Spatially-explicit Assessment of C Stocks and Fluxes for Canada: a Pilot

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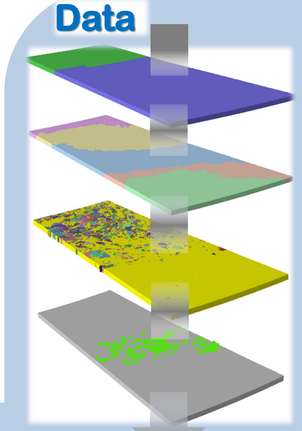
Background

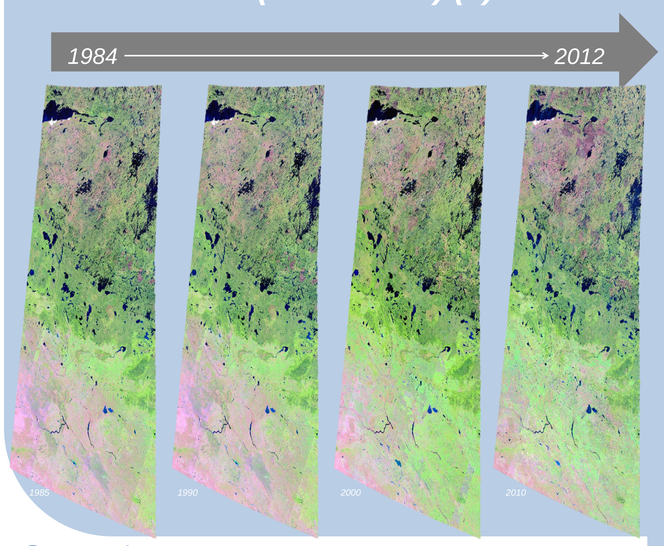
Forest and forest dynamics are an integral component of the global carbon (C) cycle with the photosynthesis footprint of terrestrial primary producers visible in the seasonal hemispheric CO_2 records. Forests are the largest terrestrial primary producer and Canada's forest cover represents 30% of the world's boreal forest and 10% of the world's overall forest cover. Quantifying the contribution of Canada's forest to the global C balance is a key objective of carbon science in Canada and as such, Canada maintains the well-established National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) for its managed forest. This research will contribute improvements to Canada's NFCMARS.

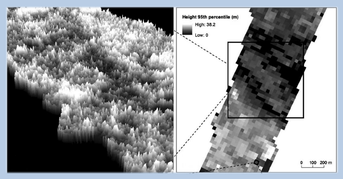
Data



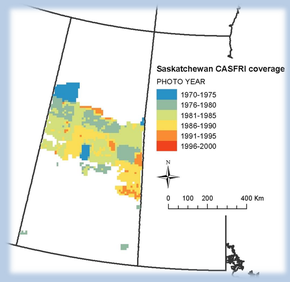
- *Administration Boundaries*
- *Ecological Boundaries (2)*
- *Forest Inventory*
- *Permanent Sample Plots (Saskatchewan Ministry of Environment Forest Service)*

Annual Landsat pixel-composite time series (1984–2012) (1)



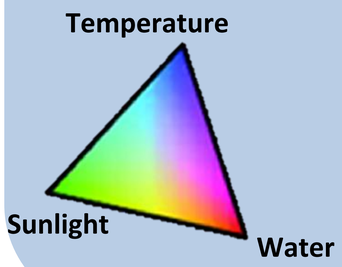


- *LiDAR metrics from 2010 National LiDAR Transects (3)*



- *Inventory: CASFRI database (4)*

Remotely Sensed Growth Potential



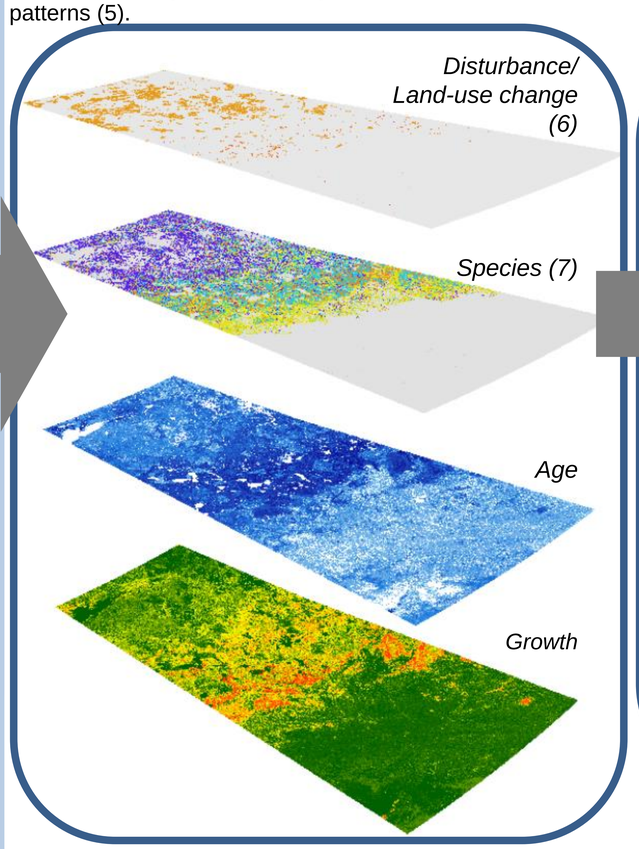
- *Topographic Solar Radiation Index*
- *Topographic Wetness Index*

