

A Strategy for Mapping Canada's Forest Biomass with Landsat TM Imagery

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Abstract - Estimates of forest biomass are needed to meet Canada's international reporting requirements and to provide important inputs for global change, carbon accounting, and forest productivity models. The Canadian Forest Service, in cooperation with the Canadian Space Agency, has developed a strategy for mapping Canada's forest biomass as part of the Earth Observation for Sustainable Development of Forests (EOSD) Project. The strategy includes: (i) development of a biomass mapping method, (ii) regional expansion of the method, and (iii) national implementation. The method estimates forest biomass at the forest management stand level using forest cover type and structure information extracted from Landsat Thematic Mapper (TM) data. Regional expansion of the method has occurred over several pilot regions that represent a range of forest ecosystems across Canada. Validation of regional products provides an indication of the precision of the method, defines the data requirements and limits to regional expansion, and has led to the development of research themes. Specific research themes address known limitations of the method by i) improving the extraction of cover type and structure information from satellite imagery, ii) defining the role of environmental variables and other factors for biomass estimation, and iii) separating understorey and overstorey biomass. National implementation of the strategy will take place once specified mapping criteria have been met over a range of test areas.

I. INTRODUCTION

Forest biomass, the mass of the above-ground portion of live trees per unit of area [1], is a basic forest property that is linked to many forest ecosystem processes. As such, it is an important input to global change and productivity models. National estimates of forest biomass are needed for assessing carbon stocks and the contribution of Canada's forests to the global carbon cycle [2], as well as for monitoring and reporting on several criteria and indicators of sustainable forest management identified by the Canadian Council of Forest Ministers [3].

Mapping forest biomass is a challenge on many fronts. Measuring biomass is complex; and must be modeled at both

tree and stand levels in order to acquire sufficient source data for mapping. In addition, Canada is a very large territory with a wide diversity of ecosystems and limited source data to represent this diversity. As forest inventory techniques vary by province [4], this complicates the use of forest inventory information for biomass calibration. The estimation of biomass from spectral response is also non-trivial and requires resolution of biomass accumulation that goes beyond that which can be detected by remote sensing imagery alone.

In response to the need for spatially explicit maps of forest biomass as well as the challenge associated with mapping biomass, this paper overviews a strategy for mapping Canada's forest biomass with Landsat Thematic Mapper (TM) imagery. This strategy will be employed in the Earth Observation for Sustainable Development of Forest (EOSD) Project, a joint Canadian Forest Service and Canadian Space Agency project to use space-based remote sensing technology to create products and develop methods to support Canada's priorities and international commitments for monitoring the sustainable development of its forests [5].

II. KEY PRODUCTS

The key biomass products of the EOSD Initiative will include:

- A national forest biomass map and related statistics.
- Regional and national stand-level databases to support process modeling and forest management activities.
- Remote sensing mapping methods adapted to Canadian ecosystems.

The forest biomass maps and databases will express the total above-ground biomass per hectare, without specifying the individual contribution of each species or the various tree and stand-level components. Mapped estimates of component biomass may be possible as value-added products by making use of partitioning equations available from published literature. Here, component biomass refers to the proportion of biomass in understorey and overstorey species, roots, stems, foliage, etc. One of the advantages of a biomass mapping method that uses remotely sensed information is that biomass estimates will correspond to the time of image acquisition.

Fig. 1. Strategy for biomass estimation and mapping in Canada.

A. Strategy

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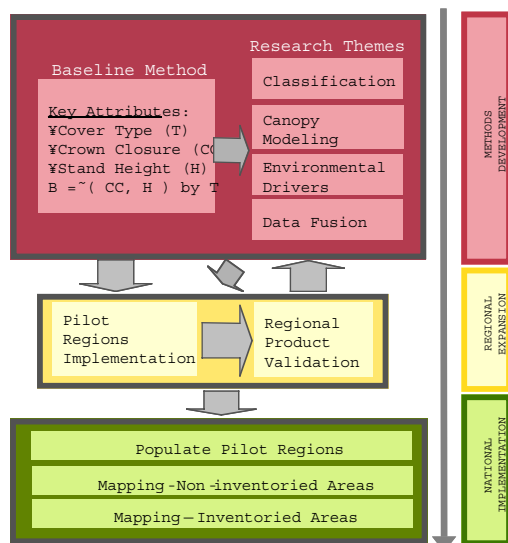
B. Framework

C. Baseline Method

IV. RESEARCH THEMES

A. Classification

Basic information on forest cover type and structure is needed to estimate above-ground forest biomass. The first research theme looks at refining and applying classification methods to improve the mapping of these basic attributes.



