Updated spruce budworm damage maps for Ontario

Clara Risk, Patrick MA James

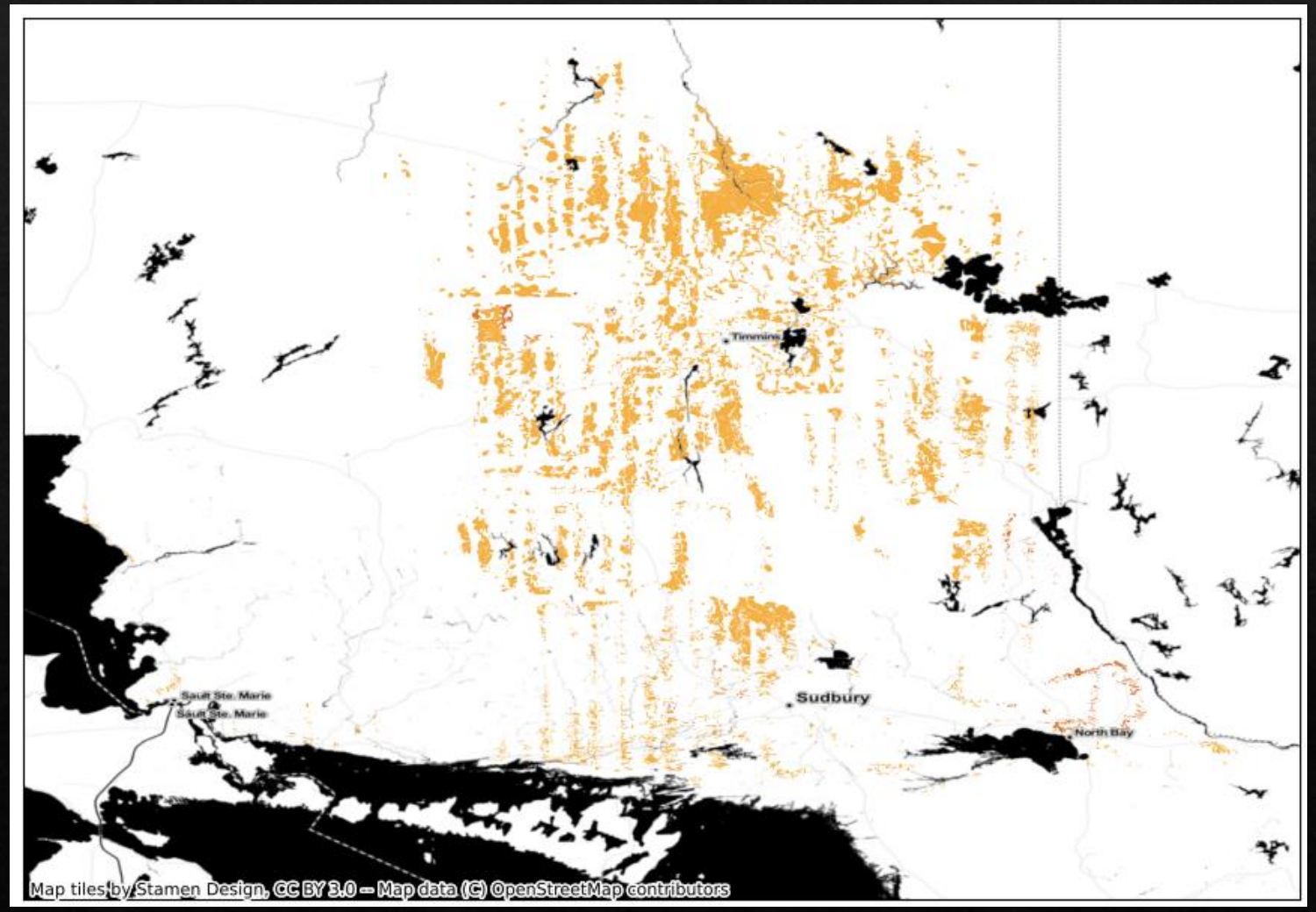
University of Toronto

