Risk estimation using landscape fire simulation models

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Introduction

- Climate change is altering Canada's boreal and temperate ecosystems, **increasing fire risk.**
- **More frequent and intense wildfires** are expected due to extreme weather.
- Wildfires threaten caribou habitat, impacting their **survival and population dynamics.**
- Models **can help assess** how fire and climate change affect caribou.
- Better fire risk modeling is key for **accurate forecasts and effective management.**

Methods

Fire simulation models
Projection of future fire activity (Wotton *et al.*, 2010)

SpaDES: Spatial Discrete Event Simulation

R — GitHub

Fire regime
Quantitative description of a population of fires characteristic of a place and time (Whelan, 1995)

01 Annual area burned

Compound Count Model (CCM)
(Marchal *et al.*, 2017)

$$Y = \sum_{k=1}^{N} X_k$$
$$EY = EN * EX$$
$$VY = EN * VX + VN * EX^2$$

N : n fires
X : fire size
Y : annual area burned
E : mean
V : variance

Observed model
EY = mean annual area burned from actual data
VY = variance of annual area burned from actual data

Empirical model
EY and VY estimated with CCM using observed EN, VN, EX and VX

CCM assumes :
- ✓ $N_i \sim$ Poisson or $N_i \sim$ negative binomial (usually);
- ✓ Fire sizes are independent and identically distributed;
- ✓ Fire sizes are independent of N_i.

02 Number of fires

Negative binomial model
CCM with model estimation following a negative binomial distribution :
$VN = EN + EN^2 / \theta$

Poisson model
CCM with model estimation following a Poisson distribution :
VN = EN

Ignition rate (in simulation)
- Poisson rate: Expected value the same every year
- Poisson-gamma mixture rate: Expected value sampled every year

Risk of underestimating the **inter-annual variability in Y :**
$VY = EN * VX + VN * EX^2$

03 Fire size

EX = mean fire size from actual data
VX = variance of fire size from actual data

What's Next

Simulation experiments for several sites in Canada :
- with **boreal woodland caribou population size** as an indicator ;
- to evaluate the sensitivity for **inter-annual variability in fire sizes.**

Objectives

- Adapt simulation tools to better capture **inter-annual fire variability** ;
- Run simulations for multiple Canadian sites with **boreal woodland caribou population size as an indicator** ;
- Improve fire risk integration in **standardized, reproducible models** for Canada's forests.

Results

Data source : Canadian Wildland Fire Information System (CWFIS)
Fire years : 1970 to 2020
Fire cause : Natural causes (ex: lightning, ...)

Study area 1 — Ecoregion 87 : Athabasca Plains (Saskatchewan)

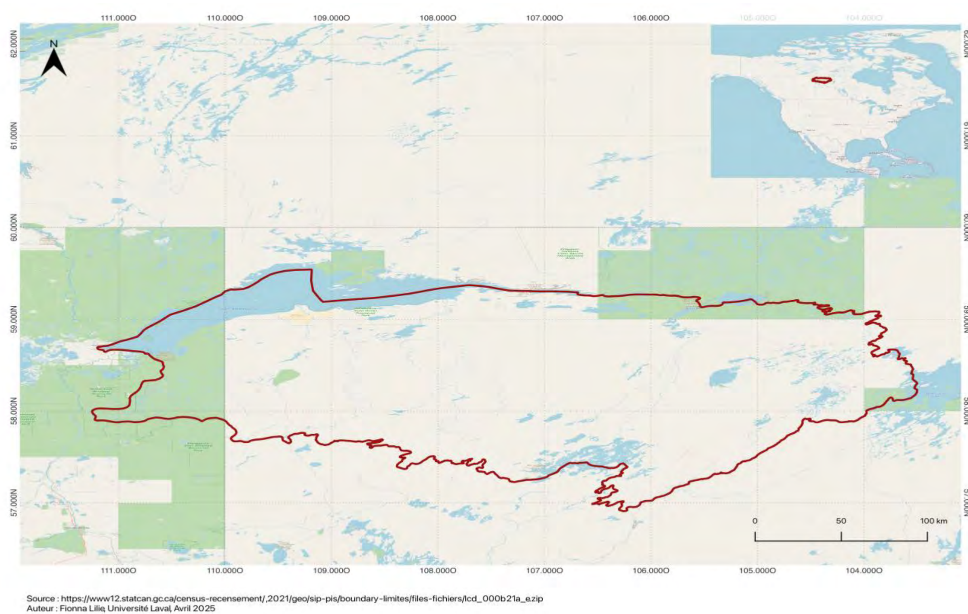


Figure 1. Map of vegetation for 87

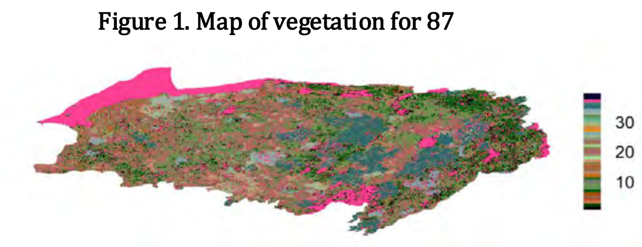
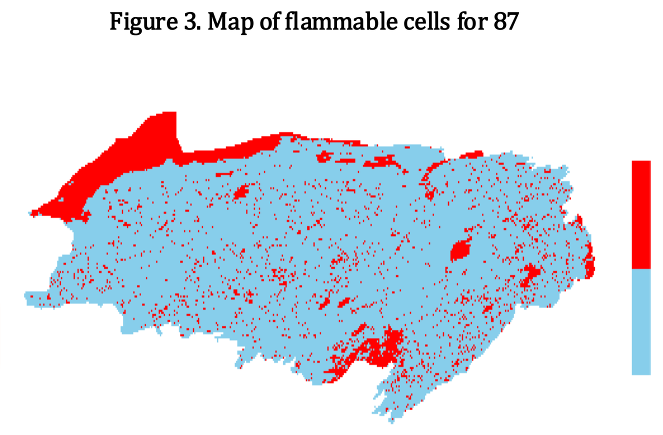


