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Climate, topography, or fuels? Top-down vs. bottom controls on fire refugia in western forests

Christine Kuntzemann — Canadian Forest Service

Ellen Whitman — Canadian Forest Service

Diana Stralberg — Canadian Forest Service

Doug Lewis — Government of British Columbia

Amiskwaciwâskahikan ᐊᒥᐢᑲᐧᒋᐧᐋᔅᑲᐦᐃᑲᐣ
Treaty 6 Territory and Métis Homeland

Canada

About me

- MSc from University of Alberta (2019-2022)*
  - Forest biology and management
  - Applied Conservation Ecology (ACE) lab
- Climate change analyst (2022-Present)
  - Canadian Forest Service
- Princeton alumna!

UNIVERSITY OF ALBERTA

*Kuntzemann, C. E., Whitman, E., Stralberg, D., Parisien, M. A., Thompson, D. K., & Nielsen, S. E. (2023). Peatlands promote fire refugia in boreal forests of northern Alberta, Canada. *Ecosphere*, *14*(5), e4510.

Outline

- Province overall
- Special focus on Thompson Okanagan area

© Darren Robinson Photography

Fire and vegetation change in western Canada

- Beneficial to local environment[1]

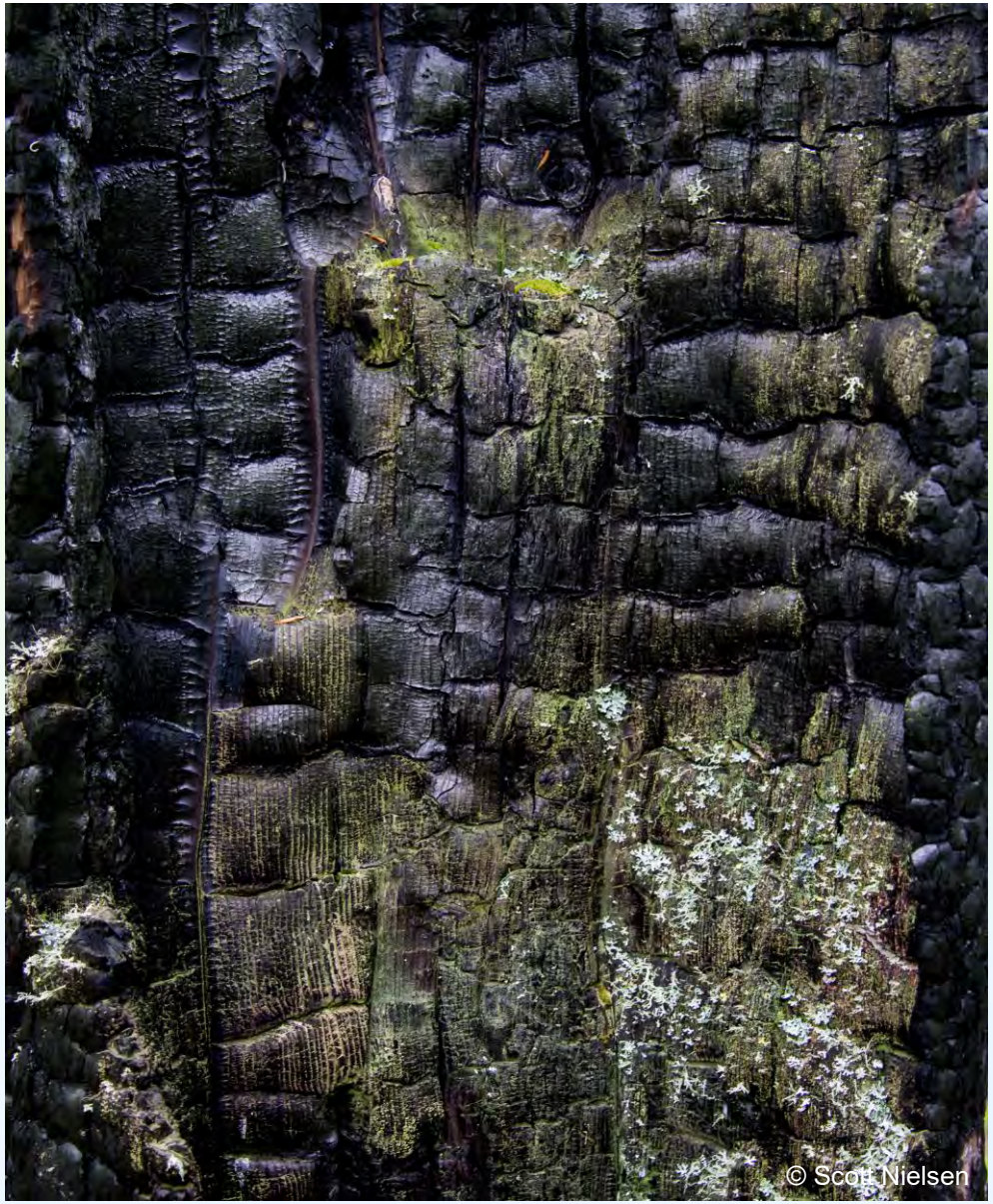
BUT

- Increased fire activity is detrimental
- Western Canadian forests particularly vulnerable
  - Promote vegetation changes[2]
- Effects on communities

Agee 1993[1]
Stralberg *et. al.* 2018[2]

Fire severity[1,2,3,4]

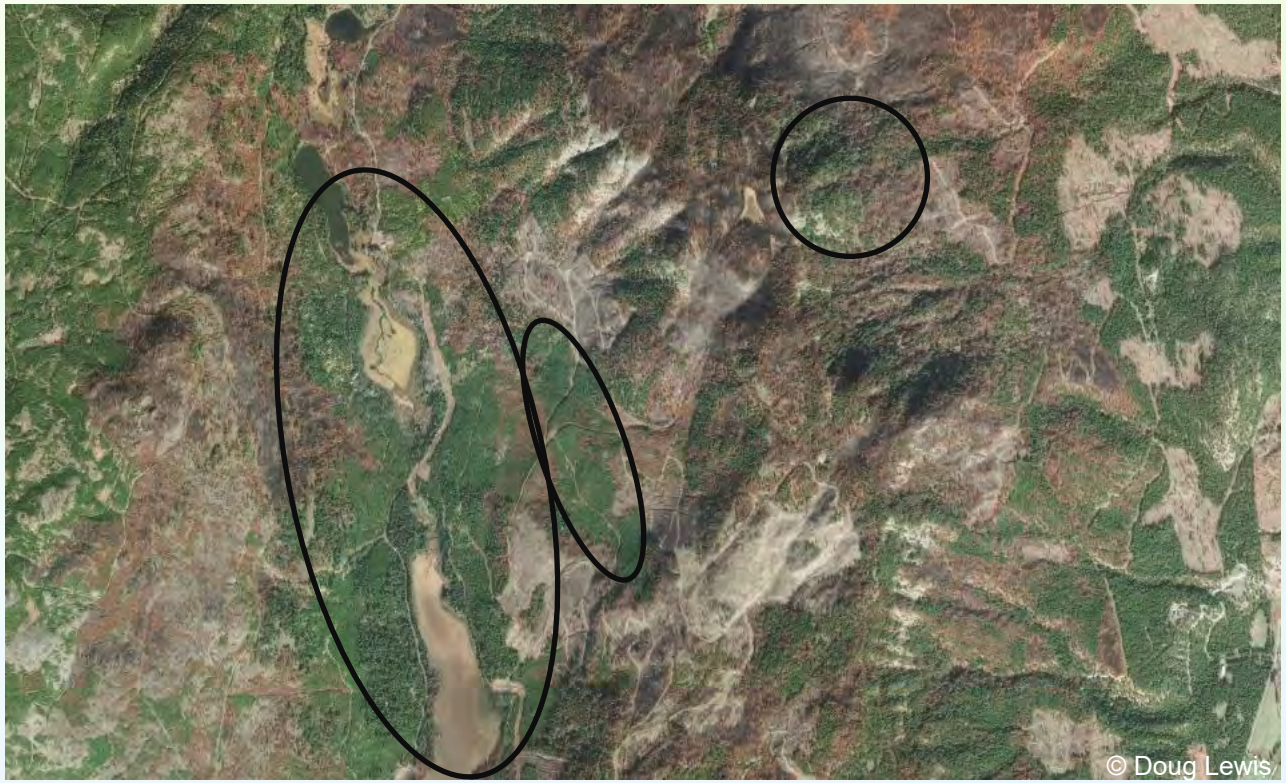
- Fire severity: impacts on vegetation and soils
  - Different from intensity: heat energy released
- High severity fires can alter vegetation regeneration:
  - Combustion of organic soils
  - Damage to root systems
  - Overstory tree mortality
- Result is decreased seed/cone availability
- Allows opportunity for other species to establish



Boucher *et. al.* 2018[1]
Johnstone *et. al.* 2016[2]
Whitman *et. al.* 2019[3]
Stralberg *et. al.* 2018[4]

