forests' ecological, economic, and social functions are increasingly appreciated. To meet this demand for information, Canada is implementing, in co-operation with provincial and territorial resource management agencies, a new National Forest Inventory and a satellite-based forest mapping and monitoring program. The new plot-based forest inventory will provide a statistically valid estimate of the current forest conditions and their changes over time. The satellite-based forest cover information will be used to extend and update some of the inventory attributes. These programs are designed to address various current and future information and reporting needs. One specific application described here is the National Forest Carbon Accounting Framework. It combines data from these (and other) sources to estimate forest carbon stocks and stock changes. Information from these three integrated national programs will support international reporting requirements and will assist in the development of policies aimed at the sustainable development of Canada's forest resources.

Introduction

Canada's forests cover 417.6 million hectares. They occupy nearly 50% of the total landmass of the country (NRCan 2001) and contain ≈ 10% (Table 1) of the global forest cover (Westoby 1989). Canadian forests make significant contributions to the global environment by filtering air and water, contributing to global bio-geochemical cycles, reducing erosion, and by providing habitat to a wide range of species. Forestry is the largest industry in Canada, supporting over 373,000 direct jobs and contributing over $37 billion to our balance of trade (NRCan 2001). Canadian forests also support multibillion-dollar recreation and tourism industries. Sustainable management of forests continues to be one of the key environmental issues in Canada in the early 21st century. At the same time, much international attention focuses on environmental issues, such as climate change and biodiversity.

Canada's ability to manage its forest resources in a sustainable manner is being challenged, both in Canadian and international market places. The capacity to respond to such concerns, and to deliver on national and international commitments regarding sustainable forest management, is constrained by the existing federal, provincial, territorial, and industrial forest inventories and information systems. Failure to provide information in a timely, transparent, and verifiable manner can erroneously convey a message to the world that Canada is a poor steward of its forest resources.

Canada, therefore, requires forest measurement and monitoring systems that can provide timely information in response to national and international concerns about the sustainable development of Canada's forests. In response, several national programs are developing, in co-operation with provincial and territorial agencies. The combination of these national programs is enabling the development of a new forest measurement and monitoring system (Figure 1) for Canada. The stewardship of most natural resources is the responsibility of provincial and territorial governments (Table 1). Programs intended to address national and international reporting requirements must be developed in close co-operation with provincial and territorial agencies. In the past, national information was often compiled from provincial and territorial programs. Difficulties and inconsistencies may arise, however, where provincial and territorial programs are not based on similar standards, sampling schedules, spatial scales, or data formats. The data generated by these national programs is also spatially explicit – with estimates of various aspects of forest condition on a locationally specific basis. The spatially explicit nature of the data enables the appropriate stakeholders to act upon the information generated. For instance, with the national scope of the monitoring programs, regionally specific differences in forest conditions can be discerned. The regionally specific differences may be natural, or the result of management practices. In the case of management differences, a course for mitigation may be planned.

Here we describe two national programs aimed at generating new data: the new plot-based National Forest Inventory (NFI) and the satellite-based program on Earth Observation for Sustainable Development of Forests (EOSD). A third national program, the development of the National Forest Carbon Accounting Framework, uses these (and other) data to provide information on carbon (C) stocks in Canada's forests. We briefly summarize each program and describe their integration.

In support of these and other programs, Canada is also developing a National Forest Information System (NFIS, Morrison et al. 1999; http://nfis.org). It will facilitate the storage, integration, and analysis of many core data sets. The data within the NFIS will be available to conduct analysis and generate reports (Figure 1).

Canadian Forest Monitoring Programs

National Forest Inventory

Canada's National Forest Inventory (NFI) is an interagency partnership project. The current version of the NFI (commonly referred to as CanFI) is compiled about every five years by aggregating provincial and territorial forest management inventories. Basically, stand level data provided by the management agencies are harmonized to a national classification scheme, and then aggregated to the map-sheet, provincial/territorial, and national levels for storage, analysis, and reporting. Forest management inventories are the main source of information for the national inventory. Management agencies are continually updating and upgrading their forest inventories, so the age of the inventory and the inventory standards are constantly changing. As a result, the current NFI is a compilation of information of different vintages, collected to a number of different standards.

