Using GIS To Analyse The Spatial-Temporal Distribution And Spread Of The Mountain Pine Beetle In Canada

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Problem Context

The mountain pine beetle (*Dendroctonus ponderosae*, MPB) is a native bark beetle that attacks, infects, and kills pine trees with symbiotic fungi in northwestern Canada. Due to this, the MPB has killed large amounts of lodgepole pine forests and continues to threaten other pine forests. In particular, the boreal forest, which has historically been outside the extent of the MPB. However, future climate projections of warmer winters suggest that the MPB could survive and establish in these regions.

Purpose

The purpose of this research is to develop a GIS-based model that will integrate multiple biophysical factors to assess the spread and future distribution of the Mountain Pine Beetle in Canada.

Research Objectives

1. To identify biophysical factors that influence MPB distribution and spread in Western Canada.
2. To develop a GIS model that will predict future spatial and temporal variations in the distribution of the MPB.
3. To apply this model to the MPB and evaluate the future distribution and spread of the MPB.
4. To evaluate the strengths and limitations of the MPB distribution model.

Methods

Following Koch (2008)'s cost-weighted distance analysis protocol for the MPB, this study used three main variables and assumptions :

1. Rate of spread: future rate of spread will remain similar to the historic rate of spread.
2. Host density: the ability for the MPB to establish in an area is related to the density of host trees (pines). The volume of pine trees can be used to estimate the relative density of hosts.
3. Climatic suitability: the MPB will be limited by the same climatic conditions characterized by their historic extent. Primarily, the MPB is limited in its northern range by –40oC temperatures, causing 100% population mortality (Safranyik *et al*. 2012).

Results

1. Rate of spread

- From 2004 – 2017, the MPB expanded into northern B. C. and central Alberta (Fig. 1)
- Average rate of spread = ~30 km/yr from 2004-2010
- Estimated maximum distance of ~2500 km by 2100

2. Host density

- Pine tree volume (Fig. 2c) was estimated as pine percent composition (Fig. 2a) multiplied by total tree volume (Fig. 2b).
- Resistance was calculated as: $Resistance = \ln\left(\frac{1}{Pine\ Volume}\right) + 6.25$
- Maximum resistance values of ~18 occurred at ~0 m3/ha of pine
- Minimum resistance values of ~0 occurred at maximum pine volumes of 489 m3/ha

3. Climate suitability

- By 2020: -40oC temperatures restricted to Nunavut (Fig. 4a)
- By 2050: -40oC temperatures restricted to some regions of Ellesmere and Devon Island (Fig. 4b)
- By 2080: no more predicted –40oC temperatures in Canada (Fig. 4c)

4. Cost-weighted distance analysis

- By 2100, MPB spread is predicted to diverge northwest into the Yukon as well as eastward through northern Saskatchewan (Fig. 5)

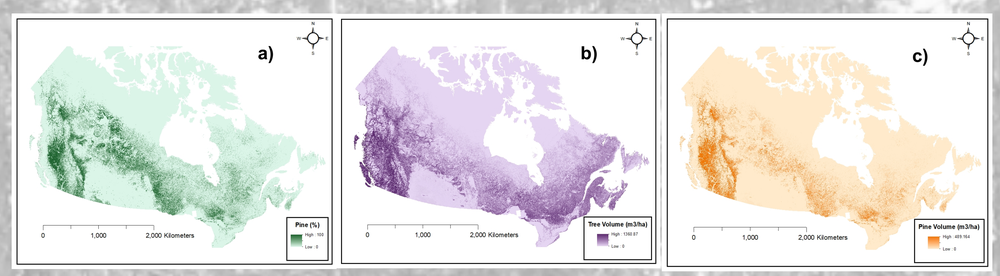

Figure 2: a) pine percent composition, b) tree volume (m3/ha), and c) pine tree volume (m3/ha) (Data: Beaudoin *et al.* 2017)