Fire refugia

- Tree canopies within fire perimeters that survived[1]
  - Site characteristics[2]
  - Patterns of fire severity/movement[3]



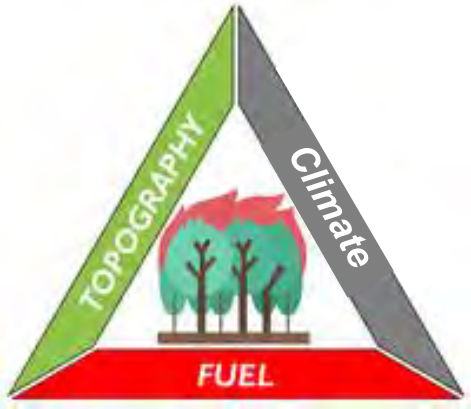
Whitman *et. al.*, 2020[1]
Camp *et. al.* 1997[2]
Krawchuk *et. al.* 2016[3]

Fire refugia

- Important to post-fire recovery[1]
  - Behave like islands
  - Help to reseed with original vegetation
    - Especially important after frequent/high severity fires which may destroy cones and seeds
- May reduce combined effects of climate change and natural disturbance[2]
  - Forest resilience and ecosystem resistance[3]

Coop *et. al.* 2019[1]
Krawchuk *et. al.* 2020[2]
Tepley *et. al.* 2017[3]

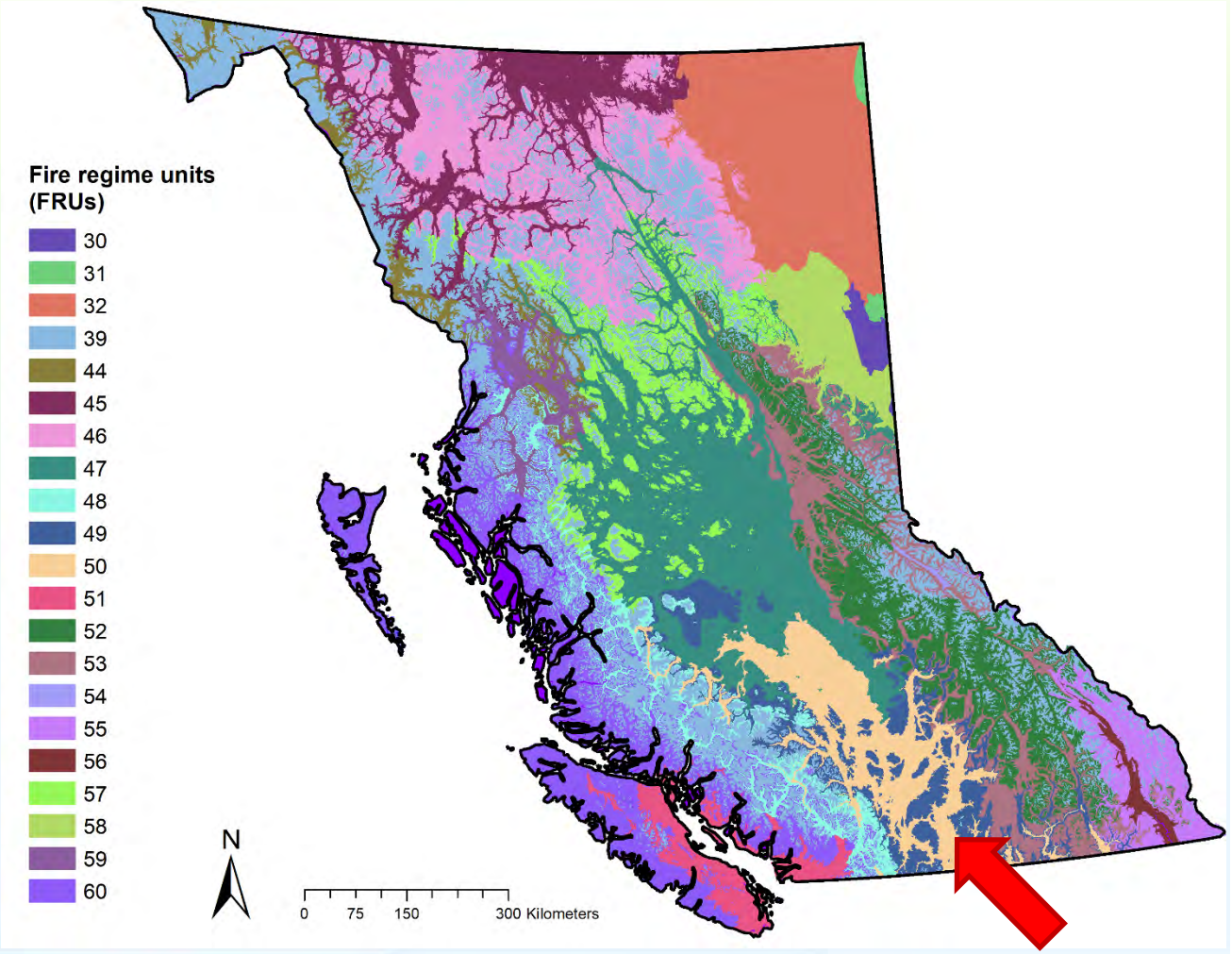
Bottom-up vs top-down controls



- Bottom-up
  - Strong/diverse **terrain** can indicate potential for long-term refugia
  - **Fuels** can be altered (targeted planting, thinning, prescribed fires)
- Top-down
  - **Climate**
    - What can we expect in various regional climates?
    - How will extreme conditions affect fire patterns?

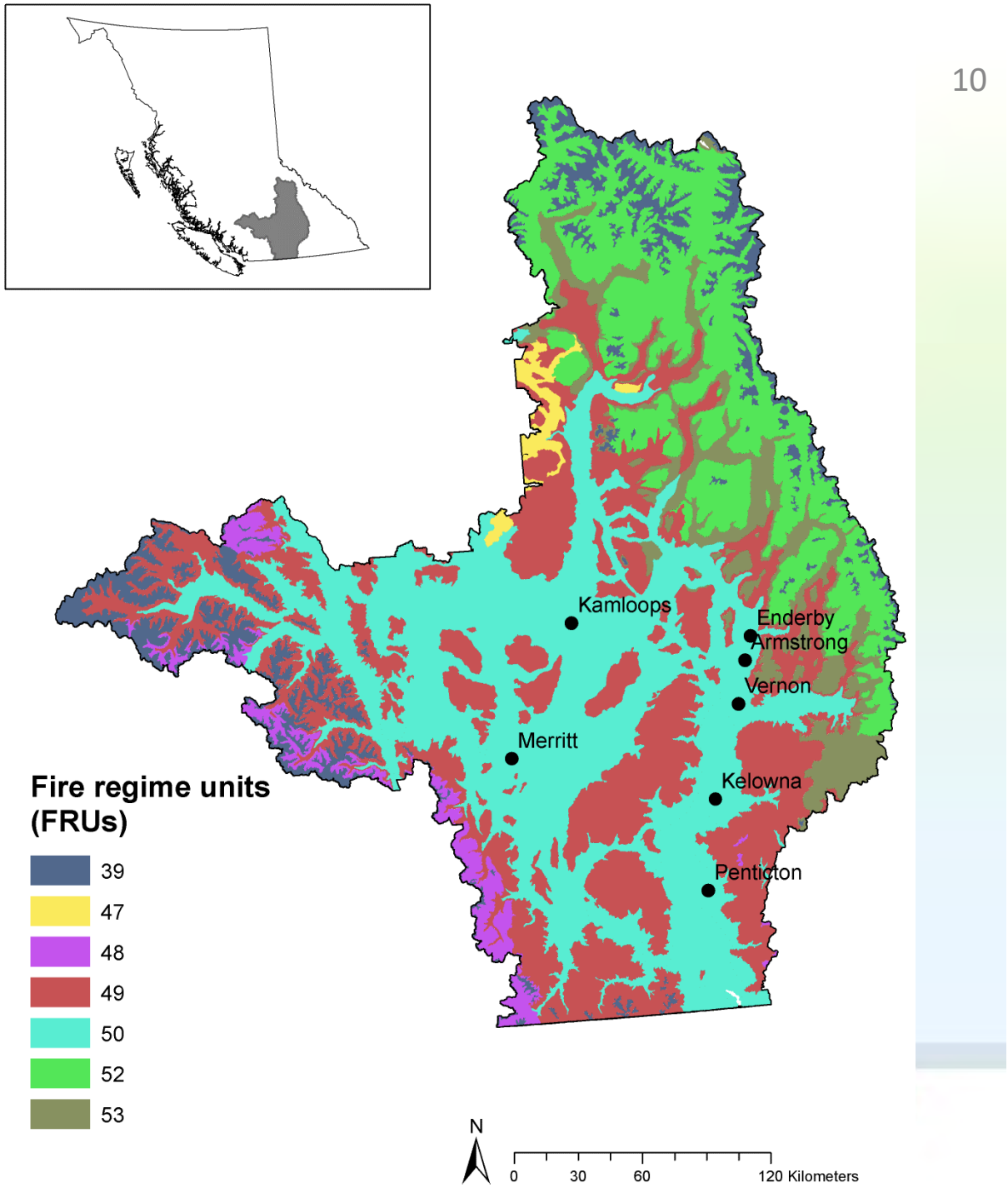
Fire in British Columbia

- Diversity of fire regimes
- 23 unique fire regime units[1]
  - Different fire-related attributes:
    - Fire frequency
    - Fire severity/intensity
    - Fire size, etc