The current approach to national inventory is cost-effective in that it is based on existing data. The process is well established and accepted by the contributing agencies. The approach provides detailed information about the state of Canada's forests that is consistent with forest management information. The inventory also contains location-specific information on the characteristics and quantity of the forest resource, providing mapping and spatial analysis capabilities. However, by design, some data in the current inventory could be up to 25-years old, and data standards could be variable. The current inventory lacks information on the nature and rate of changes to the resource, does not reflect the current state of the forests, and cannot be used as a satisfactory baseline to monitor change. The inventory also generally lacks information on non-timber vegetation attributes and is of unknown precision.

In support of increasing demands for additional information on forest resource attributes and policy development, national and international reporting (e.g., Kyoto Protocol, Criteria and Indicators of sustainable forest management processes (Canadian Council of Forest Ministers and Montreal Processes), FAO/ECE Forest Resource Assessments) a national forest inventory must provide:

- data that are timely, reflecting the state of the resource at a defined time;
- data types with uniform definitions and collected to the same quality standards nation-wide;
- data that reflect consistent, and complete area coverage; and
- the ability to derive accurate trend assessments from successive inventories.

Provincial forest management inventories have been collected to varying standards, coverages and ages, and, as a result, do not meet these requirements. Because the current version of the NFI is based on provincial management inventories, it does not satisfy current and emerging requirements. In the fall of 1997 the Canadian Forest Inventory Committee (CFIC), a group of inventory professionals from federal, provincial and territorial governments, met to design a new format for the NFI. Instead of a periodic compilation of existing inventory information from across the country, the CFIC decided on a plot-based system of permanent observational units located on a national grid. The new plot-based NFI design will collect accurate and timely information about the extent and state of the Canada's land base, to establish a baseline of where the forest is and how it is changing over time.

Flexibility was a guiding principle in the development of the new plot-based NFI. Design details can be flexible as long as data consistency can be assured. The same attributes must be measured using the same standards in a statistically defensible manner at an acceptable level of precision. A core design, described in *A Plot-based National Forest Inventory Design For Canada* (Natural Resources Canada 1999), has been developed with the following essential elements:

- a network of sampling points across Canada;
- stratification of the sampling points by terrestrial ecozone, with varying intensity among the strata;
- estimation of most attributes from remote sensing sources (photo plots) on a primary (large) sample;
- estimation of species diversity, wood volumes and other desired data from a (small) ground-based sub-sample; and
- estimation of changes from repeated measurements of all samples.

The new inventory will cover all of Canada. All potential sample locations reside on a countrywide 4 km x 4 km network. Each province and territory of Canada will decide on a 'best design' that will include samples located on a subset of the National Forest Inventory sample locations, on the 4 km x 4 km net, or samples selected by a different yet statistically valid design. To provide reliable area statistics, the objective is to survey a minimum of 1% of Canada's land mass. A 1% sample translates into a nominal design of 2 km x 2 km area plots located on a 20 km x 20 km network, resulting in approximately 20,000 sample plots for Canada. The 2 km x 2 km plots will be identified on conventional, mid-scale aerial photography, and will be delineated and interpreted in full according to land cover classes and other forest stand attributes. Satellite imagery will be used as a surrogate for aerial photography to provide attribute data for areas otherwise not covered by photo or ground plots (e.g., Canada's north). Attributes to be estimated from aerial photographs include area, land cover, forest type, age and volume of trees, disturbance activity, land use changes (reforestation, afforestation, and deforestation), mortality, access and human influence, and soil erosion. The flexibility of the design allows the network to be more intense to achieve regional objectives or less intense for non-forest, non-managed, or remote areas. Additional details can be found in Gillis (2001).