Stephen Mayor

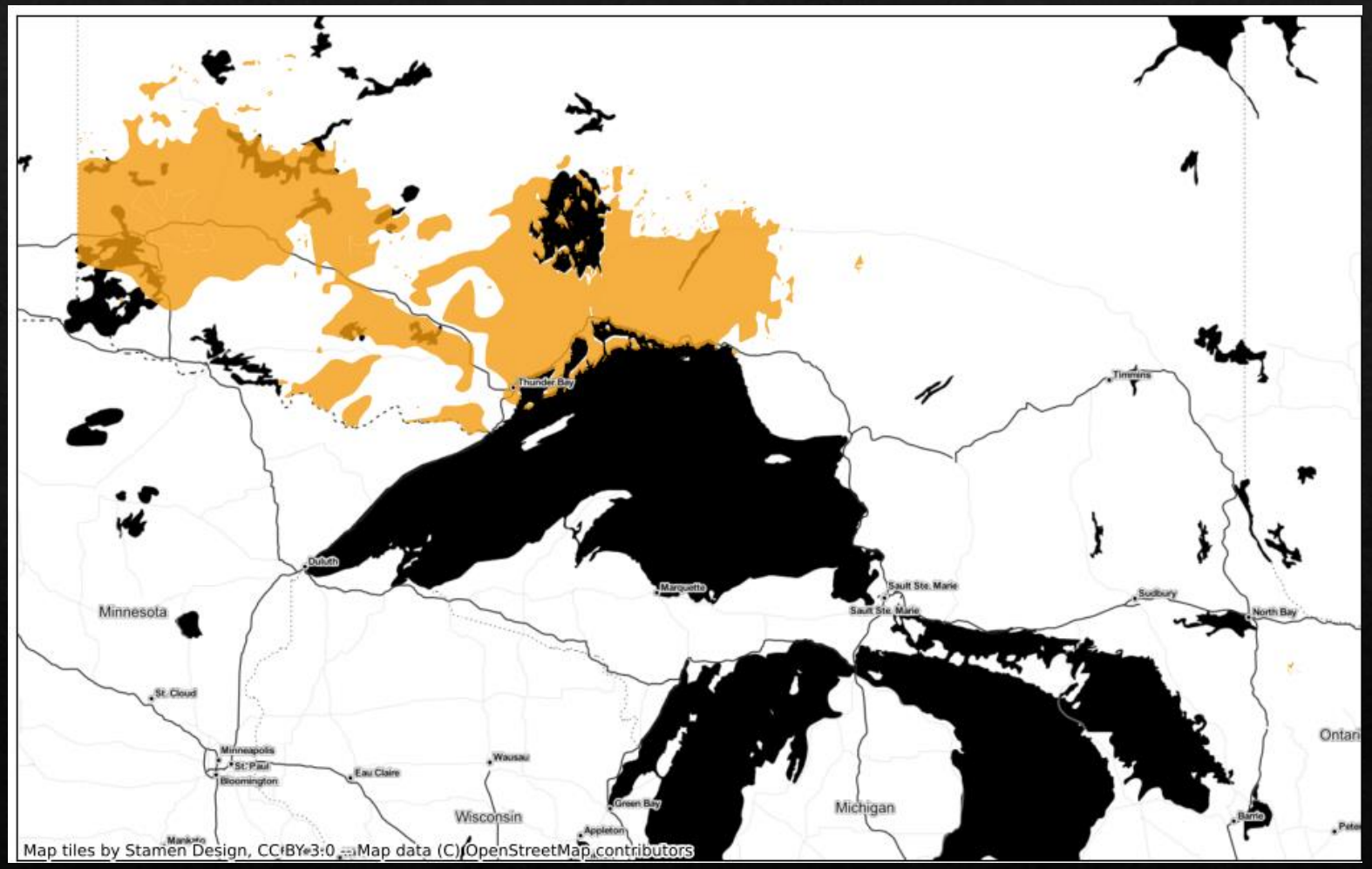
MNDMNRF

What is the problem with Ontario's spruce budworm aerial survey data?

