McMaster University

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Carbon Emission Mapping from Disturbnaces in Canada and Alaska Using Synthetic aperture radar (SAR), Landsat and Lidar

By

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A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment
of the Requirements for the Degree Doctor of Philosophy
in Earth and Environmental Sciences

December 2023

Abstract

no more than 250 words for the abstract

- a description of the research question/knowledge gap – what we know and what we don't know
- how your research has attempted to fill this gap
- a brief description of the methods
- brief results
- key conclusions that put the research into a larger context

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Acknowledgements

Thank you for following this tutorial!

I hope you'll find it useful to write a very professional dissertation.

Introduction

Worldwide, forests are vital carbon sinks and they store carbon belowground and aboveground. The boreal forest is the largest forest biome in the world and more than 20% of this zone is in Canada contributing to 8% of the world's forests (Brandt, 2009). Canada's boreal forests accumulate over 28 Pg of Carbon (Kurz et al., 2013) making them important global C reservoirs. A vast amount of Carbon has accumulated within this zone because of slow decomposition from cold temperatures and from their anoxic conditions (Kurz et al., 2013).

Although this zone has been known for a very long time be a C sinks, drier air temperatures attributed to climate change are now making them vulnerable to wildfire by enhancing drier fuels below and aboveground. Wildfire is currently the dominant disturbance impacting the boreal forest and accounting for vast amounts of C (Potter et al., 2023). Carbon loss is the release of particles, gasses and aerosols into the atmosphere. Wulder et al. (2020) estimated that about 1.79 Pg of biomass had been lost as a result of fire disturbance from 1985–2016. In addition to this, fire regimes are also changing, and these trends are projected to increase as climate change progresses Changes to fire regimes in Canada for an increase in area burned, fire intensity and fire severity leading to more carbon emission from fires aboveground and belowground. For example, over 17 Mha have burned just from the fires in 2023 alone in Canada. This is 5 times higher than the 2.37 Mha annual burn reported by Potter et al. (2023) in the past two decade. Changes in Canada's fire regime (fire frequency, intensity, burned area, ire severity) have the ability to convert some of these forest biomass C stocks to carbon sources and this ecosystem might not return to their original biomass carbon storage.

To understand the impact of fires on Canada's boreal forest where small fluctuations in temperature are already noted and projected to have significant effect on climate change (Phadnis and Carmichael, 2000), there is a critical need to estimate and understand the carbon loss from fire. This will not only help to improve carbon modelling and reporting but also provide mitigation measures for the areas where these trends are expected to be high.

There are two approaches to estimating carbon loss from fires. The first is the more traditional approach where the area burned, the fuel load (biomass consumed), the combustion completeness and the fraction of carbon are taken into account (French et al., 2011). The second approach is the remotely sensed method where statistical techniques are used to model combustion by establishing a relationship between field combustion and remotely sensed variables. For the more traditional approach of C emissions, a lot of uncertainties arises when accounting for fuel load and the combustion completeness as it differs from landscape to landscape (Hook et al.; Rogers et al., 2014)Hook et al., 2013). The latter is now used widely because of the availability of satellite imagery and the integration of field C measurements. Fuel load can be mapped with remote sensed observations and C loss information can be cover for a larger extent both spatial and temporally. Typically, remote sensing estimates of C loss rely on statistical approach between field measurements of C loss and absorption properties from either active or passive sensors. Several studies have found a significant relationship between remote sensing observation and carbon combustion across the boreal forests (Veraverbeke et al., 2015). The difference normalised burn ratio along other environmental spectral inputs, topographic and climate variables are derived to explain C loss. For example, Rogers et al. (2014) was able to estimate the amount of below and aboveground carbon loss from fire disturbance in Alaska using dNBR and field combustion. Veraverbeke et al. (2015) using geospatial data and Environmental variables reported that elevation, the day of burning, Burn severity (dNBR) and tree cover were the drivers of carbon emission from boreal fires in Alaska. Similarly, Potter et al. (2023) related file combustion measurement with predictor variables of climate, fire weather indices, environmental variables and remotely sensed variables. He reported that the period where a larger fire year was witnessed and later season burning generally accounted for a higher mean combustion. Tree cover, elative humidity, Normalized Difference Infrared Index (NDII), and dNBR were the most important variable for aboveground combustion, while silt, slope, solar radiation, tree cover and sand were the drivers of combustion for belowground combustion.