Figure 2. Map of forest age for 87

Model	VN	EY	VY
Observed	1722.958	230107.2	154 064 551 892
Empirical	1722.958	230107.2	48 227 143 963
Poisson	66.37255	230107.2	28 315 948 856
Negbin	1823.063	230107.2	49 430 344 440

Table 1. Model-based values of VY and EY for Athabasca Plains

Figure 3. Map of flammable cells for 87



Study area 2 — Ecoregion 96 : Abitibi Plains (Ontario-Québec)

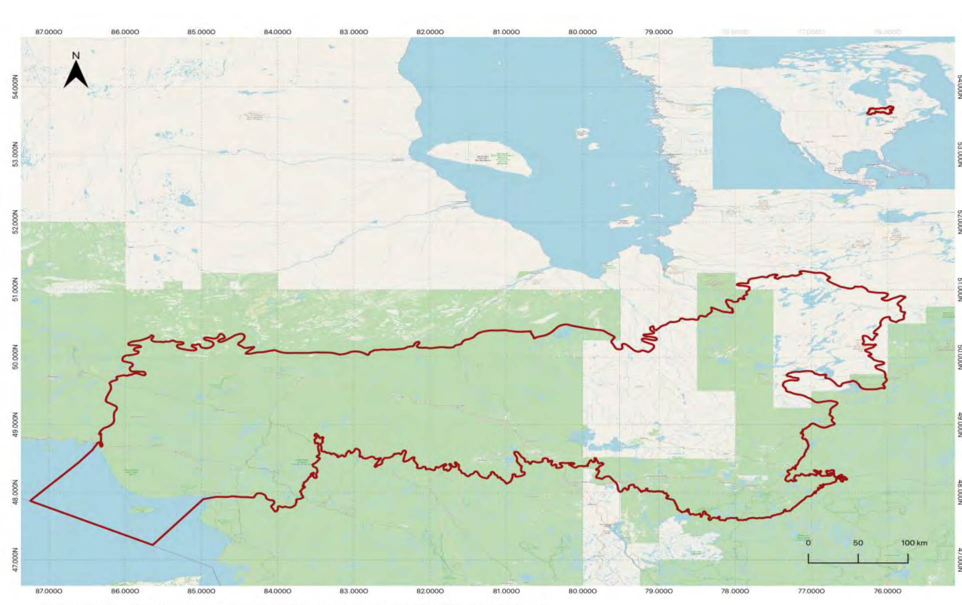


Figure 4. Map of vegetation for 96

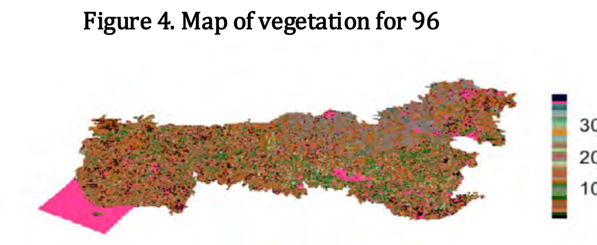


Figure 5. Map of forest age for 96

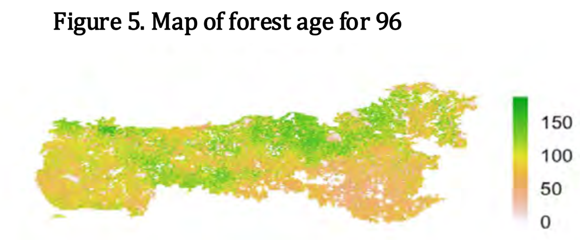
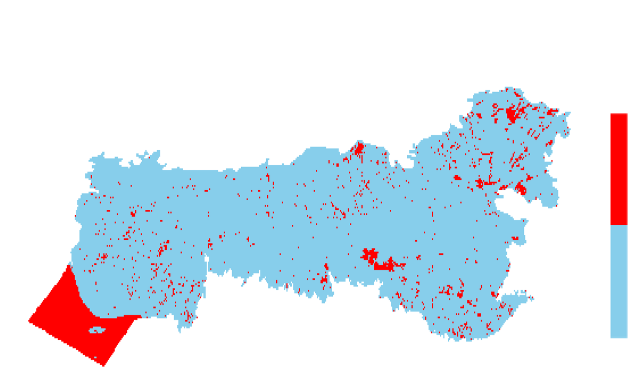


Figure 6. Map of flammable cells for 96



Model	VN	EY	VY
Observed	40974.09	26690.9	1 550 835 782
Empirical	40974.09	26690.9	1 272 658 245
Poisson	189.2157	26690.9	461 115 476
Negbin	36001.08	26690.9	1 173 704 618

Table 2. Model-based values of VY and EY for Abitibi Plains

Highlights

- Apparent overdispersion in real fire count data, which is **better captured** by the negative binomial distribution ;
- For ecoregion 87 : observed VY >> empirical VY, which implies that the assumptions on the fire sizes <u>are violated</u>, probably because of inter-annual variability in X.

Acknowledgements

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