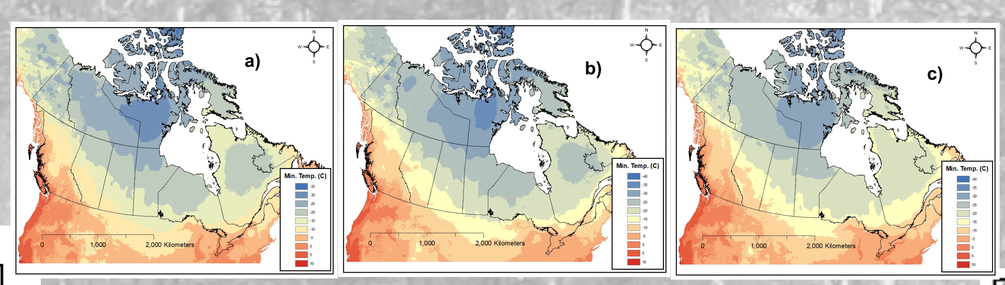

Figure 4: Projected minimum January temperatures for a) 2020, b) 2050, and c) 2080 (Data: AdaptWest Project 2015).

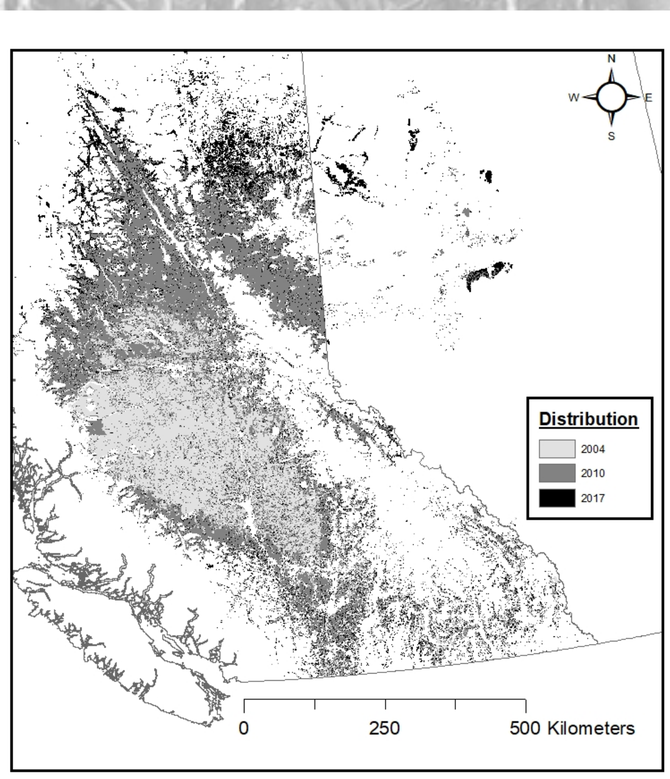

Figure 1: MPB distribution from 2004 – 2017 (Data: Government of AB, B.C. 2017)