The new NFI design also calls for a minimum of 50 forested ground plots per ecozone, although no sampling is planned for the arctic ecozones. More intensive sampling will be required in some areas to meet regional objectives. The ground samples will in most cases be located at the centre point of the photo plot. Approximately 10 percent of the photo plot locations will be selected at random. Whenever a random location happens to fall on a permanently non-treed area, a substitute sample location is chosen, again at random; the initial locations maintain their status as NFI ground plots, and although no measurements are taken, the locations are retained in the analysis. Measurements of ground plots will be synchronized as well as possible with the interpretation of photo plots. Attributes and data collected in ground plots will complement and enhance the attributes and data from the photo plots. Additional attributes to be measured on the ground include species names of all plants in a plot (includes place of origin in case of exotics), mortality due to stresses (fire, insects, diseases), total above ground-biomass including coarse and fine woody debris, and current (5-year) volume growth based on periodic re-measurements. The ground plots will also contain information that is not normally collected in forest inventories such as litter and soil carbon. Attributes related to land use, ownership, protection status, access, human influence, conversion of forest lands, and the origin of exotic trees will be collected from management records, other data sources, and mapped information.

Remotely sensed data will also be used to enhance the new National Forest Inventory, to assess whether the location of plots are skewed in any fashion, to assess the extent of change and the need to revisit plots, and to provide other area-based parameters such as forest condition.

All NFI plots are permanent. Change will be estimated from repeated sampling of photo and ground plots. The intent is to completely sample the country within the next 5 years, covering 1/5 of the area each year in a statistically defensible manner. The first re-measurement will be spread over a 10-year period, covering 1/10 of the area each year in a statistically defensible manner. Each subsequent re-measurement will be spread over subsequent 10-year periods.

Since the CFIC meeting in 1997, considerable progress has been made on the development of the new NFI design. A number of documents have been produced including a design document (NRCan 1999) and planning documents examining the approaches, tasks and costs associated with the implementation of the plot-based NFI. Many jurisdictions have participated in pilot projects that led to refinements of data standards and procedures. Data standards have been defined, providing the basis for the construction of data models, databases and supporting data management tools. The information management systems will be finalized over the next two years with the development of the analysis and reporting functions.

The inventory is being implemented through memoranda of understanding between the federal government and the partner province or territory. The field implementation has begun in a number of jurisdictions, and agreements are being finalized with the expectation that the remaining jurisdictions will begin implementation next year.

EOSD – Land Cover

Large-area forest monitoring programs are undertaken by many nations (DeFries and Belward 2000) using a range of sensors and methods (Franklin and Wulder 2002). These programs may be based upon extrapolation from plot based information or from earth observation data at national (Loveland et al. 1991; Cihlar and Beaubien 1998) and international (Townshend et al. 1994) scales. Common to these programs are the definition of a purpose for the mapping. Once the purpose has been defined, the appropriate sensors, processing methods, and classification system can be developed. For instance, if the purpose is to map a continental area to indicate yearly land cover composition, a sensor with a frequent revisit rate (such as the AVHRR) is required. Once a sensor such as the AVHRR is selected, the spatial resolution of the data is also imposed. The information that can be generated is directly linked to the spatial resolution. Larger pixels are mixtures of many surface conditions and features. These mixtures lead to the development of composite classes, or the opportunity to use mapping methods that are sensitive to the information content (DeFries et al. 2000). Higher spatial resolution approaches will reduce, yet not preclude, the presence of cover-type mixtures.

The size of the area and the level of detail (from forest resource management information to broad cover-type assignments) desired from the mapping program have an impact on the type of monitoring program that is developed. Smaller nations may be well characterized using inventories based on plots or air photos, while larger nations tend to utilise air photos, and subsequent forest inventory information, or satellite data. The requirement to map also introduces additional issues, such as obtaining cloud free imagery. To avoid cloud cover, the data collection period may be lengthened from ideal phenological conditions, during peak photosynthetic activity of the late summer, to spring and fall seasons. The image information content is tied to the phenological conditions present, especially for mixed forests; therefore, image selection is preferential in an off-year, rather than off-season. Wulder and Franklin (2002) demonstrate that imagery obtained outside of the optimal seasonal window results in markedly differing classification surfaces. Complete coverage for the mapping of large areas with medium-spatial-resolution sensors (such as Landsat ETM+) often requires images from a range of seasons and years centred on either side of the target base year.