Fire in the Okanagan

- Region has a variety of fire regime units
- Region relies on and is shaped by fire
- Stand initiating (crown) fires becoming more frequent



Historic fire and fuels

- History of Indigenous cultural burning
  - Syilx people; Smelqmix territory
- Frequent ignition of low-severity surface fires
  - Helped to keep the landscape open and surface fuels down
  - Promoted habitat for species like elk

Current fire and fuels

- Fuels
  - Some species are fire resistant, others less so
    - ✓ Ponderosa pine (*Pinus ponderosa*)
    - ✗ Lodgepole pine (*Pinus contorta*)
  - Past forest management has resulted in an unnatural fuel buildup
    - Ladder fuels
    - Overstocking

Photo of stand before treatment.

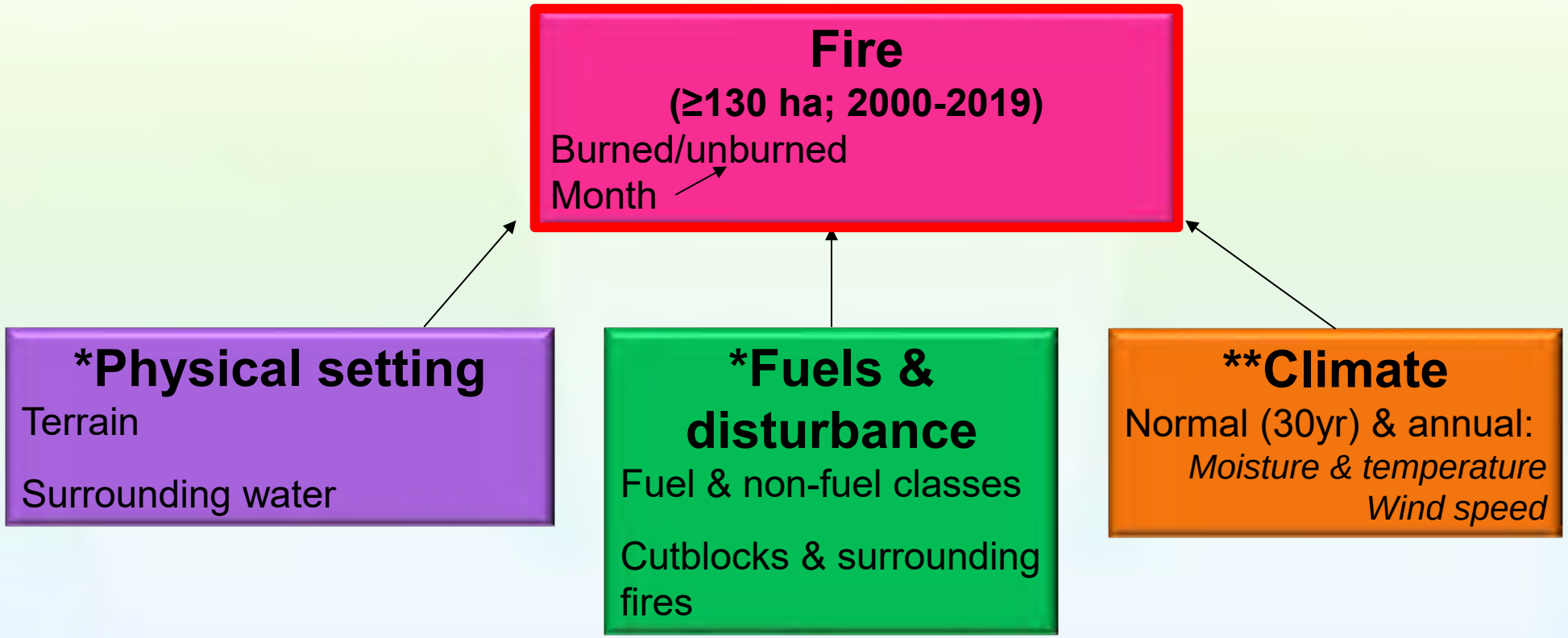
Aerial view of stand after treatment.

Ground view of stand after treatment. The remaining ground fuel will be cleaned up with a secondary manual treatment.

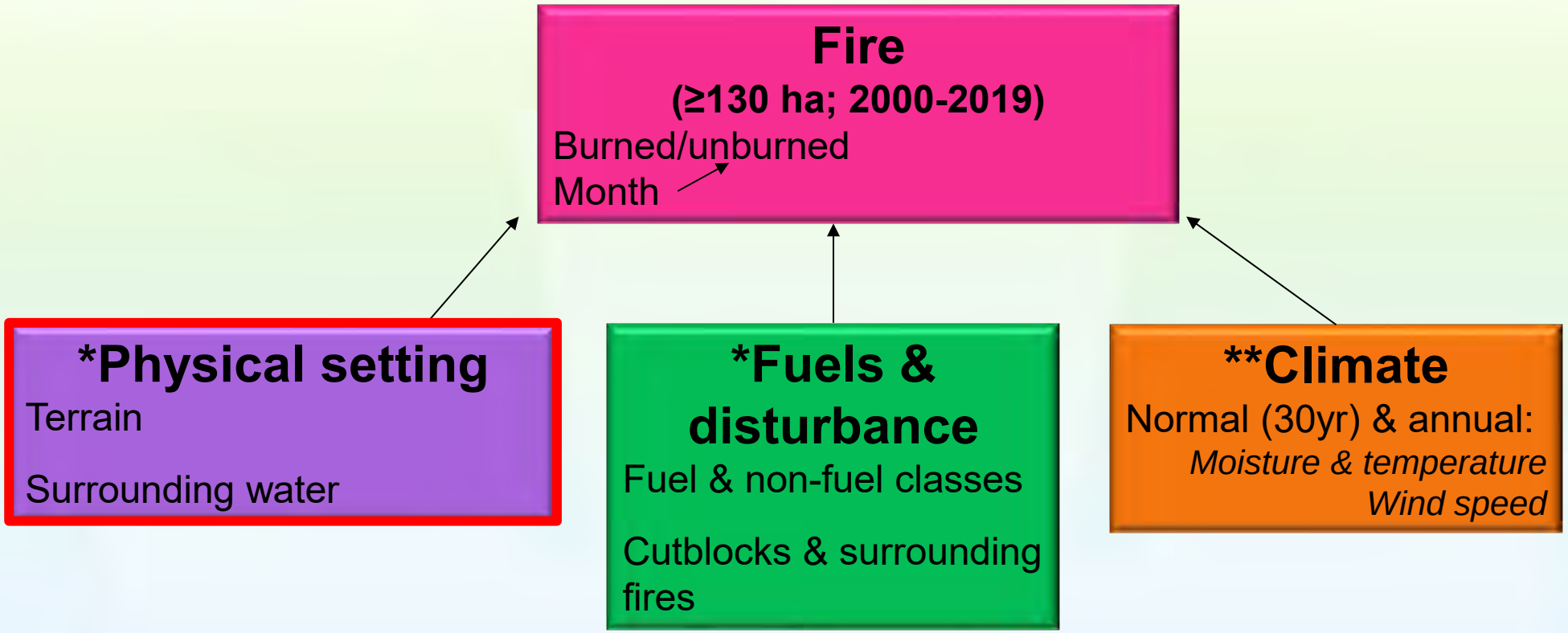
Research objectives

- What are the main drivers of refugia? (top-down vs bottom-up)
- Predict where/when fire refugia form under different conditions

Variables


Fire
(≥130 ha; 2000-2019)
Burned/unburned
Month
*Physical setting
Terrain
Surrounding water
*Fuels & disturbance
Fuel & non-fuel classes
Cutblocks & surrounding fires
**Climate
Normal (30yr) & annual:
Moisture & temperature
Wind speed

