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Effects of climate change on the impacts of spruce budworm infestations

INTRODUCTION

In Canadian forests, outbreaks of insects and diseases cause significant losses to the quantity and quality of available wood. These losses are estimated to be 80-110 million m³ of timber per year, which is more than half the annual rate harvested of 160-180 million m³ per year. Large outbreaks that result in significant tree mortality also increase the risk of fire and susceptibility of the forest to other insects and diseases. Changes in forest composition can also affect wildlife populations by altering habitat and food sources. The changing climate – average temperatures in North America are predicted to increase by 5-10° C by the end of the century – will accentuate the impacts of pest infestations even more. This warming trend will lead to changes in the geographic distribution of tree species and alter the frequency and intensity of pest outbreaks. Although the degree of change is unclear, the resulting impacts will affect forest management planning, wood supply projections and pest protection programs.

GREAT LAKES FORESTRY CENTRE (GLFC) RESEARCH

In light of these expected changes, scientists Jean-Noel Candau and Richard Fleming of GLFC are developing models to predict how impacts of spruce budworm outbreaks may change in the future, based on historical records of past outbreaks and climate scenarios over the next 30 years.

Assessment of past spruce budworm outbreaks

Spruce budworm outbreaks are large-scale events, with moderate-to-severe defoliation sometimes lasting 5-15 years and populations remaining at low levels for even longer. In 1981, at the peak of the last outbreak, wood volume losses were estimated to be 16 million m³ for Ontario alone, while the annual harvest rate was 20 million m³. Balsam fir and white spruce are the preferred hosts, and budworm also occasionally attacks black spruce. A detailed history of spruce budworm outbreaks in Ontario has been collected since 1939 by the Canadian Forest Service, and more recently by the Ontario Ministry of Natural Resources (OMNR); this information has been useful in studying patterns of spruce budworm defoliation. A total of 41 million hectares have been defoliated at least once since 1941. Maps depicting defoliation patterns since that time show three zones of frequent defoliation, separated by longitudinal zones of lower frequency (Image 1).
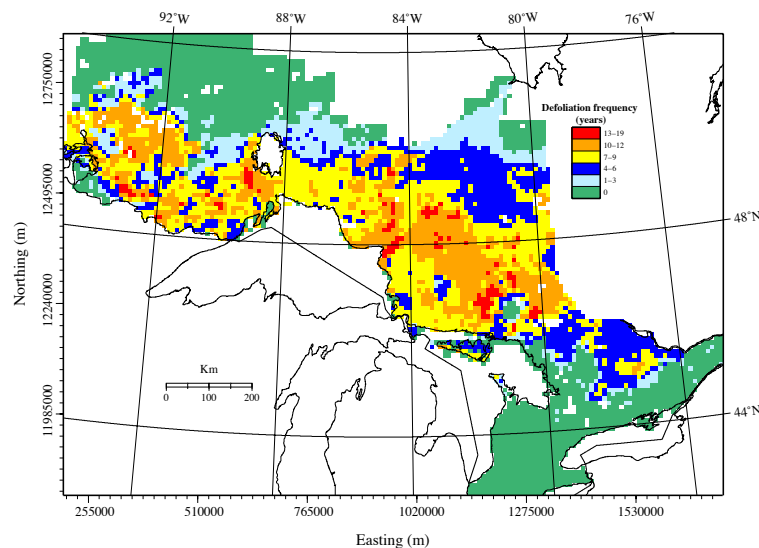

Image 1: Frequency of moderate-to-severe spruce budworm defoliation in Ontario from 1967 to 1998. The key indicates the total number of years that defoliation was recorded. Three zones of high frequency (western, central, and eastern) are separated by two corridors of less frequent defoliation. Dashes outline the area for which forest composition data are available.

Effects of climate on patterns of defoliation

The model showed that the maximum winter temperature and the minimum temperature in May were key factors in determining where defoliation occurred. The model used eight variables related to temperature, precipitation and forest composition to explain where defoliation had occurred. High defoliation frequencies were associated with relatively dry conditions during June (less than 86 mm of precipitation) and cool springs, with an average minimum temperature less than 2.7°C. Low defoliation frequency was linked to cold winters in the north and a low abundance of suitable tree species in the south.