Carbon emission mapping such as our studies here will allow for improving C emission accounting, modelling and reporting and also more accuracte prediction of C losses which is a very key importance discussion within the united nations framework accounting.

Most of the research modelling carbon emission from disturbances such as wildfire only looked at Alaska and sometimes a combintaio of Alaska and western Canada. This research will be the first to provide belowground, soil and aboveground C emissions for the entire Canada Here, we are looking at the carbon emission rom fire from the entire Canada considering that this year, Canada had the worst fire seasons compared to other years. It is therefore important to understand the C that has been released from this disturbance and mitigation measures that can be carried out to help this ecosystem recovered from his disturbance. And also, carbon emission modelling of Canada will help in improving Canada C loss emission report and modelling and also to understand the drivers of C emission within Canada's forests.

Methods

Study area

The study area (Figure 1) is Canada's forests region which comprises of boreal, great lakes, acadian, carolinian, subalpine, columbia, montane and coastal forest. Tree species within the zone are generally conifers such as black spruce, white spruce, Tamarack, balsam fir and jack pine while deciduous trees within the zone includes Aspen, balsam poplar and paper bitch. The climate of Canada's forest varies but it is mainly characterized by cold winters and short summer (Brandt, 2009), although we are beginning to observed more warmer winter due to climate change. The mean temperature in Canada's boreal forests ranges 10ºC- 20ºC and this varies from region to region (Zhang et al., 2019)

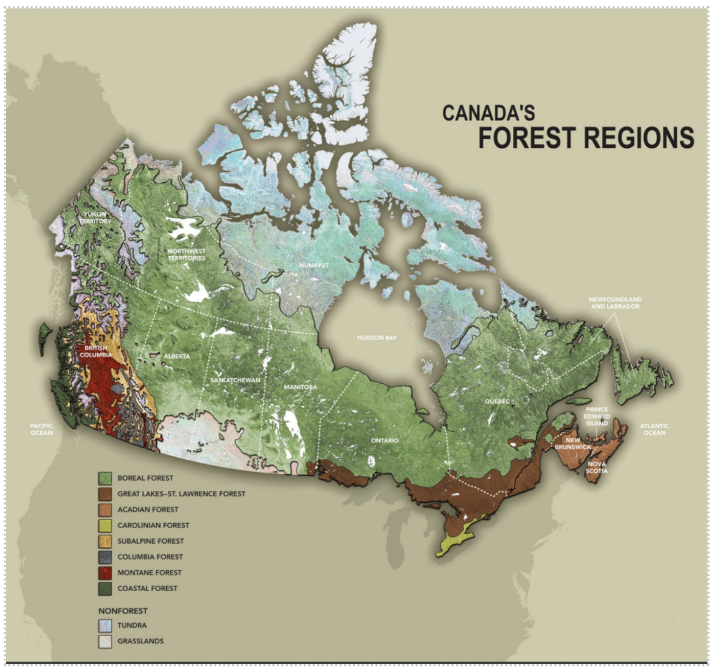

Figure 1: Canada's forests regions (Natural resource Canada)

Wildfire is the major standing disturbance within Canada's boreal forest and also other forest region with more than 2 Mha burn annually on average (Stocks et al., 2002) although this range varies from year to year.o determine areas that burned, a burned area map derived using a support vector machine learning algorithm will be used to identify area burned. To determine the areas that are primarily forests, a land cover map will be used to stratify the various land cover types. a land cover map will be used to stratify the areas of various landcover classes.

2.2 Field data

Field combustion area

To estimate the amount of C loss across Canada's major disturbances, Field combustion measurements for the year 2014 and 2015 as shown in Figure 2 were acquired from a number of publications that carried out combustion measurement within Canada's boreal forests and published online as a single database (Walker et al., 2020a).

This field measurements resulted in 456 plots and were used with other predictor variables to estimate C loss from Canada 's boreal forest fires.