Variables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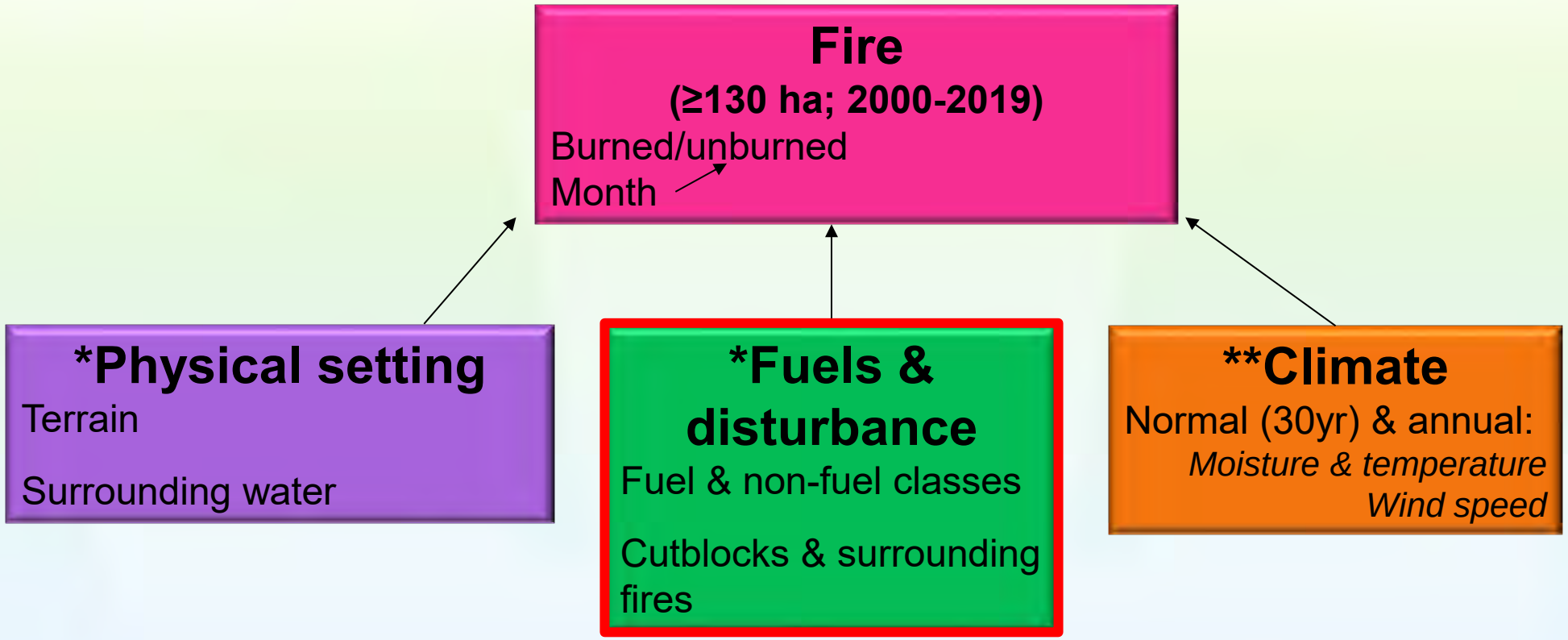
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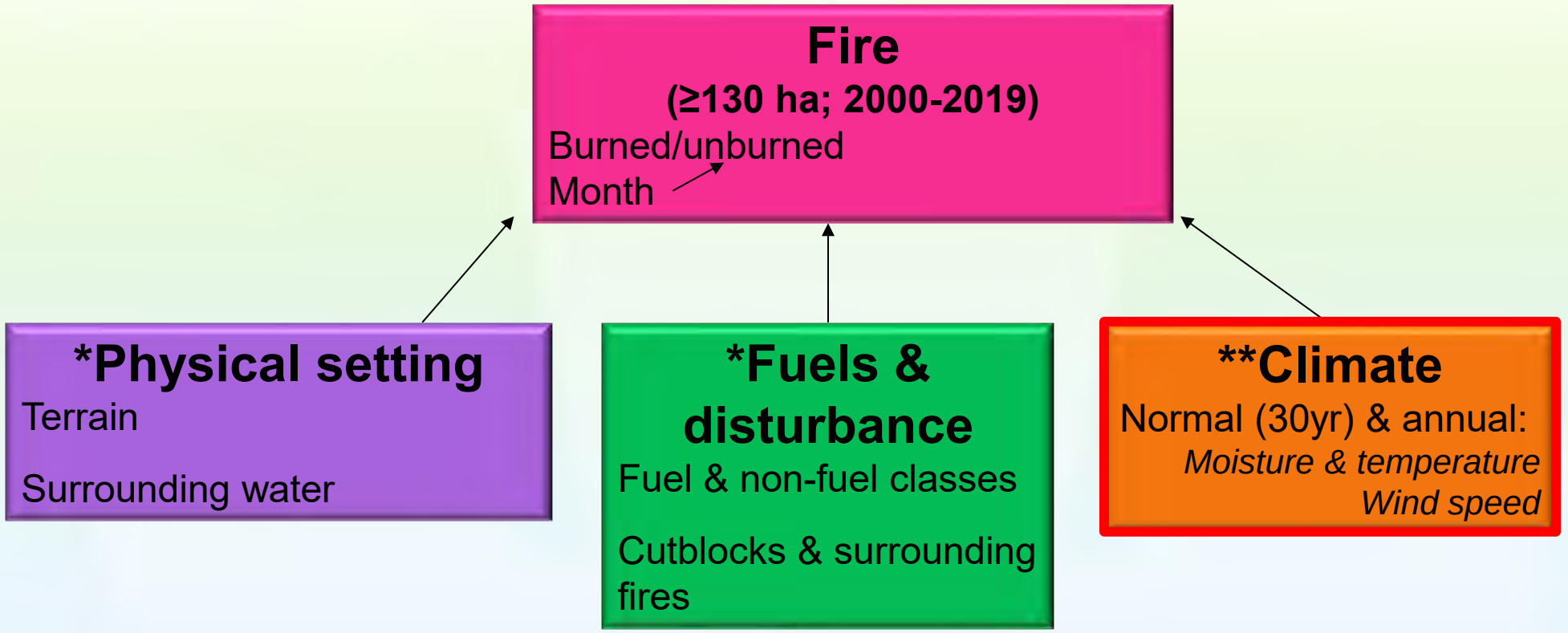
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Normal (30yr) & annual:
Moisture & temperature
Wind speed

Regions and model groupings

Boreal
FRU 30/58
FRU 31/32

Alpine
FRU 39/44

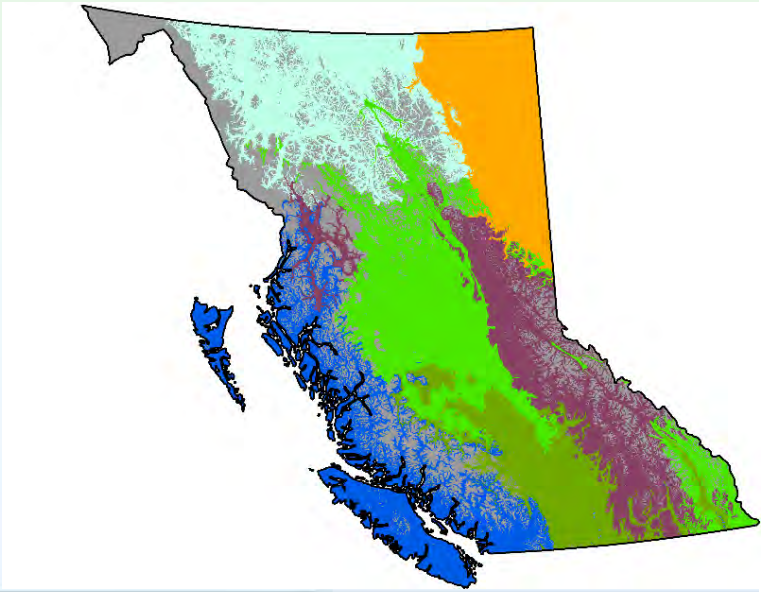
Humid maritime & highlands (coastal)
FRU 48/51
FRU 60