Overview

- Spatially-explicit modelling of C estimates for Saskatchewan's forest at 30 m resolution using a recently modified spatially-explicit version of CBM-CFS3, the core model of the Canadian carbon accounting system.
- Expanding C estimates to unmanaged forests in Saskatchewan (SK) using a combination of a dense time series of Landsat imagery, LiDAR data, and growth modelling (~7% of Canada's forests are considered unmanaged, and 37% of the forested land base in SK falls in this category).
- Using a 30 m change product characterizing annual forest change (1984 – 2012).
- Combining permanent sample plot data, Landsat imagery, forest inventory, and LiDAR data, to represent forest productivity in a spatially-explicit manner.

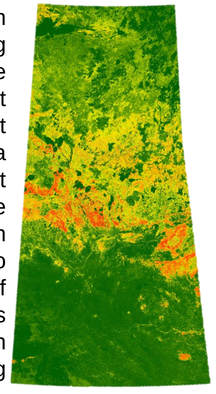
Model Inputs

The C Budget Model of the Canadian Forest Sector 3 (CBM-CFS3) is an annual time-step model that uses growth and yield data and forest cover inventory and change information to estimate stand- and landscape-level biomass C dynamics (5). Using forest attributes and disturbance information, the model can assess past changes in C stocks as well as evaluate future changes that might result from modified management strategies or altered disturbance patterns (5).



Growth from ΔBiomass

A spatialized representation of growth for all the forests of SK is being developed using permanent sample plots, proxy-filled time dense Landsat pixel values, and many different species, age and height values (8) in a piece-meal approach for different regions of Saskatchewan, where the best available data is used for each piece in a Random Forest model to estimate biomass for each year of simulation. Once this stack of biomass rasters is produced, forest growth representation will be built by clustering approaches.

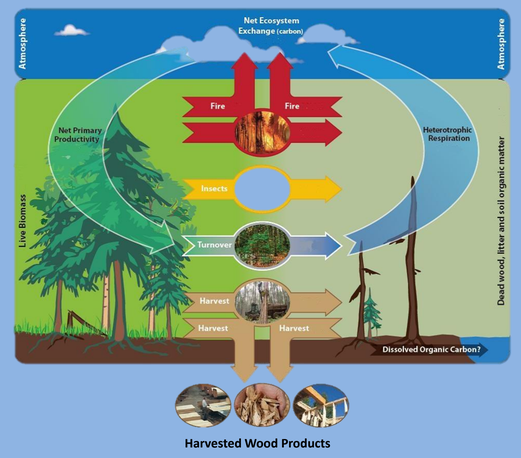


Benefits

- Systematic, repeatable, spatially and temporally exhaustive high resolution annual C flux and stock estimates, both for managed areas and for unmanaged areas where remote sensing techniques are the only economical or practical method of data collection.
- Model input based on Landsat products enables the use of a common information source for annual input into CBM-CFS3.
- Timely estimation of C stocks and fluxes for large areas benefiting both the science and policy communities.

CBM-CFS3

Model runs will associate numbers with the arrows below for Saskatchewan 1984-2012



Challenges

- Characterizing uncertainty in overall C estimates associated with multiple data inputs and modelling assumptions.
- Upscaling from plots to Landsat reflectance in unmanaged areas that have few existing ground plots.
- Data size and processing power: each raster for Saskatchewan contains over 1 billion 30 meter pixels

Acknowledgements

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References

(1) White JC, et al. 2014. Pixel-Based Image Compositing for Large-Area Dense Time Series Applications and Science. Canadian Journal of Remote Sensing 40:192-212.
(2) Wiken, E.B. 1986. Terrestrial Ecozones of Canada. Ecological Land Classification, Series No. 19. Environment Canada. Hull, Quebec. 26pp. + map.
(3) Wulder MA, White JC, Bater CW, Coops NC, Hopkinson C, Chen G. 2012. Lidar plots — a new large-area data collection option: context, concepts, and case study. Canadian Journal of Remote Sensing 38:600-618.
(4) Cumming, S.G., Schmiegelow F., Bayne, E., Song, S. (2010) Canada's forest resource inventories: Compiling a tool for boreal ecosystems analysis and modelling - A background document
(5) Kull, S. J. et al., 2007. Operational-Scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) Version 1.0: User's Guide, Edmonton, Alberta: Canadian Forest Service, Northern Forestry Centre.
(6) Hermosilla T, Wulder MA, White JC, Coops NC, Hobart GW. 2015. An integrated Landsat time series protocol for change detection and generation of annual gap-free surface reflectance composites. Remote Sensing of Environment 158:220-234.
(7) Internal data set Wulder and White lab.
(8) Beaudoin A, Bernier PY, Guindon L, Villemaire P, Guo XJ, Stinson G, Bergeron T, Magnussen S, Hall RJ. 2014. Mapping attributes of Canada's forests at moderate resolution through kNN and MODIS imagery. Canadian Journal of Forest Research 44:521-532.