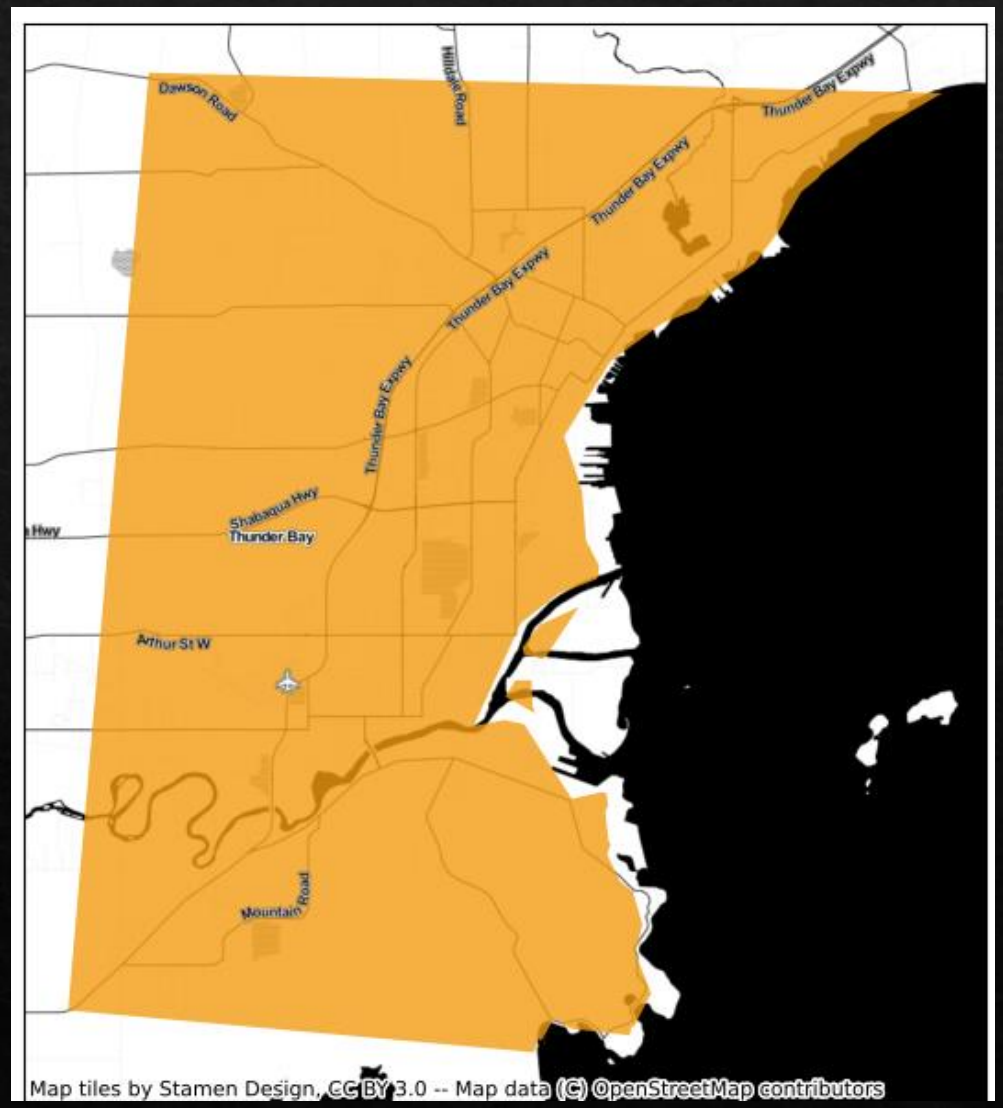
Let’s zoom out a bit:



It’s not straightforward



What's the problem here? Let's zoom in:



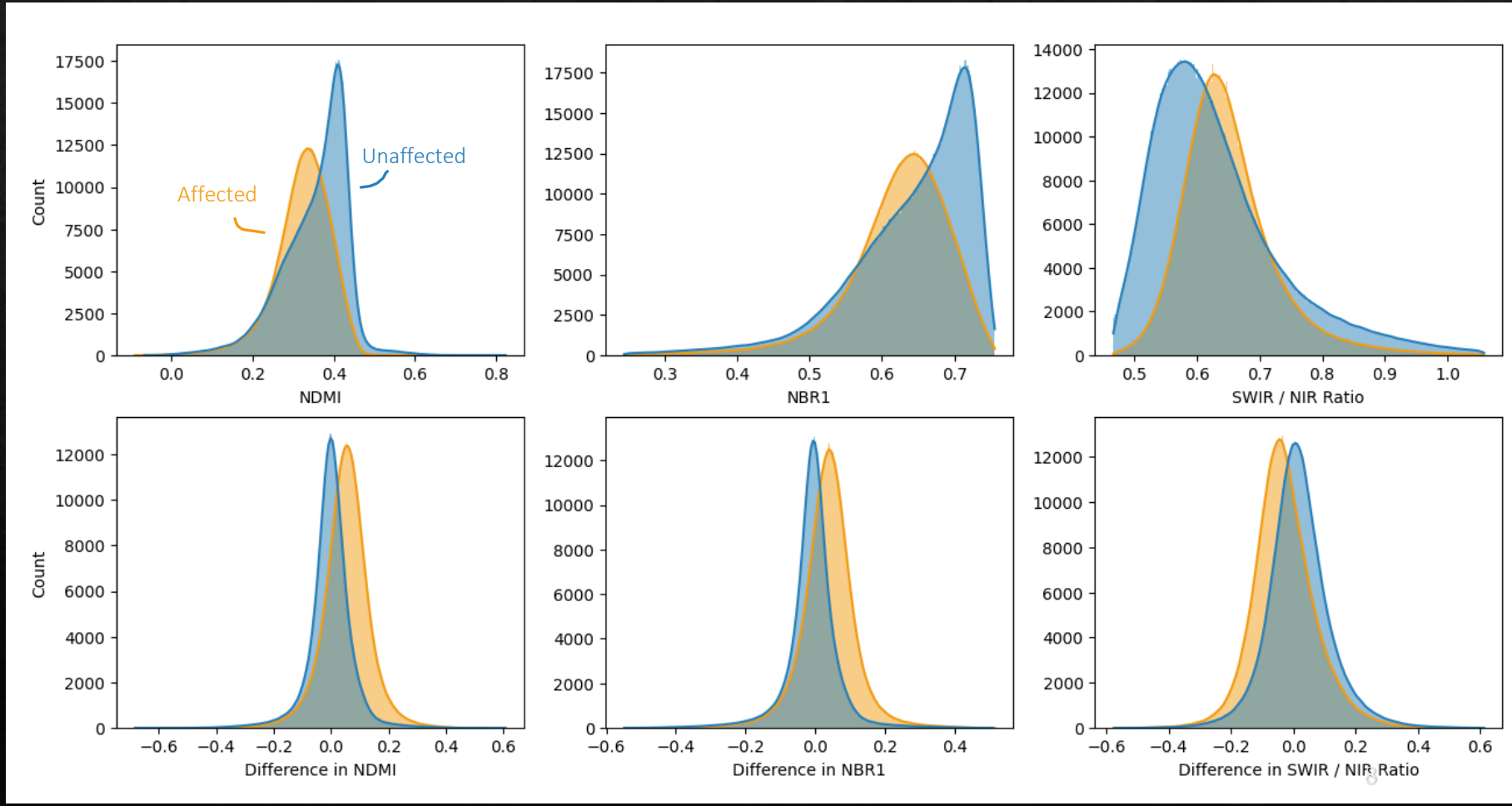
Can we use satellite imagery to estimate the true extent of current and historical spruce budworm damage?