Predicted effects of climate change on spruce budworm outbreaks and distribution

Candau and colleagues predicted the effects of climate change on the frequency and spatial pattern of spruce budworm defoliation for the period 2011-2040 by applying their bioclimatic model to 6 future climate scenarios. Researchers expected that the model would show an increase in frequency and duration of outbreaks as temperatures rise, because a warming climate would improve spruce budworm growth, survival and reproduction. All of the climate scenarios pro-

jected broadly similar changes in the patterns of defoliation (Image 2): (1) an extension of the northern limit of defoliation; (2) a decrease in the frequency of defoliation in the center of the historical defoliation belt; (3) persistence of the southern limit of defoliation. These changes will cause an overall increase in the total area of expected defoliation compared to the previous period (1967-1998). However it appears that the mean frequency of defoliation calculated over the whole study area would decrease or only slightly increase compared to 1967-1998.
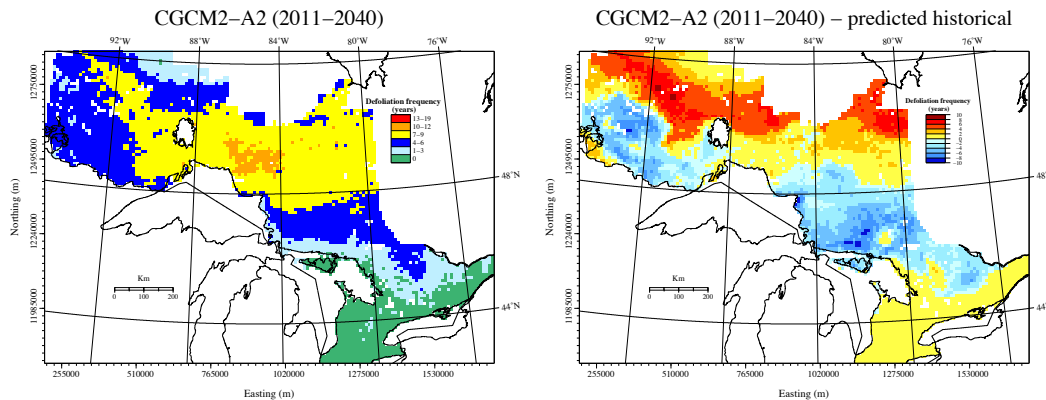

Image 2: (left) Projection of spruce budworm defoliation frequency in Ontario for 2011-2040 based on a climatic model of defoliation for 1967-1998 and climate projections from the Canadian Global Circulation Model CGCM2-A2; (right) Projected changes (in years) in the frequency of defoliation by spruce budworm in Ontario projected for 2011-2040 based on the Canadian Global Circulation Model CGCM2-A2 and frequencies observed during the last outbreak (1967-1998).

Changes in spruce budworm population dynamics (such as size and age composition) are expected, in part due to the effects of climate change on mortality agents such as parasitoids and disease. Indirect effects will also result from changes in abiotic factors such as fire, as stands killed by spruce budworm are susceptible to burning. Host tree distribution will also likely be affected by climate change, with an increase in the balsam fir component in the north and a decrease in the south. Net results are difficult to predict because of the inter-relations between numerous biotic and abiotic factors.

Future work

Fire and spruce budworm are the dominant boreal forest disturbances and historically, the extent of insect outbreaks has been much greater than fire. The interaction between the two disturbances is also critical, but poorly understood. The analyses show that in a warmer climate the spruce budworm can be expected to attack more stands, which will burn more easily. Using the predictions of the effects of climate change on spruce budworm outbreaks, dynamic landscape models are being developed that describe how the interaction between spruce budworm defoliation and fire will affect the frequency and extent of future forest fires.

CONCLUSION

The ability to predict the effect of climate change on insect outbreaks such as the spruce budworm increases our overall understanding of the effects of climate change on the forest. These models are a useful tool for forest managers, because they will help in long term planning, for example by indicating where expenditures for forest protection will be required. Predictions of changes in forest composition and species distribution will be useful in forest management planning and business decisions. These models also allow policy makers to weigh the value of efforts to address climate change and suggest where resources should be directed.

PRINCIPAL COLLABORATORS

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