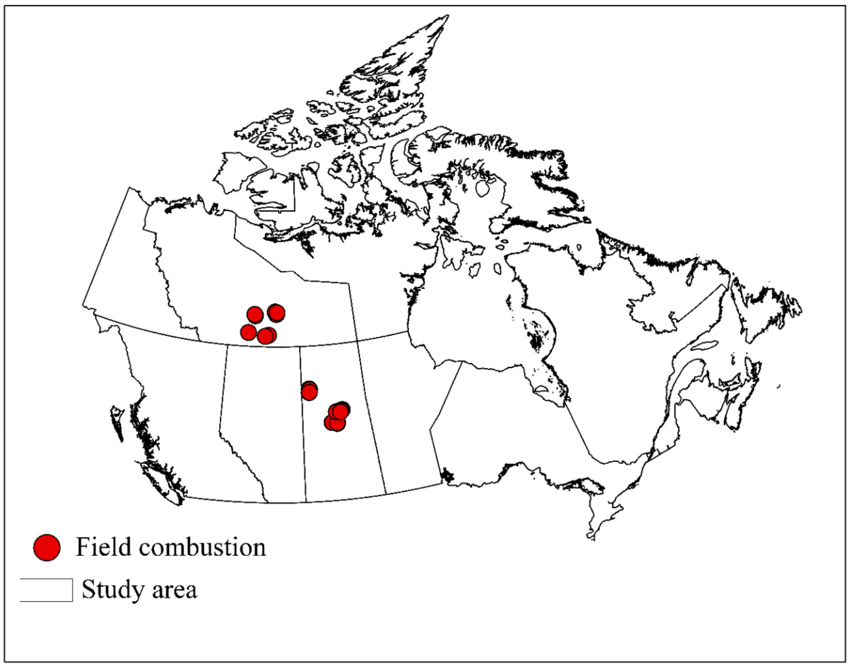

Figure 2: Field combustion area

Burned-area, harvest and insect disturbance mapping

Disturbnace map across the entire sty area will be drive using a random forest approach where we integrated different spectral indices, spectral bands and environmental variables. A threshold value established from literature and other filed collected disturbance site will be used on the final disturbance product to identify each disturbance types(fire, harvest and insect infestation) within Canada's forests.

Combustion models

Predictor variables

Field combustion measurements for aboveground and belowground C loss was obtained from Walker et al. (2020) and related to gridded environmental, fire severity and remotely sensed variables of combustion (Figure 3).

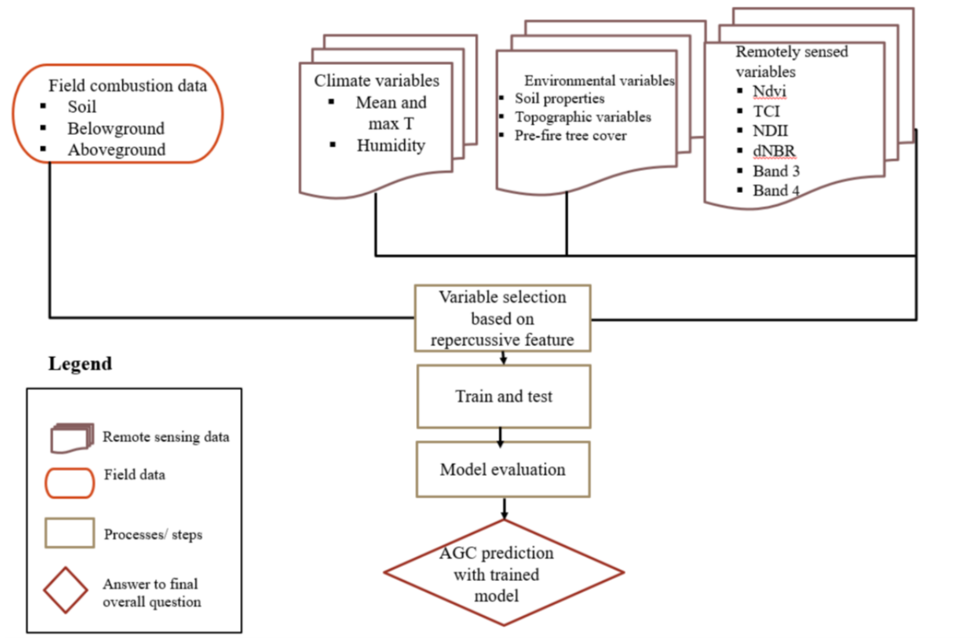

Figure 3: method to map C emissions from disturbance

The predictor variables of combustion used in this study was selected first by spanning across the literature and also discussing with experts and also further validated with a selection from random forests.