Methods Walk-Through

1. Train a machine learning model using the 2021 aerial survey data
2. Sample damaged pixels from within the surveyed area and sample unaffected pixels from outside an 8 km buffer
3. Classify all pixels as either experiencing damage or not
4. Filter “noise” using a concave hull procedure
5. Provide certainty in the dataset by selecting “patches” of damage greater than 3 km^2

Why do we think we can do this?

Spectral indices are mathematical combinations of satellite image bands (ranges of wavelengths detected by the onboard sensor)

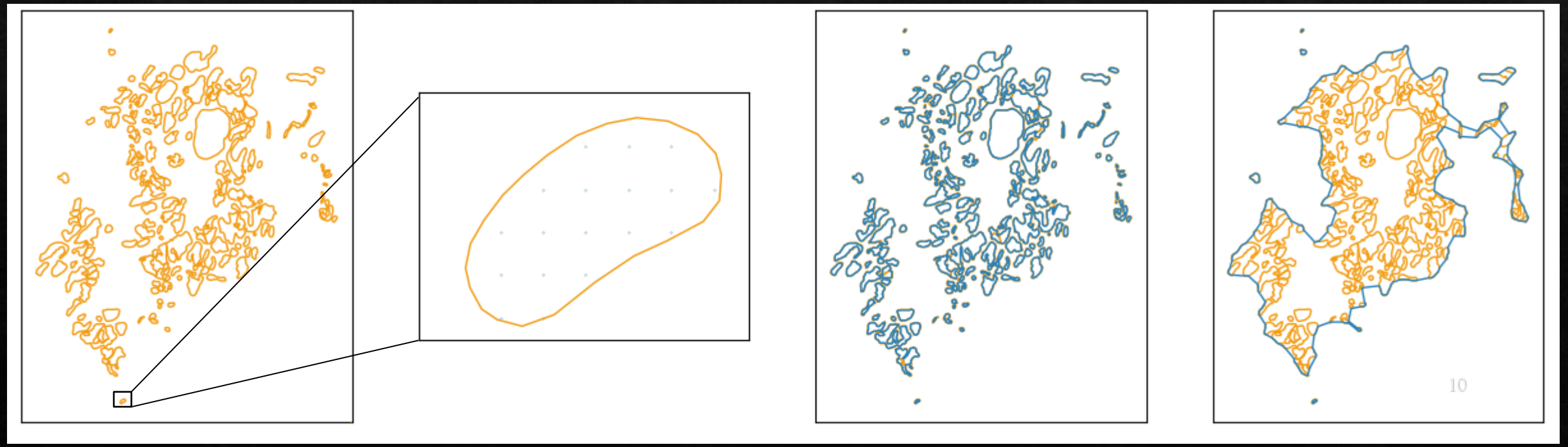


Why machine learning?

- Helps us **detect patterns** that aren't obvious to a human
- A human can look at those distributions and tell you the range of spectral index values where a pixel is more likely to be affected
- A human can't easily determine the **interactions between the spectral indices** that could help us detect affected pixels
- Random Forest models build **complex decision trees** to determine whether or not a pixel is likely to be affected

Why do we need the concave hull operation?

- You'll have noticed that the distributions overlap quite a bit
- The concave hull operation is for where they overlap
- Spruce budworm outbreaks tend to occur in "patches" close together
- Concave hull operation helps us detect these patches



Why these methods?

