Estimating landcover change and greenhouse gas emissions using spatiotemporal MODIS data: A case study in northern Ontario

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There is a positive effect of the changing climate: in northern Ontario, the warming weather has lengthened the growing season. The study area in northeastern Ontario is referred to as the Great Clay Belt. It extends from Quebec into Ontario; in Ontario, the area spans about 120,000 sq. km. As its name suggests, the region is known for its predominantly clayey soil. The soil has typically allowed barley, oat, and wheat crops to be grown successfully. Yet, with the increased temperature in recent years, other crops (including soybeans, canola, corn grain, and silage corn) are now being grown. However, this area has harsh weather. Average temperature in July is about 17°C, with peak mean monthly rainfall amounts of about 95 mm in July, and an average of 557 mm of rain annually. Furthermore, the first frost occurs in the mid-September.

These weather conditions have forced several aspiring farmers away from the Great Clay Belt.

In recent years, annual crop heat units (CHUs) have risen by 25 percent. (The CHU is related to the minimum and maximum temperatures for a day.) The rise has come with an increase in yield per acre. The government of Ontario wants to expand agricultural opportunities in northern Ontario. One way it will do so is by attracting potential farmers to undertake both livestock and crop farming in the region (Government of Ontario, 2013, 2016).

HISTORY REPEATED?

This is not the first government initiative to populate the Clay Belt region with farmers. The 1920 *Report [of the] Commission of Enquiry, Kapuskasing Colony* detailed the failed effort to maintain farmers living in that area. Soldiers who returned from the First World War were enticed to Ontario's Clay Belt with the promise of free land, 20 million acres of virgin soil, where (as another promotion declared) alfalfa, clover, field roots, barley, and other grains could be "grown with … phenomenal success" (Temiskaming and Northern Ontario Railway Commission, 1912, p. 7). The Temiskaming and Northern Ontario Railway Commission stated that the area had no stones and good drainage, and the winter "sometimes touches a lower notch than at Ottawa or Montreal" (1912, p. 7). Unfortunately, the conditions were too harsh for many; furthermore, the government had overpromised on the potential for success. Thus, those who had settled there got refunds on land and animals and were given free transport to relocate to any other place in Ontario.

While challenges to agriculture in the Clay Belt region still exist, the summer months are still wet, with an average of 14 rain days per month (Beef North, n.d.). A solution to the poor drainage has been found with tile drainage, and with long-term warmer weather being expected as a result of the effects of climate change, agricultural endeavours could become even more profitable.

CHANGING LANDSCAPE

Most of the area the Ontario government has initially targeted to establish agricultural lands is currently forested. The project, tagged the Northern Livestock Pilot, is funded from investments by the government of Ontario, the Beef Farmers of Ontario, and northeastern Ontario municipalities (Government of Ontario, 2016). These entities are promoting research projects in the areas of environmental, social, and economic sustainability, and our study is among the environmental sustainability projects. Our aim is to identify the possible soil carbon and greenhouse gas (GHG) changes that might occur when the currently forested land undergoes transformation to agricultural land. The long-term effects of land conversion from forests to agriculture are not yet known. However, past studies indicate that soil carbon, nutrients, and GHG emissions will be affected by the conversions.

REMOTE SENSING TOOLS FOR OBSERVING LAND CHANGES

Land-use dynamics have been studied extensively over the years through observations made with various remote sensing tools. Our study uses Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery. MODIS satellite data is commonly used for large-scale and long-term monitoring of the earth's environment. In agriculture and forestry,

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changes detected from such satellite imagery can be used to monitor crop growth, detect soil moisture, and monitor deforestation and forest fires (Kempeneers et al., 2012).

First, we aim to observe the land-use and landcover changes that have occurred in the study region over the past two decades to establish the trend in historical land disturbance—for example, wildfires, harvesting, or forest insect damage. Thereafter, we can predict the frequency and extent of future land disturbances in the region. We will then model the GHG emissions, which will result from land conversions and disturbances.

Given the expansive area covered by Ontario's Clay Belt, it was deemed prudent initially to use moderate-resolution imagery to identify areas of landcover change. Subsequently, plots that have undergone landcover change will be examined in closer detail, using high-resolution satellite imagery.

We have developed an automatic and operational method to determine where landcover change has occurred. It uses a vegetation index and the land surface temperature as input parameters. By performing a statistical test on these parameters, it could be determined whether significant change has occurred in the region.

MODELLING CARBON AND GREENHOUSE GAS EMISSIONS

Using the Canadian Forestry Services Carbon Budget Modeller (Kurz et al., 2009), we have estimated the changes in ecosystem carbon by simulating the land disturbance impacts, climatic conditions, and forest growth dynamics. It was observed how carbon from living materials (biomass) increases as trees are growing. When an area is harvested and the debris burned, the biomass carbon reduces since the woody biomass is not on the land anymore. Additionally, the carbon amount from dead organic matter increases from the stems, branches, and other organic waste on the land. Differences in organic matter were also observed in the soil types. For instance, the luvisolic type of soil had the lowest dead organic matter carbon value, while brunisolic non-forest soil type had the highest initial carbon value.

There is also livestock farming, such as beef and dairy cows, in the Great Clay Belt. Additionally, commercial tree harvesting is conducted, taking advantage of the large, quality trees in this boreal forest region. With the warming effects of climate change, it is expected that more forest will be cleared and converted to agricultural land. We continue to estimate the associated carbon fluxes from these activities and intend to make recommendations on appropriate land management schemes, which will keep GHG emissions to a minimum.

REFERENCES

Beef North. (n.d.). Cow herd expansion in northern Ontario. https://www.beefnorth.com/cochrane

Government of Ontario. (2013). Northern Ontario agriculture facts and figures in brief. http://www.omafra.gov.on.ca/english/livestock/beef/news/info_vbn0713a4.htm

Government of Ontario. (2016). Northern livestock pilot action plan. http://www.omafra.gov.on.ca/english/policy/nlpap.htm#sustain

Kempeneers, P., Sedano, F., Strobl, P., McInerney, D. O., & San-Miguel-Ayanz, J. (2012). Increasing robustness of postclassification change detection using time series of land cover maps. *IEEE Transactions on Geoscience and Remote Sensing, 50*(9), 3327–3339. https://doi.org/10.1109/tgrs.2011.2181854

Kurz, W. A., Dymond, C. C., White, T. M., Stinson, G., Shaw, C. H., Rampley, G. J., Smyth, C., Simpson, B. N., Neilson, E. T., Trofymow, J. A., Metsaranta, J., & Apps, M. J. (2009). CBM-CFS3: A model of carbon-dynamics in forestry and land-use change implementing IPCC standards. *Ecological Modelling, 220*(4), 480–504. https://doi.org/10.1016/j.ecolmodel.2008.10.018

Legislative Assembly of Ontario. (1920). *Report, Commission of Enquiry Kapuskasing Colony*. https://archive.org/details/kapuskascomm00onta/page/n7/mode/2up?view=theater

Temiskaming and Northern Ontario Railway Commission. (1912). *The great clay belt of northern Ontario*. http://archive.org/details/greatclaybeltofn00temi/page/6/mode/2up?view=theater