Political constraints also affect the design of forest monitoring programs. For instance, in Canada, provincial and territorial agencies hold ownership and associated stewardship responsibilities for 71% of the country (Table 1). Each province is responsible for the generation of forest resource statistics. Federal programs that do not take into account provincial or territorial efforts may generate numbers that do not agree with the provincial statistics, may not be sanctioned by the province, or that may result in a duplication of effort. Several Canadian provinces also have existing satellite land cover mapping programs (Franklin and Wulder 2002). The ability to capitalize upon existing programs reduces the occurrence of the aforementioned issues of statistical disagreement or duplication. One aspect of duplication that has been reduced recently is image purchase and pre-processing. The data sharing policy of the Landsat-7 program (Goward et al. 2001) has allowed for the development of consortia to purchase, process, and share image data for a complete coverage of Canada with orthorectified Landsat ETM+ data representing, for the most part, year 2000 (Wulder et al. 2002).

The Canadian Forest Service (CFS), in partnership with the Canadian Space Agency (CSA), has developed an initiative to use space-based earth observation technologies to develop a forest measurement and monitoring system for Canada. The Earth Observation for Sustainable Development of Forests (EOSD) project will produce land cover map products to support Canada’s national and international reporting requirements (Wulder 2002). EOSD also has research components focused on biomass estimation, forest change monitoring, and the development of automated processes to aid in map production (Wood et al. 2002). The EOSD project will use space-based earth observation technologies to create products to support the measurement and monitoring of the sustainable development of Canada’s forest as well as to support reporting requirements related to climate change (resulting from the Kyoto Protocol) and landscape management. Research programs to develop techniques for change monitoring, biomass estimation, and automated processing to aid in production are also components of EOSD. The provinces and territories are vital to the implementation process. EOSD was initiated in the fall of 2000 with funding from the CSA.

Techniques have been developed to map land cover in Canada using a classification legend that is based upon the NFI classification scheme (Wulder and Nelson 2001). The NFI classification scheme is hierarchical and based upon a full vegetation resources inventory. The EOSD cover legend is developed from the appropriate level in the NFI class hierarchy, resulting in a 22 land cover class legend. Determination of what classification level is appropriate is based upon the information content of a single date of Landsat imagery. Multiple dates of Landsat imagery can confer additional information

(Scott et al. 1996) but the expense was beyond the abilities of the program and would not allow for map integration with provincial agencies. Landsat imagery, with a 30 m spatial resolution, or pixel size, allows for successful classification at cover-type level. A study has also been carried out to translate several provincial and international land cover classification systems into the EOSD land cover categories (Wulder and Nelson 2001). A review of large area land cover mapping methods with medium spatial resolution satellite information was conducted in support of EOSD (Franklin and Wulder 2002). A key recommendation of this review is the appropriateness of a hierarchical hyper-clustering and labelling procedure to meet Canada-wide mapping needs. Up-to-date methods and supporting documents may be found on the EOSD Land Cover web site[1]. The determination of appropriate methods for image processing and analysis must be undertaken in the context a of range of considerations from physical issues (e.g., Canada's large area) to political issues (e.g., resource jurisdictions and organizational mandates). For instance, an international workshop on image radiometry was held to determine what type of image radiometric adjustment is appropriate in the context of Canada. The workshop indicated that a top-of-atmosphere (TOA) radiometric processing approach was best. This selection is based largely upon a paucity of data to parameterize absolute correction procedures and a lack of improvements to actual classification outcomes when more complex approaches are used (Song et al. 2001).