Spectral Indices:

- Multiple indices improve damage detection over single index (Rahimzadeh-Bajgiran et al., 2018; Rullan-Silva et al., 2013)
- Selected based on investigations and past research (Dorion, 2016; Rahimzadeh-Bajgiran et al., 2018)

Difference between Healthy and Affected Years:

- Essential for detecting spruce budworm damage, per past research

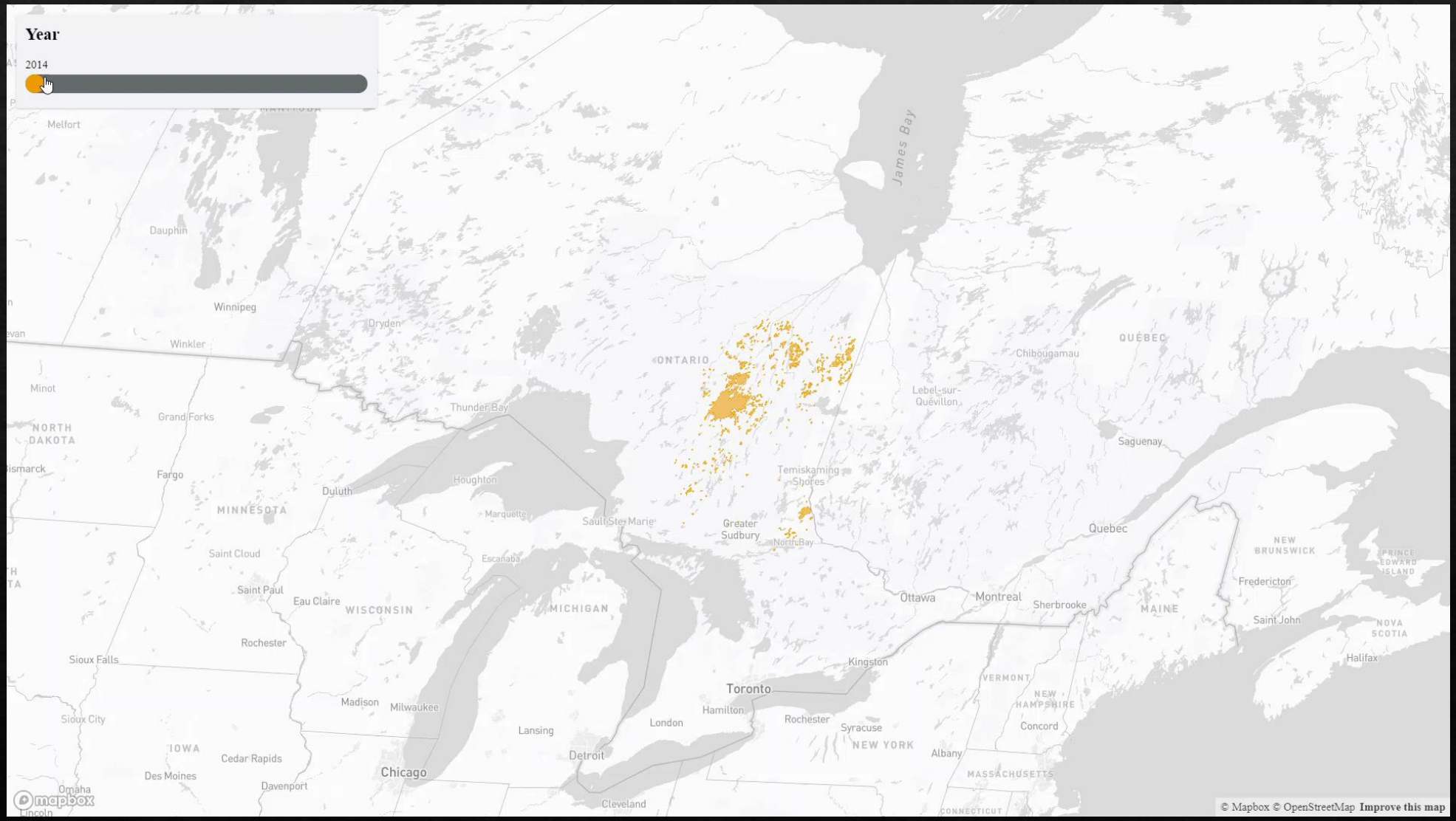
Random Forest Model:

- Effective in detecting spruce budworm damage, per multiple studies (Bhattarai et al., 2020; Donovan et al., 2021; Rahimzadeh-Bajgiran et al., 2018)