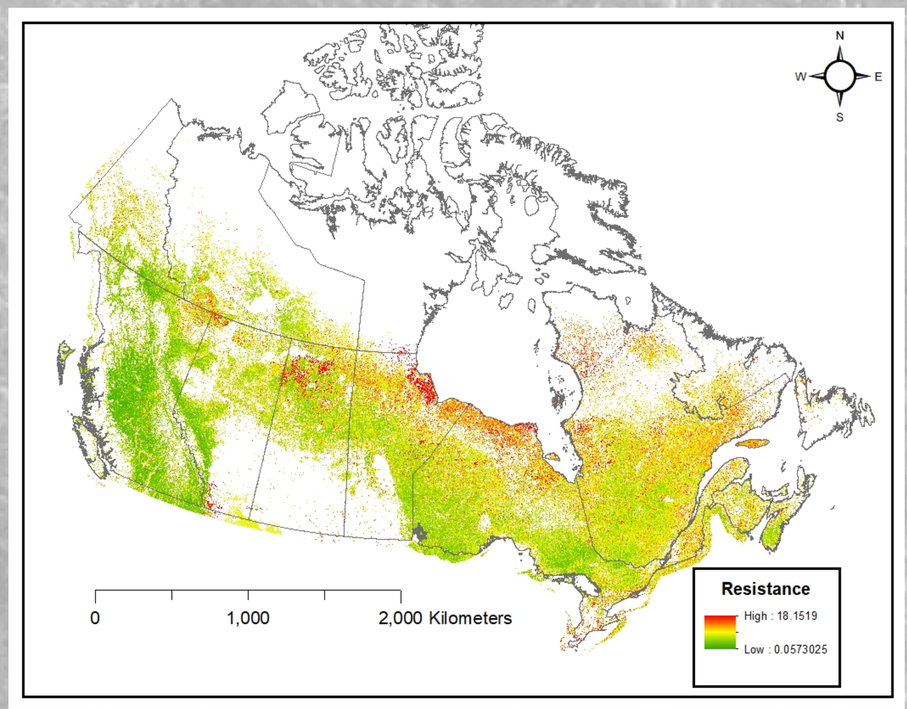

Figure 3: Resistance surface

Findings

1. From 2004-2017, MPB rapidly expanded northward through the interior of B.C. and into Alberta, eventually tapering off suggesting non-linear and non-uniform rates and patterns of spread.

2. Tree data acquired in 2011 suggest high percent composition of pine trees and pine tree volume near the historical extent of the MPB possibly providing connectivity to new habitat in the future.

3. Low-emission ensemble CMIP5 projections suggest that -40°C temperatures most likely will not be limiting the MPB in its northern range in the future. Projected warmer temperatures suggest that MPB populations will have most likely have higher overwinter survival rates.

4. If travelling at rates similar to 2004-2010, by 2100, the MPB could spread well outside its historic range into the boreal forest from central Yukon almost to the northwestern border of Manitoba (Fig. 9). MPB switching to jack pine as their primary host within the boreal forest could lead to different patterns than seen with lodgepole pine.

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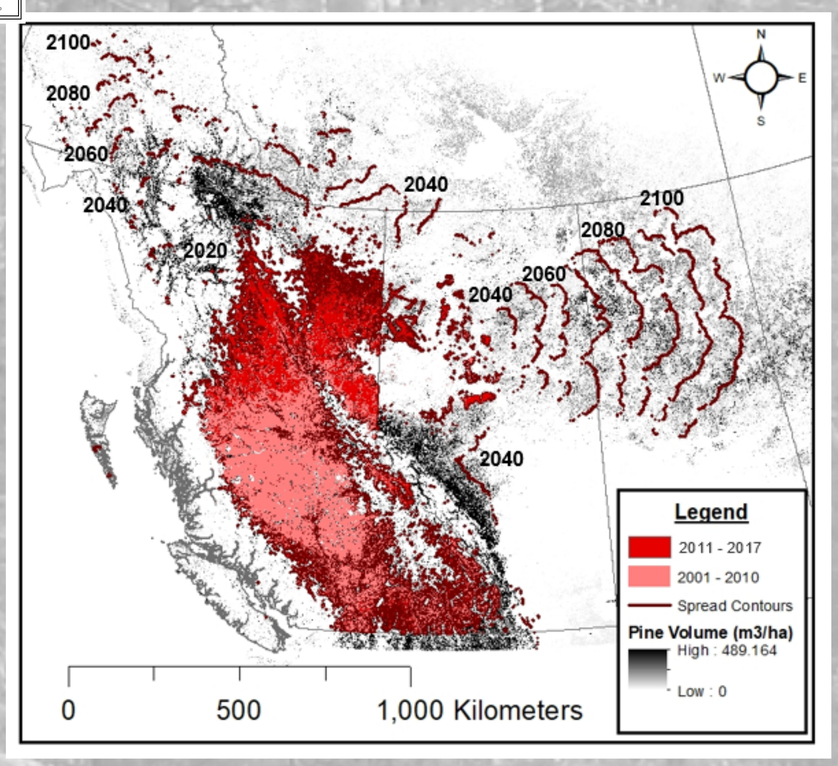

Figure 5: MPB projected spread contours until 2100 (Data: Government of AB, B.C. 2017)