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Large Area Forest Biomass Estimation and Mapping in Canada: Context and Case Studies

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Abstract

Knowledge of forest biomass is necessary for reporting on the state of Canada's forests. Biomass information is also required for ecosystem productivity and carbon budget models, and it serves as an indicator of the structural and functional attributes of forest ecosystems. Forest biomass information used in national reporting is mostly derived from regional and national estimates of forest biomass from Canada's National Forest Inventory (NFI), and subsequent mapping of biomass using compiled NFI inventory data. Extending inventory data into maps of forest biomass, however, can be a challenging exercise that is influenced by a multitude of factors related to data availability and the scaling of tree-level allometric functions to the stand level. The spatial extent of existing forest inventories results in data gaps when regional or national biomass estimates are of interest, and this is a particular problem in the northern areas of Canada where access and resource requirements preclude the creation of large area inventories. As a result, there is a requirement to incorporate some level of remote sensing information from which biomass can be modeled and mapped. There are at least four different approaches that comprise recent, current and proposed biomass estimation and mapping activities in Canada. Earth observation data contribute to each of these approaches to varying degrees and while not all approaches result in large area biomass maps, they all provide a means of generating estimates for large regions. These four approaches for estimating and mapping biomass include:

1. Inventory Compilation, Estimation and Mapping: The historical approach involves a compilation of provincial forest inventories and was used to produce the first national forest biomass inventory in Canada. This approach has subsequently been replaced by the NFI, a plot-based system consisting of a 2 km by 2 km sample plot distributed 20 km apart in a systematic grid network across the country. Inventory data at NFI plots are now

used to generate estimates of merchantable volume from which aboveground biomass is derived, and mapped through spatial interpolation techniques.

2. Models Driven by Satellite Derived Forest Type: Building upon a national Landsat-derived land cover map that was created under the Earth Observation for Sustainable Development of Forests (EOSD) project, the second approach uses a series of models, stratified by ecozone, site, and age class to estimate total volume of forest stands within three broad forest types consisting of conifer, deciduous, and mixedwood. Biomass is subsequently derived using the same methodology used in the NFI. The resulting map products are considered best suited for regional and national scale overviews, and it served as a source of land cover, volume and biomass information at NFI plots where inventory data are unavailable.
3. Multi-resolution/Multi-resolution Scaling: The third approach has been in the research and demonstration domain and it involves developing empirical relationships between a judicious sample of field plots and its corresponding image spectral response values from high spatial resolution satellite imagery (e.g., QuickBird). The mapped estimates from high spatial resolution images are subsequently used in a sampling process and scaled using a k-nearest neighbour (k-NN) imputation to extend estimates over medium spatial resolution satellite images such as the Landsat Thematic Mapper. This approach was developed specifically for areas where inventory data are limited, and field data may be logistically difficult and costly to collect. Forest structure and biomass estimates from either satellite waveform LiDAR data (eg., ICESat) or airborne profiling LiDAR (PALS) are now being incorporated as an additional source of inventory data to improve the stand structure and biomass mapping process.
4. k-NN Sampling of NFI Plots: A new approach is currently under development that uses NFI plots and k-NN imputation based on 250m MODIS products along with other spatial information such as climate surfaces, topography, and vegetation land cover (eg., derived from the North American Land Change Monitoring System – NALCMS), to produce annually-updated, spatially contiguous biomass maps over Canada. As both NFI and NALCMS are intended to be monitoring systems, the potential exists to generate forest composition, structure, biomass and forest productivity estimates and maps over time.

The purpose of this communication is to describe the information needs, context and approaches for large area biomass estimation and mapping in Canada. We will endeavor to describe the status of biomass mapping in Canada, the complementarity of approaches that have been employed or under development, and the opportunities for future integration of approaches for estimating, mapping, and monitoring forest biomass in Canada.

Keywords: forest biomass, inventory, forest attribute mapping, remote sensing

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