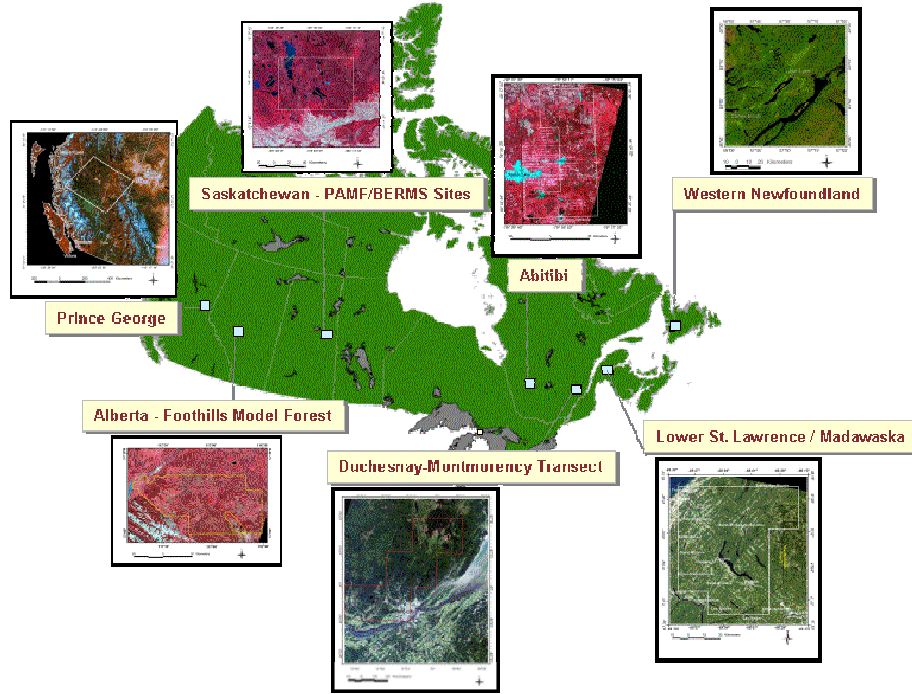


Fig. 2. Pilot regions framework for developing and testing biomass mapping methods.

Research includes hierarchical classification approaches and optimal use of existing forest inventory data. In early work, clusters generated by an unsupervised classification were labeled automatically using random samples of existing digital forest inventory maps as training data. Validation of the biomass estimates, based on forest inventory plots and a comparison with biomass maps generated using digital forest inventory maps, shows reasonable agreement for the classification of broad cover types but weaker relationships with biomass [7,8].

B. Canopy Modeling

The second research theme uses a canopy reflectance modeling approach to (i) improve the estimation of cover type and structure information particularly in areas with limited ground data, and (ii) separate the understory and overstorey contributions to the remotely sensed signal [9]. The use of canopy reflectance models provides an explicit physical structural basis to the analysis of satellite imagery and represents an alternative approach for obtaining forest cover type and structural information for biomass estimation.

C. Environmental Drivers

A third theme looks at the role of ancillary environmental data to improve biomass estimation both at national and regional scales. Early research results indicate that estimates of biomass improve on a national scale when biomass models

are developed as a function of remote sensing variables combined with environmental attributes consisting of climate moisture index, precipitation, growing degree-days and digital elevation [10]. At the regional scale, attempts will be made to improve the accuracy of biomass source data by developing plot-level biomass equations that make optimal use of environmental variables. The availability of environmental attributes as grids will allow mapping biomass over the landscape using models that incorporate environmental information.

D. Data Fusion

A fourth theme will address the fusion of Landsat-7 and Radarsat-1&2 SAR data to improve land cover mapping and biomass retrieval accuracy. Past studies using a variety of C-band SAR data (multi-polarized, polarimetric, temporal, coherence) have shown some level of sensitivity to above-ground biomass of coniferous forests below roughly 50 tons/ha, although some environmental variables have a significant impact that must be addressed. Therefore, a Landsat-Radarsat data fusion strategy will be investigated for retrieving biomass in non-inventoried northern boreal forests dominated by black spruce and with low biomass levels.

V. WAY FORWARD

The way forward follows from the proposed strategy defined earlier and is divided into three groups of tasks:

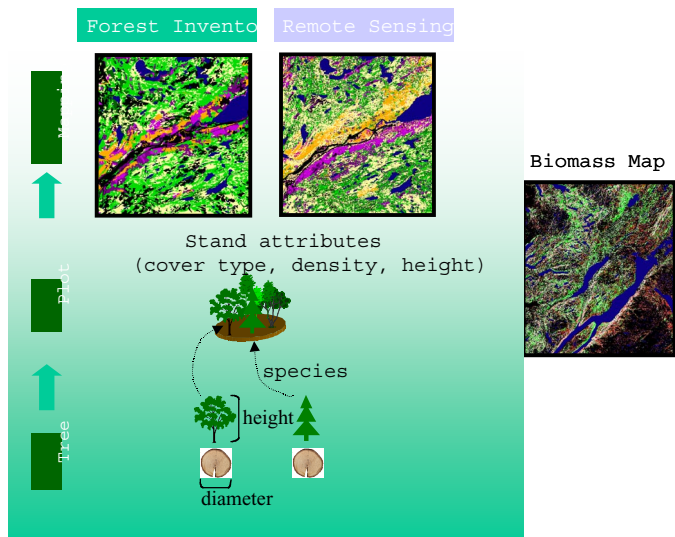


Fig. 3. Baseline method for extending biomass estimates from sample plots across the landscape.

methods development, pilot region implementation and national implementation. Since Fall 2000, the EOSD project has focused primarily on methods development aspects. Implementation of the baseline method and product validation on pilot regions began within the last year and will continue over the next couple of years. National implementation will begin when the required level of precision in biomass estimation has been achieved. The priority for using Landsat TM imagery will be placed on the non-inventoried areas of Canada, which currently have no other means of deriving biomass estimation. In subsequent years, biomass estimation from Landsat TM may complement inventory estimates for areas that have experienced significant change.

VI. CONCLUSIONS

A national strategy for spatially explicit biomass mapping at the forest management level has been proposed for the Canadian context. Key benefits of this initiative will include the provision of a national forest biomass map of Canada with a stand-level biomass mapping capability. Satellite remote sensing imagery specifically allows for mapping current biomass status and also an improved quantification of errors in biomass mapping with a similar error structure across regions. Overall, EOSD biomass products will contribute to a next-generation forest measurement and monitoring system for Canada [5].

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