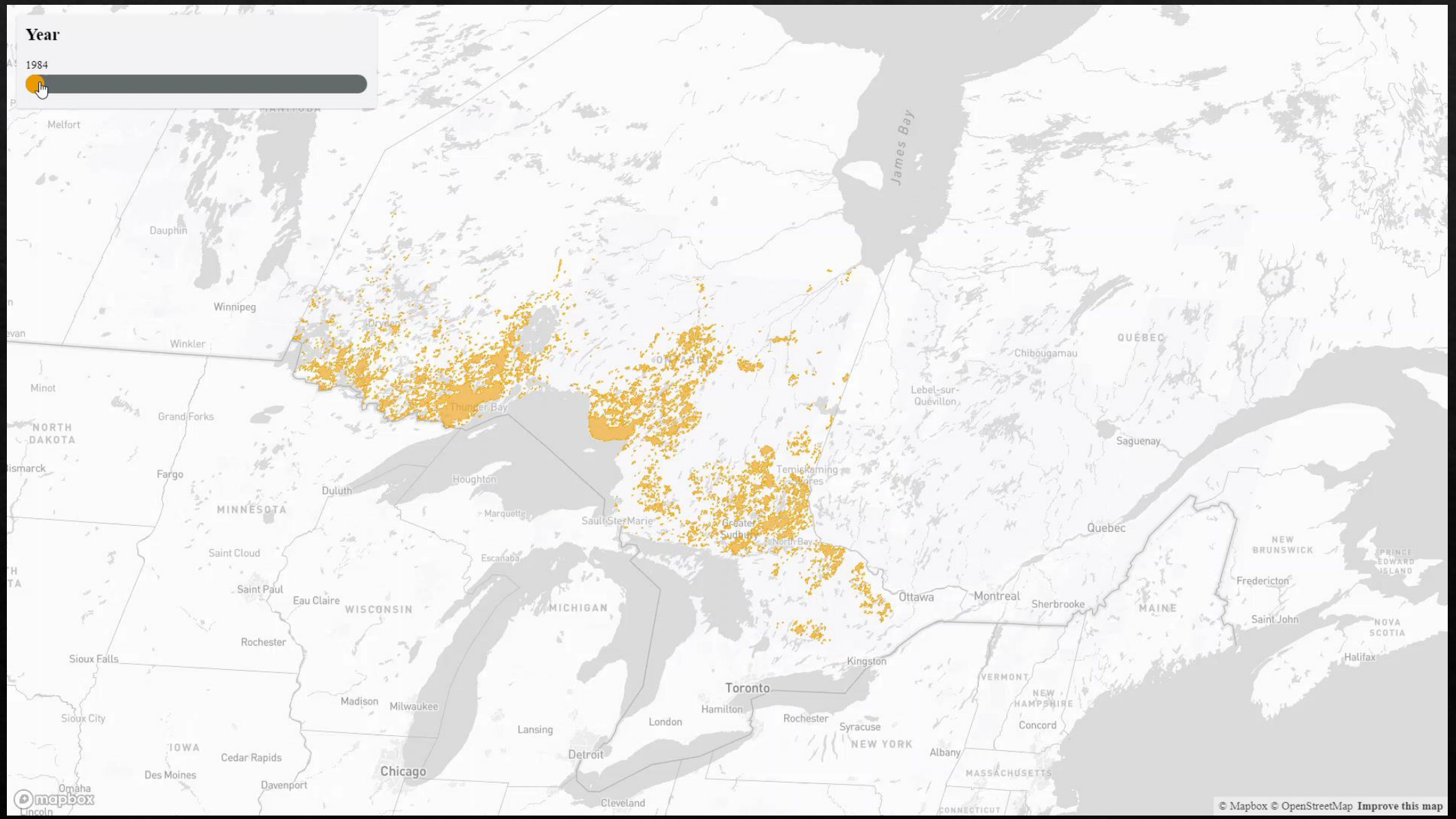
Concave Hull Procedure:

- Accounts for spatial autocorrelation in outbreaks, without using latitude/longitude (avoids banding on map)
- Improves accuracy by considering surrounding pixels (Tobler's First Law of Geography)