The primary EOSD product is a land cover map of forested areas of Canada produced from Landsat ETM+ data that for the most part represent conditions in the year 2000 (Wulder 2002). The land cover map will provide some NFI attributes, particularly in the north, and inputs for the National Forest Carbon Accounting Framework. This will take about four years to complete (late 2005) and will be accomplished in partnership with provinces and territories. The land cover information generated through EOSD is intended to form the basis for a land cover map of Canada representing year 2000 conditions. Over half of Canada is forested and will be mapped by EOSD (Wulder and Seemann 2001), leaving agricultural and northern areas to be addressed by the appropriate sectors. The regionally stratified information may in turn be combined to provide the national picture.

The EOSD land cover maps of the forested area of Canada is an important element of the National Forest Inventory and the National Forest Carbon Accounting Framework. EOSD products will also be made freely available over the web to the public and other interested parties. The linking of ground and space-based data will facilitate the use of space technologies in forest management systems. The methods and automated procedures developed under EOSD are themselves products that will be available to others. It is anticipated that after the successful completion of the EOSD project, satellite imagery and analysis methods will be a major component of an operational system to monitor and report on Canada's forests.

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[1] http://www.pfc.cfs.nrcan.gc.ca/eosd/cover/

Carbon Accounting

The increasing awareness of the impacts of land use, land use change, and forestry on sources and sinks of carbon is driving international efforts to quantify and monitor changes in forest carbon stocks. Information from the NFI and EOSD programs can significantly contribute towards Canada's efforts to develop a National Forest Carbon Accounting Framework. This new system is required to meet the reporting requirements under the United Nations Framework Convention on Climate Change (UNFCCC) and under the Kyoto Protocol.

The estimation of C stocks and stock changes in forest ecosystems requires a modelling framework that integrates, in space and time, information on various aspects of forests and forest dynamics. The approach selected for the Canadian National Forest Carbon Accounting Framework is building on over a decade of experience with the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2, Kurz et al. 1992, Kurz and Apps 1999). Developed initially as a research model, revisions and enhancements are now in progress to incorporate new scientific findings, and to make the model operational at a range of spatial scales. In compliance with international reporting requirements, the model tracks all ecosystem C pools, including above- and below-ground biomass and dead organic matter pools, such as snags, coarse woody debris, litter, and soil carbon.

Information requirements for a National Forest Carbon Accounting Framework include a detailed forest inventory and information about forest dynamics. The inventory information must include estimates of the forest type (including species or species groups), age, and other stand attributes. Change information is required for both stand-level dynamics, such as growth rates, stand mortality, and dead organic matter dynamics, and for landscape-level dynamics such as forest harvesting, natural disturbances, and land use changes. No single information source is sufficient to meet the input requirements for a National Forest Carbon Accounting Framework and work is under way to address many of the scientific and technical issues that need to be resolved for development and implementation of the framework.

Forest Inventory Information Requirements

The CBM-CFS2 can accommodate a variety of forest inventory formats. Current plans envision that, for a given area (e.g., an operational or management unit, an ecological region or an administrative province or territory), the best available inventory information will be used.

When fully implemented, the new NFI system of photo and ground plots will provide a consistent and up-to-date inventory for all of Canada. In the initial design, it will cover 1 % of the forest area. The National Forest Carbon Accounting Framework will be designed to make maximum use of the available NFI information, yet it also incorporate flexible design elements to allow for other data inputs where appropriate. Where additional inventory information is available, for example from provincial or corporate inventories in intensively managed forest areas, the framework will accommodate the additional inventory information.

One important potential interaction between the new NFI and the EOSD forest cover programs is extending the NFI information obtained for photo plots to a larger area. This may provide a cost-effective and statistically valid option for expanding the estimates for 1% of the forest area to a larger proportion of the forest area. The methods that will allow for the extension of NFI information to larger areas using remotely sensed data are being developed.

The estimation of forest C stocks and stock changes requires that stand growth and mortality rates be calculated. Stand dynamics can be defined using either empirical growth models or process-based simulation models. Remote sensing and forest inventories provide information on the current state of the forest. Until repeated measurements are available, rates of change cannot be estimated from these information sources, but they can play an important role in assisting in the assignment of growth curves to forest cover types, or in the parameterization of process models.