Subarctic
FRU 45
FRU 46

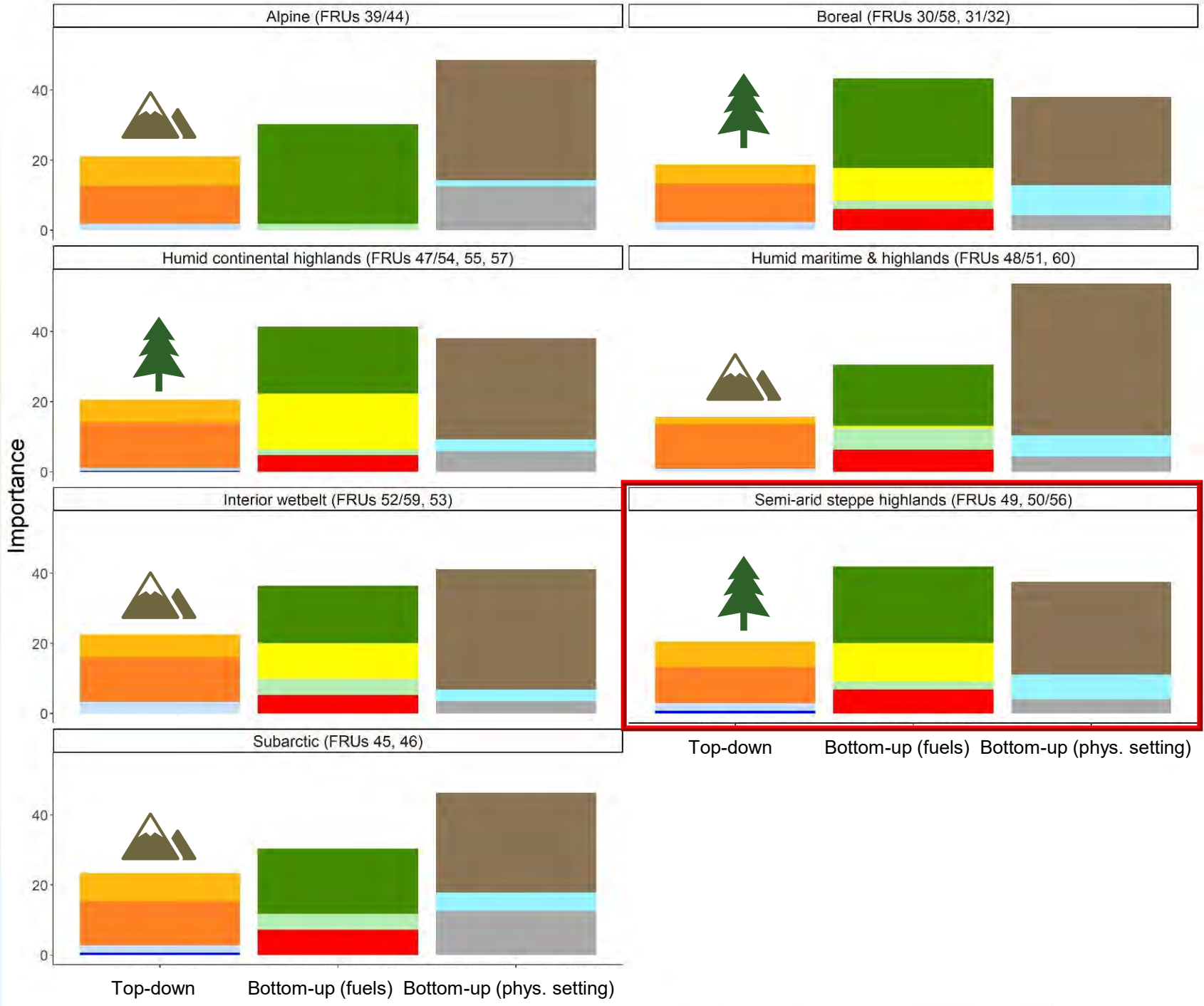
Interior wetbelt
FRU 52/59
FRU 53

Humid continental highlands
FRU 47/54
FRU 55
FRU 57

Semi-arid steppe highlands
FRU 49
FRU 50/56



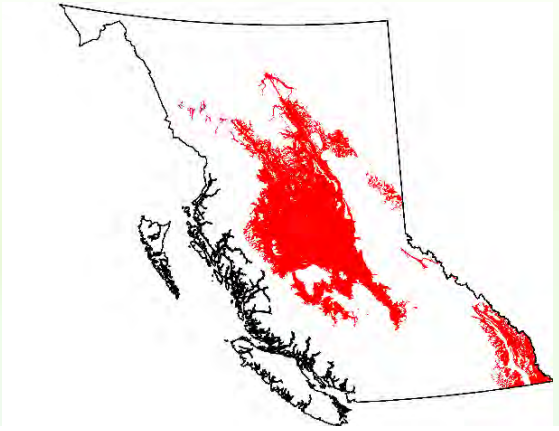
Importance of top-down and bottom-up controls

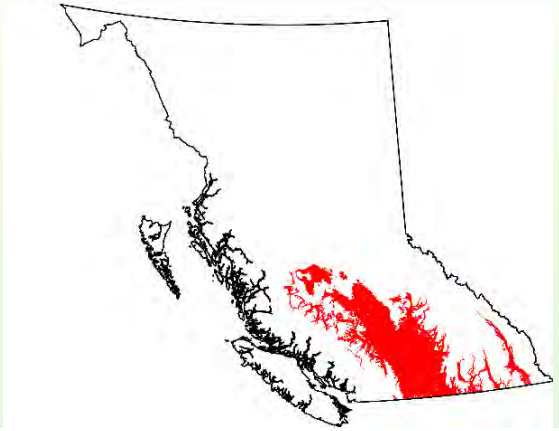


Top 20 variables; pR^2 adjusted

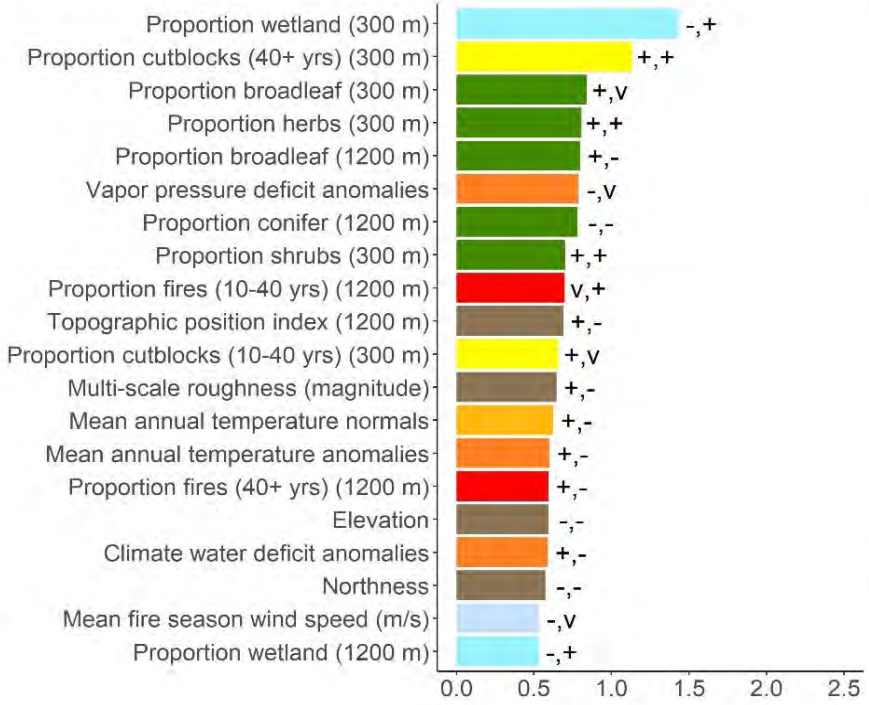
+ = positive effect
- = negative effect
v = variable effect

Variable grouping
- Climate anomalies
- Climate normals
- Cutblocks
- Month
- NDVI normals
- Other non-fuels
- Surrounding fires
- Topography
- Upland vegetation
- Wetlands
- Wind speed