Maps for 2014-2021

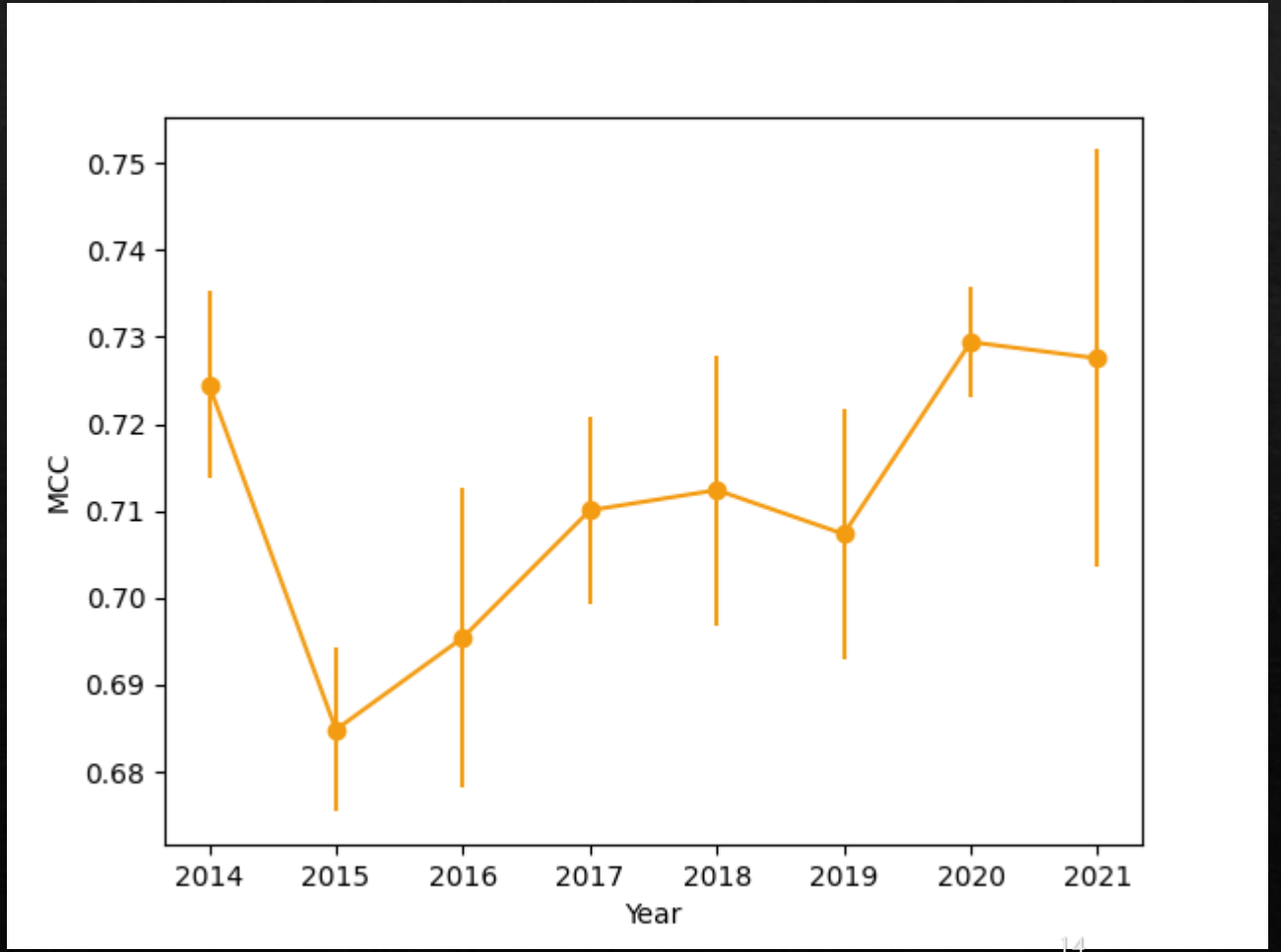


Maps for 1984-1997



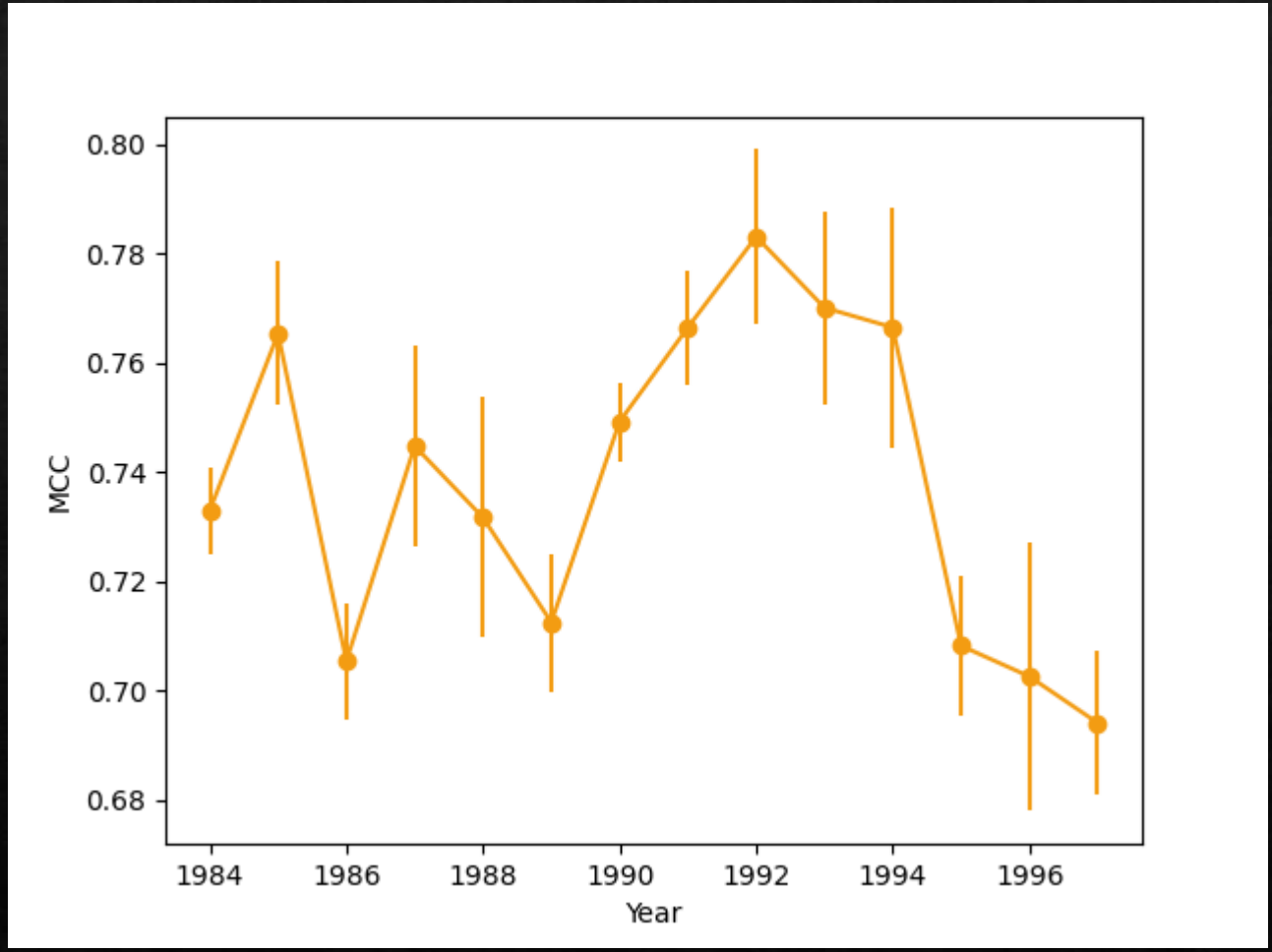
How accurate are these maps?