Landscape-level Change Information

Information on harvest rates and the extent and location of natural disturbances, such as fire and insects, are critical for the implementation of a National Forest Carbon Accounting Framework. The Kyoto Protocol imposes additional requirements, because it calls for separate accounting of C stocks and stock changes on areas subject to forest to non-forest conversions since 1990. These include deforestation, i.e. the transition from forest to other land uses, and afforestation and reforestation, defined in the Kyoto Protocol as the transitions from non-forest to forest. Reforestation in the Protocol excludes the regeneration of stands that had been harvested or killed by natural disturbances, because temporary removal of forest cover is not considered deforestation (or land use change). This poses special challenges to a space-based monitoring program, because detection of the loss of forest cover is not sufficient to determine whether a deforestation event has occurred.

Both the NFI and the EOSD programs can provide important estimates of change processes in Canadian forests. Regular re-measurements of NFI plots will provide information on changes that have occurred over the measurement period. One challenge for the implementation of a National Forest Carbon Accounting Framework will be that methods need to be developed assign activities that occurred during the re-measurement period to individual years or to the 5-year commitment periods of the Kyoto Protocol. Remote sensing may provide the additional information required to identify the year in which certain events have occurred.

The ongoing change research programs (EOSD change, Climate Change Action Fund change research, etc.) are developing methods, tools and estimates of the rates of change in Canada’s forests. Initial emphasis is on land use changes, which presently are not monitored in most provincial and territorial land inventories. Information on the areas affected by afforestation, reforestation, and deforestation since 1990, however, will be a mandatory requirement for all countries that ratify the Kyoto Protocol. Information on other forest changes, including harvesting and natural disturbances, can also be derived from the change products.

The integration of forest inventory information, forest cover updates and change information from remotely sensed sources, and other information on stand and landscape-level C dynamics, will be accomplished with the CBM-CFS2. Methods and the required software tools are currently under development in several pilot projects (Kurz et al. in press).

Some of the information requirements for the CBM-CFS2 cannot be met from inventory, monitoring or remote sensing programs. The National Forest Carbon Accounting Framework incorporates computer simulation models and data from other sources to augment the information from inventory and forest monitoring programs.

Program Integration

The close integration of the new NFI and EOSD programs is a mutually beneficial arrangement. Ground-plot and photo-plot information from the NFI will enhance the classification algorithms of the EOSD program and will allow for continuous testing and improvement of the classification schemes. In turn, EOSD will endeavour to provide the NFI with the information required to extend the inventory coverage beyond the 2 km x 2 km photo-plots for a limited number of attributes through the use of a land cover mapping legend that is fully compatible with the NFI. EOSD will also provide plot information for areas in the north where aerial photographs may not be available. In the future, EOSD products could provide the NFI with information on forest cover changes in plots. This may help identify the year in which specific events occurred (as required for Kyoto Protocol reporting) and may contribute to annual inventory updates.

The potential for biases in the NFI plots can also be tested with EOSD land cover data. EOSD land cover data can also be used to determine if the NFI sampling adequately captures forest characteristics. NFI information will also allow for the calibration of satellite data to ensure that the satellite-based estimates concur with the NFI predictions (e.g., Päivinen et al. 2001). Calibration of satellite-based (i.e. Landsat and AVHRR) estimates of forest characteristics with NFI data will allow comprehensive, multi-scale, and timely monitoring and reporting options.

Products developed from the EOSD project are expected to make a significant contribution to the National Forest Carbon Accounting Framework. For example, the EOSD project is expected to provide forest cover maps, methods for estimating biomass using satellite and inventory data, and techniques to identify areas affected by land use change and natural disturbance events (e.g., fire, insect, harvesting etc.). The EOSD project is working towards the collection of data at intervals corresponding to national reporting commitments. One important initial product anticipated from the EOSD program in co-operation with other agencies is a land cover map representing year 1990 conditions. This map will assist in the identification of areas affected by land use change activities (afforestation, reforestation, and deforestation) since 1990, for which changes in C stocks must be reported under Article 3.3 of the Kyoto Protocol.