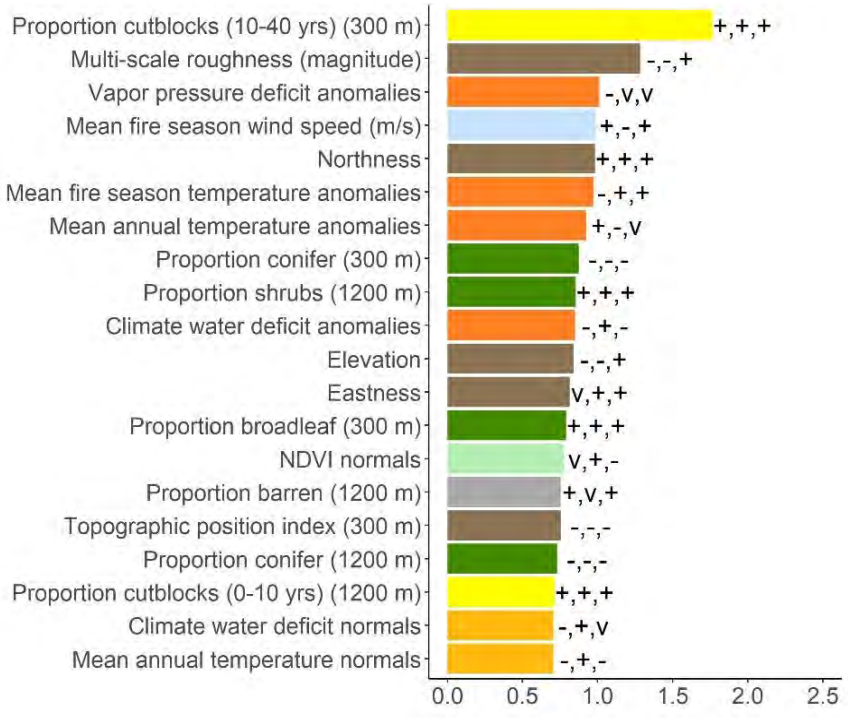




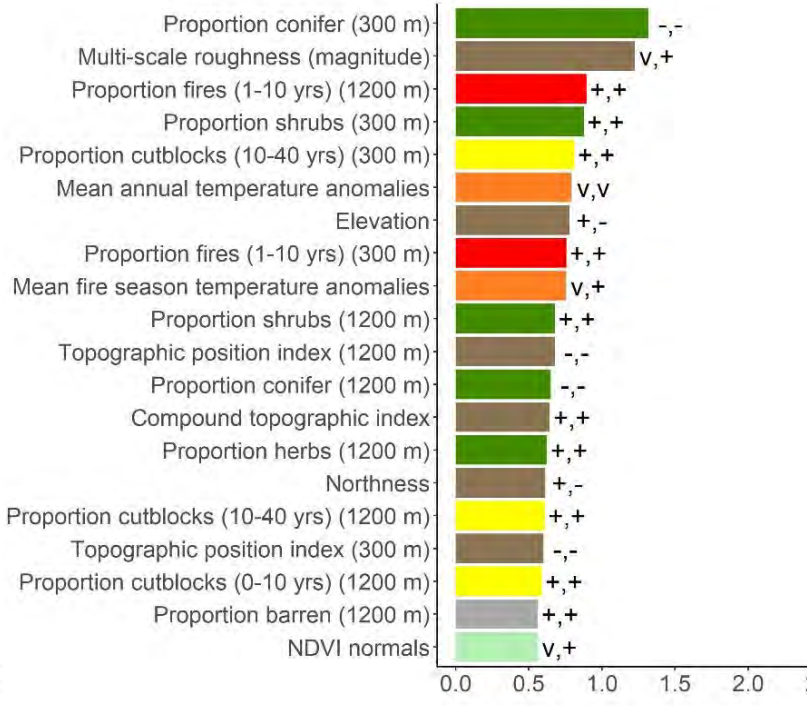
Boreal (FRUs 30/58, 31/32)



Humid continental highlands (FRUs 47/54, 55, 57)



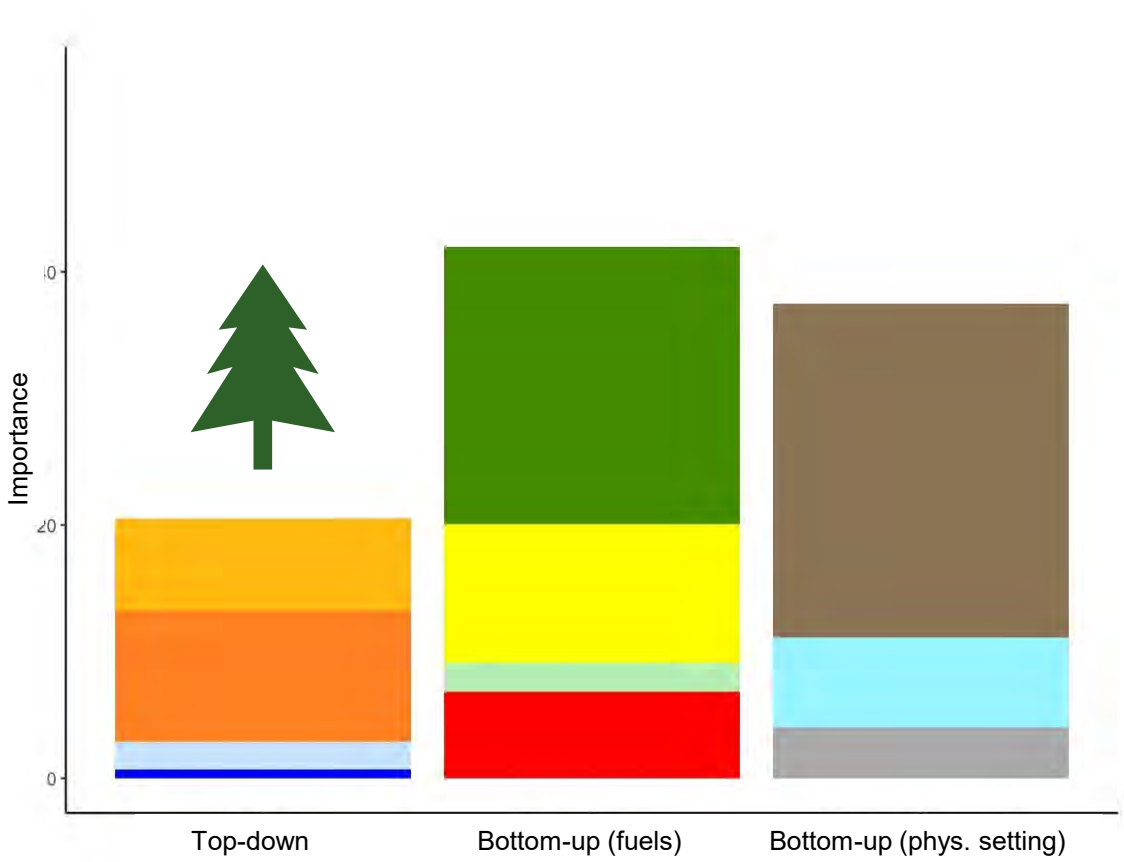
Semi-arid steppe highlands (FRUs 49, 50/56)

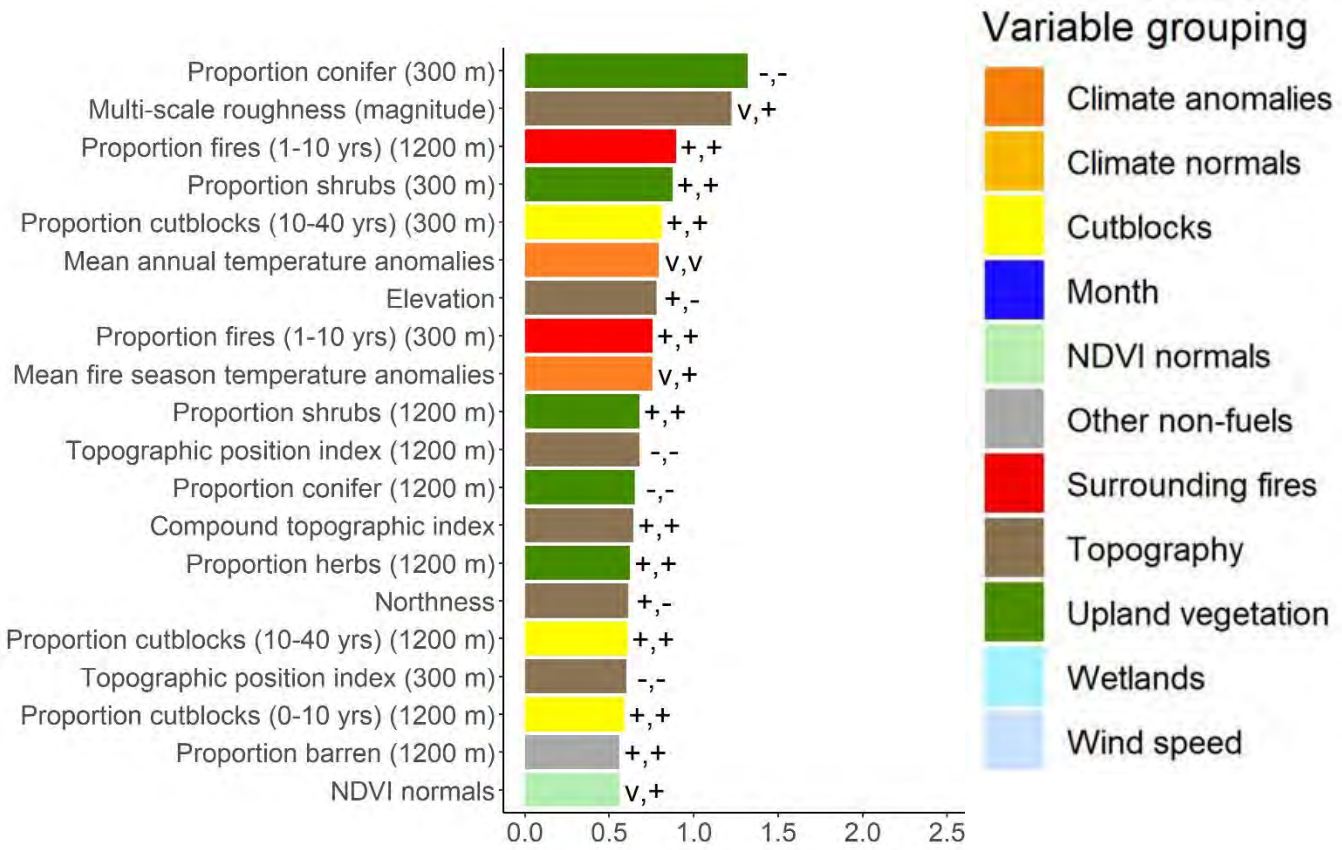


+ = positive effect
- = negative effect
v = variable effect

Controls in the Okanagan

Semi-arid steppe highlands (FRUs 49, 50/56)