Climate variables Climate variables used in this study was obtained from Climate NA. Climate NA provides monthly, seasonal and yearly gridded climate data. This data was used to generate climate impact of C combustion within Canada's boreal forests.

2.4.3 Environmental variables Aboveground combustion from fire depends on a lot of top tree influence. The environmental variables that we will use for this research includes elevation, Soil properties , slope, aspect, and pre-fire tree cover. The elevation data will be obtained from the Advanced Spaceborne and Thermal Emission and Reflectance Radiometer Global Digital Elevation Model (ASTER GDEM), and then slope and aspect will be derived in ArcGIS or R USING THE DEM.

Prefire tree cover plays a huge factor and influences below and aboveground combustion. Tree cover influences biomass fuel for burning and it is also a measure of tree stand. Studies have found out that tree cover correlates with C loss (Rogers et al., 2014). The pre-fire tree cover used in this study will be obtained rom Sexton et al et al. (2013) for the year201 and it will serve as the pre- fire tree cover for our combustion model

The differenced normalised burn ratio (dNBR) assess changes in fire impacted vegetation using the near and shortwave infrared reflectance (Key & Benson, 2004). dNBR will also be included as a predictor variable as studies have found out the dNBR correlates significantly with biomass loss. Spectral bands of Landsat 1- 9 wil be downloaded from the USGS and the NIR and SWIR band s will be used for deriving NBR (NIRSWIR)/(NIR + SWIR). dNBR will be computed as the difference between pre-fire and post fire NBR.

2.4.4 Remotely sensed variables Remotely sensed variables used for this studies were all derived from Landsat 7 and 8. This include Landsat band 1 -9, the normalised differenced vegetation indices(NdVI), the topographic wetness index, Tasseled cap indices, and the Landsat dNBR

Results

Some more guidlines from the School of Geosciences.

This section should summarise the findings of the research referring to all figures, tables and statistical results (some of which may be placed in appendices). - include the primary results, ordered logically - it is often useful to follow the same order as presented in the methods. - alternatively, you may find that ordering the results from the most important to the least important works better for your project. - data should only be presented in the main text once, either in tables or figures; if presented in figures, data can be tabulated in appendices and referred to at the appropriate point in the main text.

Often, it is recommended that you write the results section first, so that you can write the methods that are appropriate to describe the results presented. Then you can write the discussion next, then the introduction which includes the relevant literature for the scientific story that you are telling and finally the conclusions and abstract – this approach is called writing backwards.

Discussion

the purpose of the discussion is to summarise your major findings and place them in the context of the current state of knowledge in the literature. When you discuss your own work and that of others, back up your statements with evidence and citations. - The first part of the discussion should contain a summary of your major findings (usually 2 – 4 points) and a brief summary of the implications of your findings. Ideally, it should make reference to whether you found support for your hypotheses or answered your questions that were placed at the end of the introduction. - The following paragraphs will then usually describe each of these findings in greater detail, making reference to previous studies. - Often the discussion will include one or a few paragraphs describing the limitations of your study and the potential for future research. - Subheadings within the discussion can be useful for orienting the reader to the major themes that are addressed.

Conclusion

The conclusion section should specify the key findings of your study, explain their wider significance in the context of the research field and explain how you have filled the knowledge gap that you have identified in the introduction. This is your chance to present to your reader the major take-home messages of your dissertation research. It should be similar in content to the last sentence of your summary abstract. It should not be a repetition of the first paragraph of the discussion. They can be distinguished in their connection to broader issues. The first paragraph of the discussion will tend to focus on the direct scientific implications of your work (i.e. basic science, fundamental knowledge) while the conclusion will tend to focus more on the implications of the results for society, conservation, etc.

Waiting for the command to add the references...

Appendix(ces)

Appendix A: additional tables

Insert content for additional tables here.

Appendix B: additional figures

Insert content for additional figures here.

Appendix C: code