The National Forest Carbon Accounting Framework is one example of the use of NFI and EOSD products in support of national and international reporting requirements. To ensure that the products from the national programs will indeed meet the requirements, pilot projects on a limited spatial scale are being implemented. Moreover, representatives from all teams meet periodically to review and discuss the project requirements and the anticipated use of resulting data.

Conclusions

Canada's forests are vast and cover many sparsely populated areas. As the steward of 10% of the world's forest, Canada must develop forest inventory and monitoring programs that meet the growing demand for a wide range of information types, and at the same time place realistic demands on the limited available financial and human resources. Well-integrated programs are required that combine federal, provincial, territorial, and forest industry activities to support the needs of the national forest inventory, forest cover and forest change monitoring, and the development of carbon stock estimates. While the examples provided here focus on the use of the inventory and monitoring information for a specific application, the strength of both the NFI and EOSD programs is that the information is equally applicable to a variety of other planning, monitoring and reporting applications (e.g., C&I processes to monitor sustainable development, FAO Forest Resource Assessments, and to support policy). These activities are important applications of space-based technologies in support of the development of forest inventory and monitoring systems that are required for sustainable forest management.

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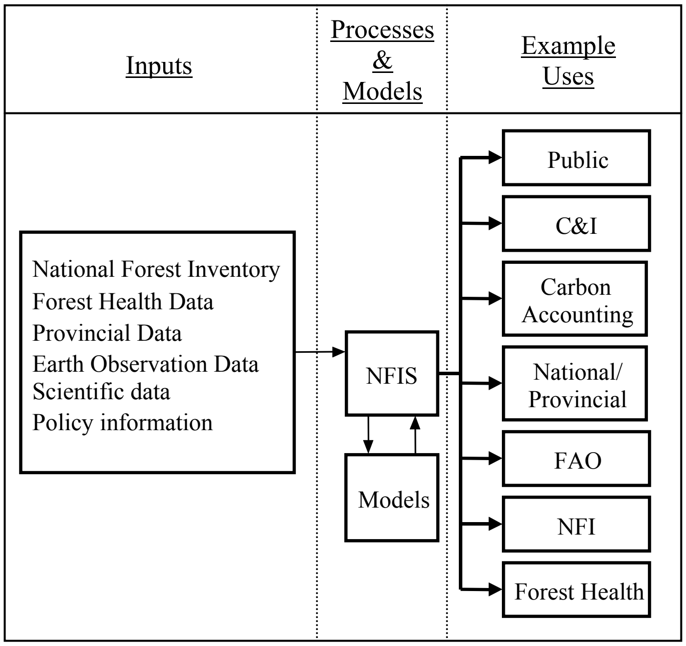

Figure 1. Illustration of linkage of monitoring systems, data processing and modeling, to information outputs generated from national measurement and monitoring systems.