- We used the Matthew's Correlation Coefficient (MCC) to assess the accuracy of the model over time
- It ranges between -1 to 1, with 1 being a perfect classification and 0 being a random one
- MCC is generally accepted as industry standard in assessing machine learning models



How accurate are these maps?

- We used the Matthew's Correlation Coefficient (MCC) to assess the performance of the model over time
- It ranges between -1 to 1, with 1 being a perfect classification and 0 being a random one
- MCC is generally accepted as industry standard in assessing machine learning models



How can this dataset benefit you?

- Save fieldwork teams **time and money**
- **Targeted Btk application**
- Allow private landowners to **assess risk to property and make informed decisions**
- Provide a **standardized dataset** to government research scientists

When should **you** use it?

- Field work in Ontario related to forest succession or spruce budworm damage assessment – allow your teams to **access sites closer to roads**
- Decision to **protect your property** using biopesticides
- You need to **avoid spatial bias** in your ecological model

How will we be using it?

- We will be using these maps quantify relative risk at the forest stand level across Ontario for different natural hazards, including spruce budworm damage and fire ignition
- The resulting maps of relative risk will be informative for housing market research (particularly in cottage country), insurance purposes, and natural hazard prevention schemes

What about the aerial sketch maps?

- They remain an excellent dataset and are indispensable to this work
- We require the aerial survey maps to assess the performance of our method over time
- What our method does is provide a “**backup plan**” – if weather conditions or smoke from wildfires obstruct technician field-of-view on the day of the survey, we can fill in the resulting gaps in the maps

Acknowledgements & Funding

- Many thanks to the Government of Ontario for funding this work
- This work was made possible by the Ministry of Northern Development, Mines, Natural Resources & Forestry, which provided data for this project

View through time:

1984 – 1997

2014 – 2021

References

- Rahimzadeh-Bajgiran, P., Weiskittel, A. R., Kneeshaw, D., & MacLean, D. A. (2018). Detection of annual spruce budworm defoliation and severity classification using Landsat imagery. *Forests*, *9*(6), 1-17. https://doi.org/10.3390/f9060357
- Rullan-Silva, C. D., Olthoff, A. E., Delgado de la Mata, J. A., & Pajares-Alonso, J. A. (2013). Remote monitoring of forest insect defoliation. A review. *Forest Systems*, *22*(3), 377-391. https://doi.org/10.5424/fs/2013223-04417
- Dorion, H. (2016). Patrons spatiaux d ' une épidémie de la tordeuse des bourgeons de l ' épinette sur la Côte-Nord : une approche de télédétection. In (pp. 37).
- Bhattarai, R., Rahimzadeh-Bajgiran, P., Weiskittel, A., & MacLean, D. A. (2020). Sentinel-2 based prediction of spruce budworm defoliation using red-edge spectral vegetation indices. *Remote Sensing Letters*, *11*(8), 777-786. https://doi.org/10.1080/2150704X.2020.1767824
- Donovan, S. D., MacLean, D. A., Zhang, Y., Lavigne, M. B., & Kershaw, J. A. (2021). Evaluating annual spruce budworm defoliation using change detection of vegetation indices calculated from satellite hyperspectral imagery. *Remote Sensing of Environment*, *253*. https://doi.org/10.1016/j.rse.2020.112204