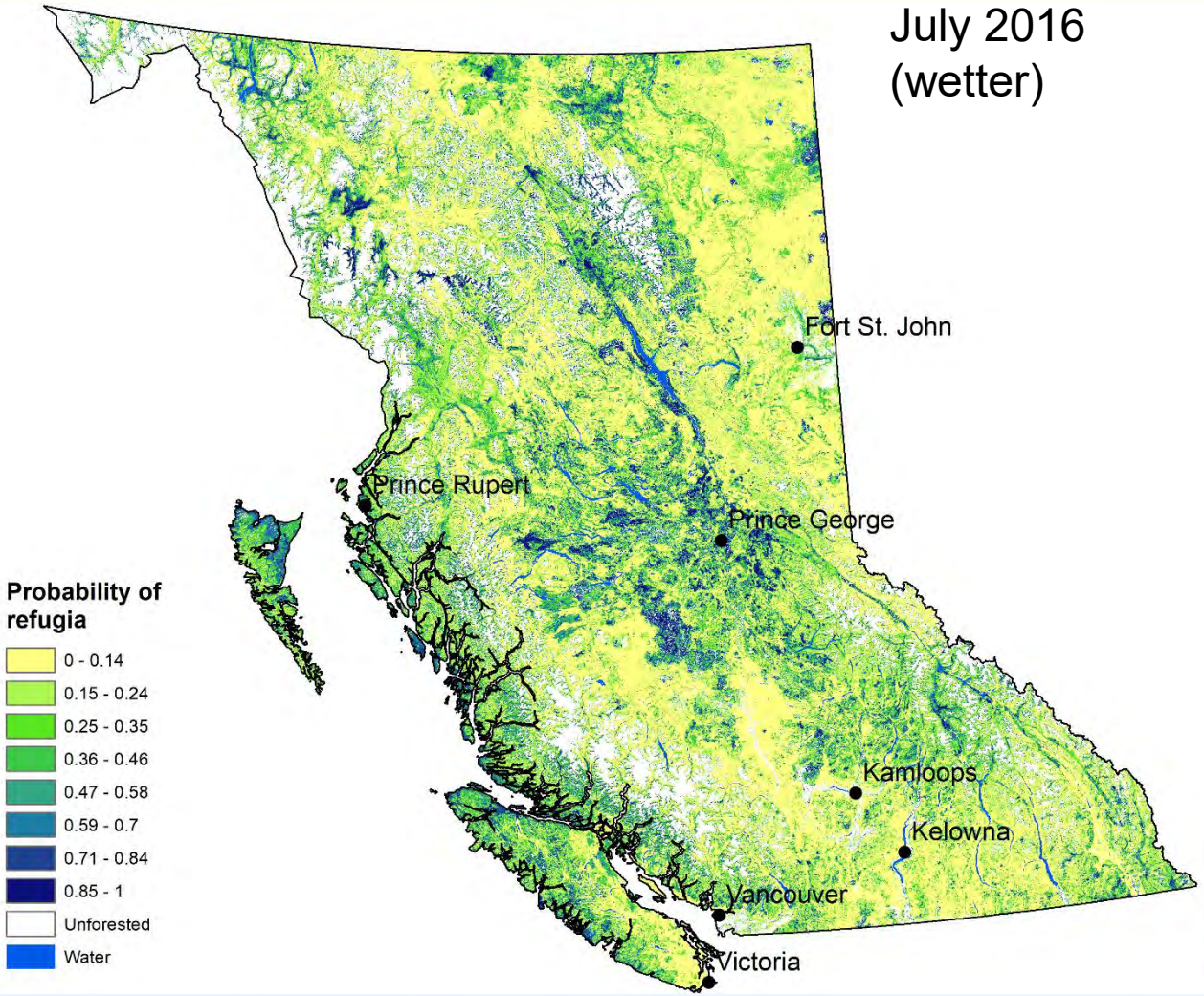
Mapping refugia probability

- Each fire regime unit mapped separately & stitched together for provincial maps
- 4 maps in total, showing:
  - Climate scenarios
    - Drier
    - Average
    - Wetter