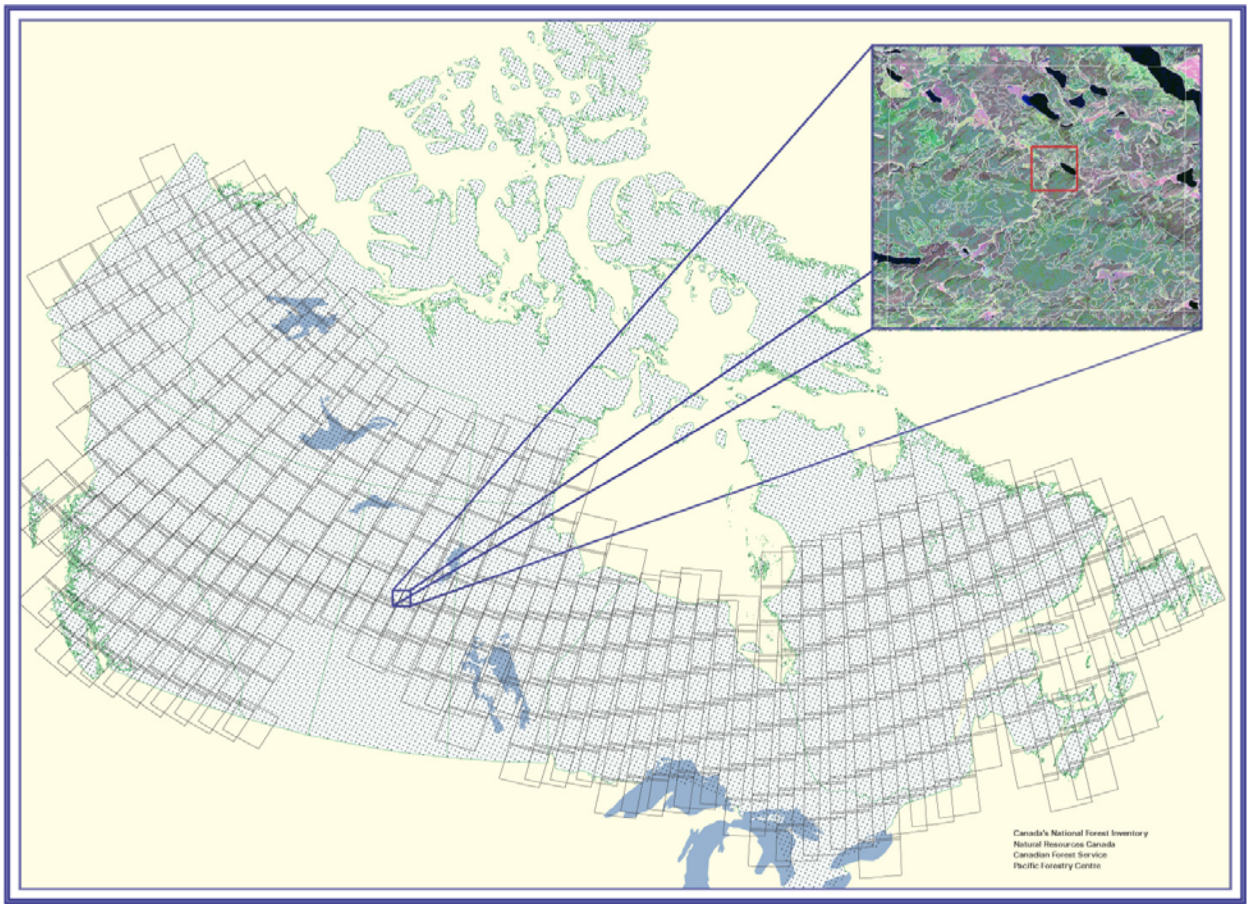

Figure 2. Example NFI grid with world-wide referencing system overlaid to illustrate forested area of Canada to be mapped by EOSD. The inset illustrates the integration of remotely sensed data, forest inventory data, and a sample photo-plot.

Table 1. Select forest statistics for Canada indicating ownership of forest land and forest area by province and territory (derived from NRCan (2001) where forest area values are after Gray and Power (1997)).

Province	Ownership (%)			Area (million ha)		
	Federal	Provincial	Private	Total	Land	Forested
Newfoundland and Labrador	0	99	1	40.6	37.2	22.5
Prince Edward Island	1	7	92	0.57	0.57	0.29
Nova Scotia	3	28	69	5.6	5.3	3.9
New Brunswick	1	48	51	7.3	7.2	6.1
Quebec	0	89	11	154.1	135.7	83.9
Ontario	1	88	11	106.9	89.1	58.0
Manitoba	1	94	5	65.0	54.8	26.3
Saskatchewan	2	97	1	65.2	57.1	28.8
Alberta	9	87	4	66.1	64.4	38.2
British Columbia	1	95	4	94.8	93.0	60.6
Yukon Territory	100	0	0	48.3	47.9	27.5
Northwest Territories and Nunavut*	100	0	0	342.6	329.3	61.4
Canadian totals	23	71	6	997.0	921.5	417.6

* Nunavut incorporated out of the Northwest Territories in 1999; current forest statistics are not yet available.