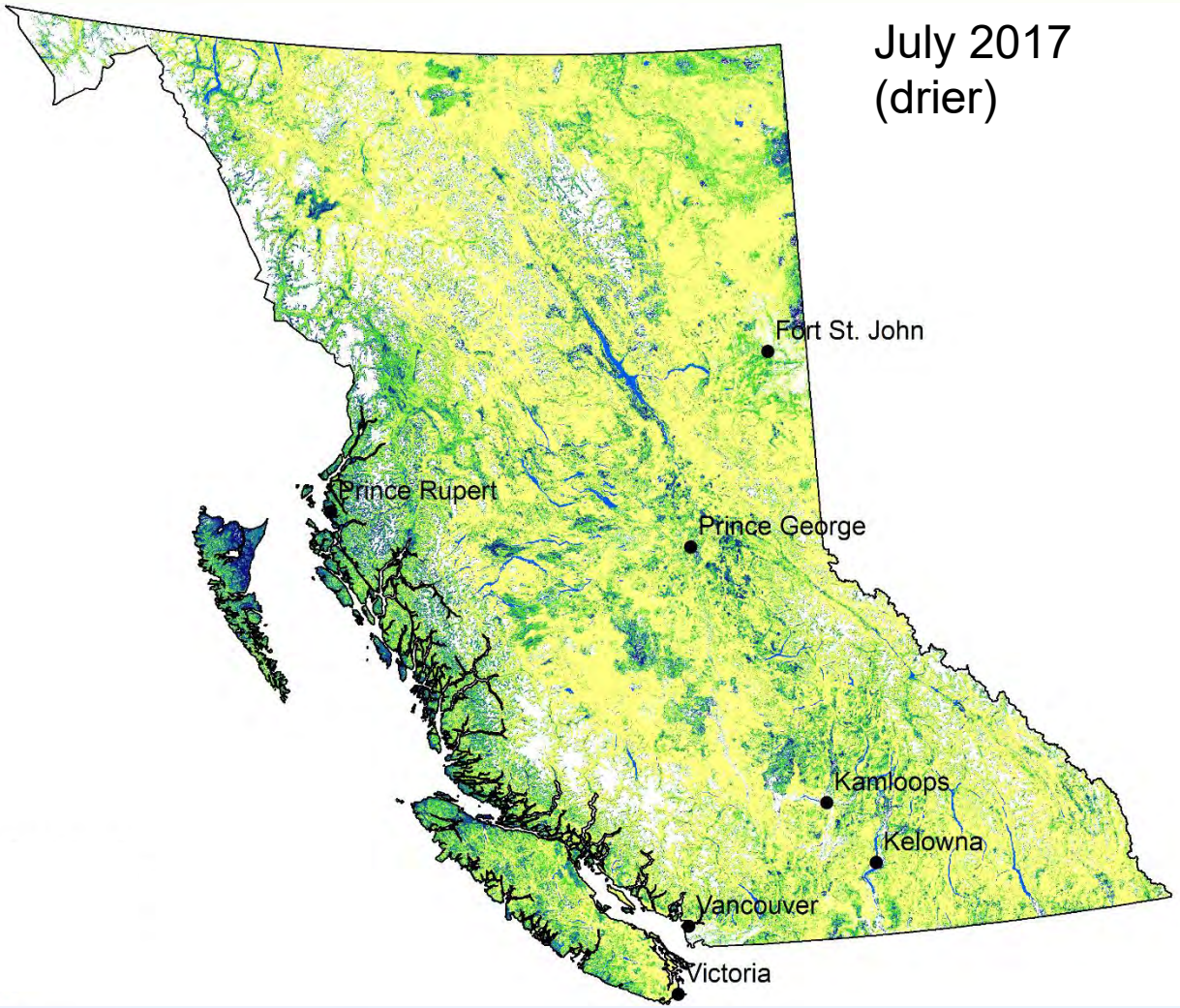
Terrain-focused

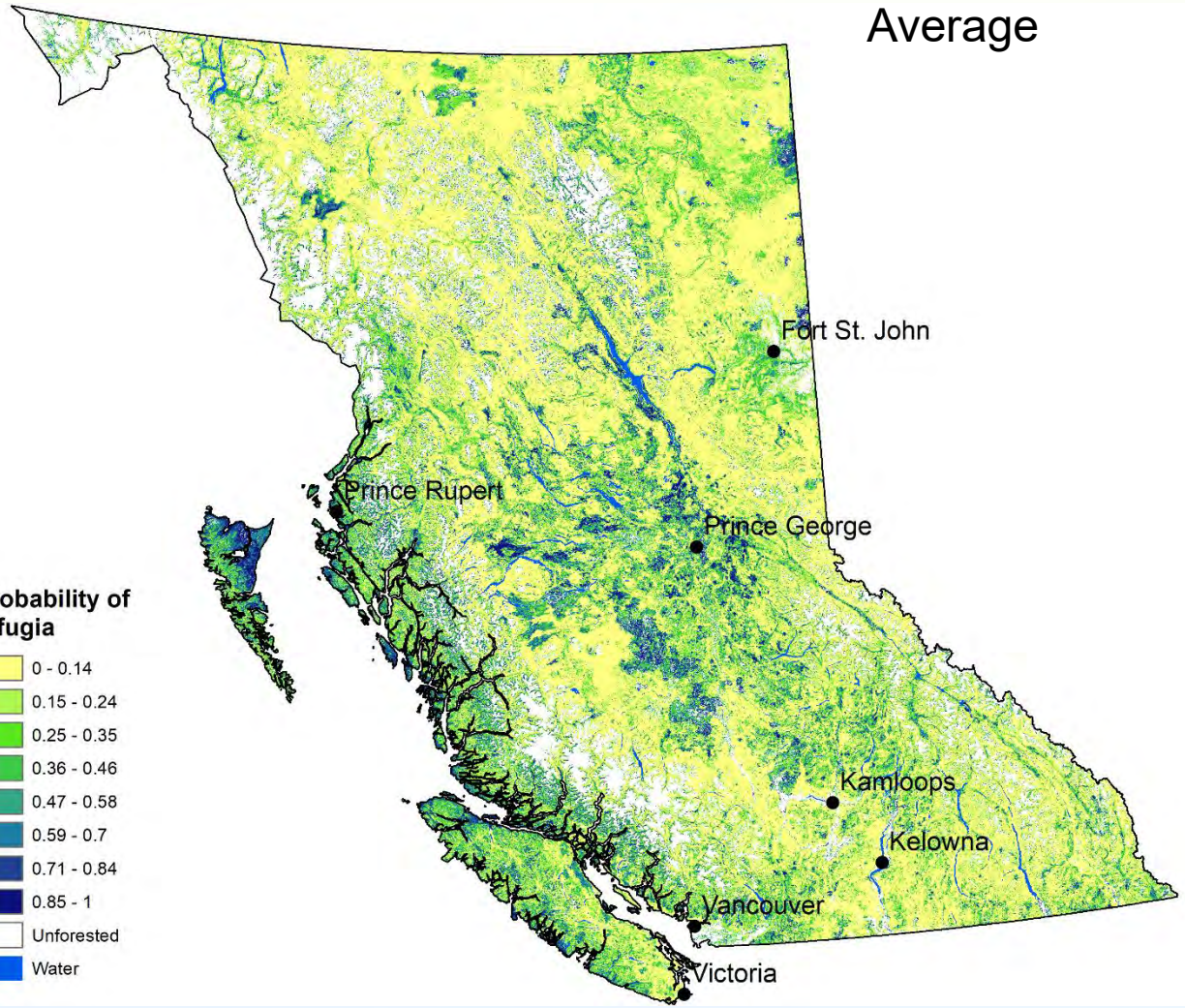
- Indication of possible long-term refugia

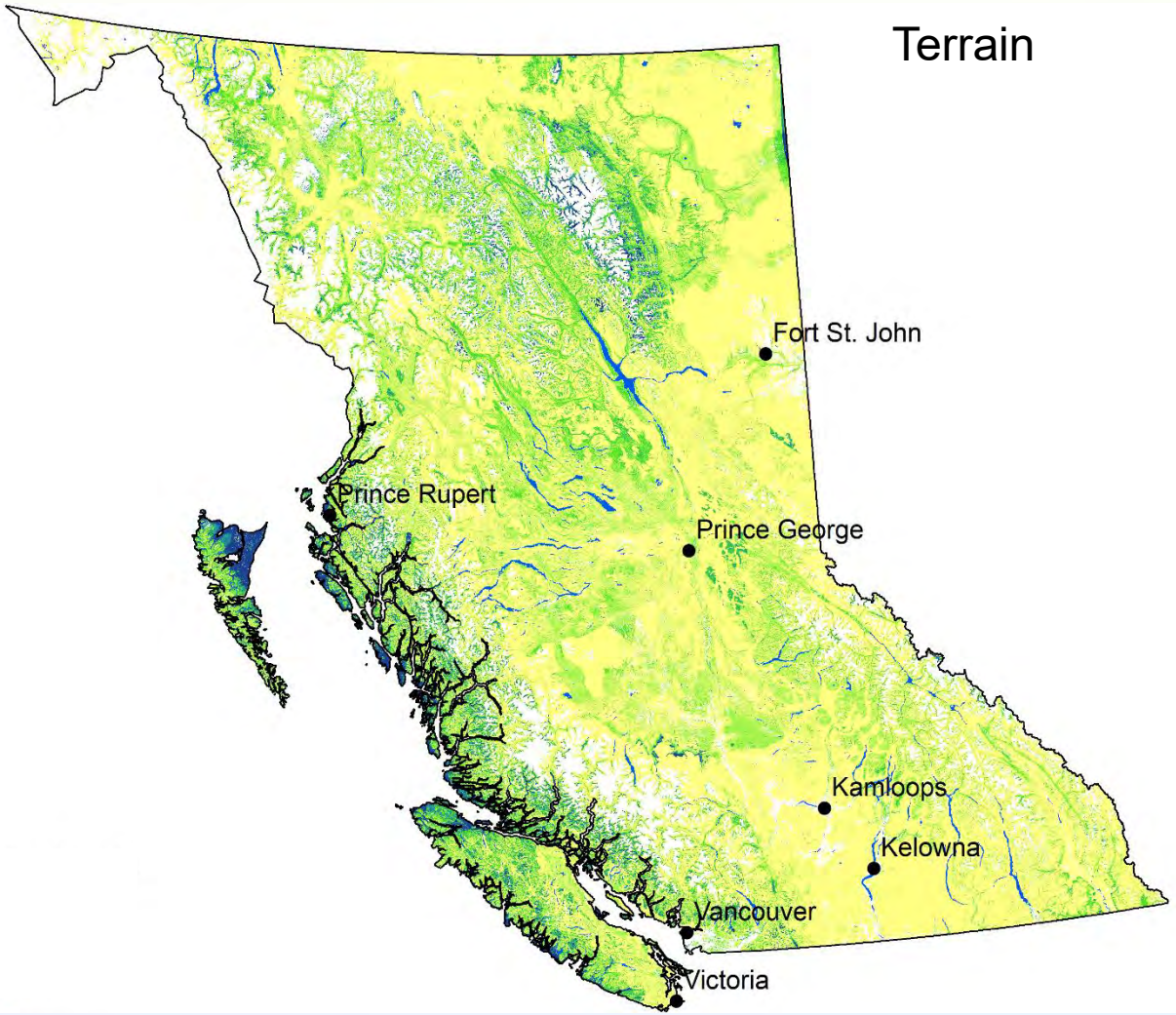
July 2016
(wetter)

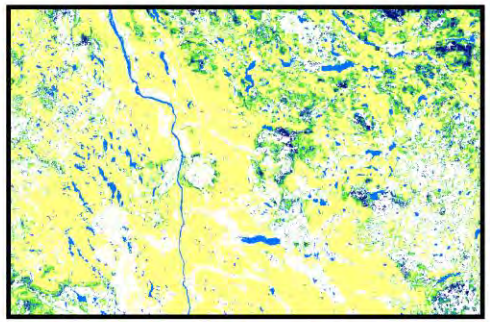


July 2017
(drier)

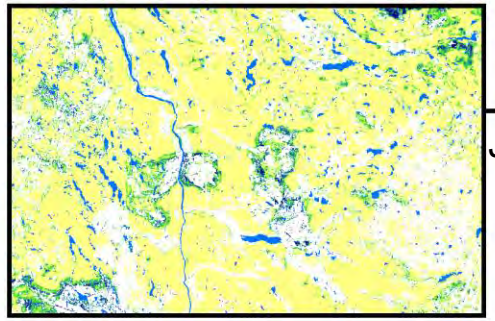



Average
Fort St. John
Prince Rupert
Prince George
Kamloops
Kelowna
Vancouver
Victoria
Probability of refugia
0 - 0.14
0.15 - 0.24
0.25 - 0.35
0.36 - 0.46
0.47 - 0.58
0.59 - 0.7
0.71 - 0.84
0.85 - 1
Unforested
Water

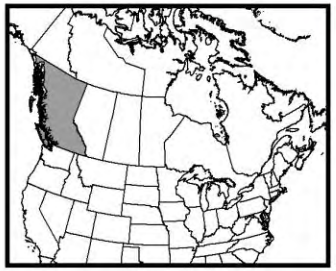

Terrain
Fort St. John
Prince Rupert
Prince George
Kamloops
Kelowna
Vancouver
Victoria

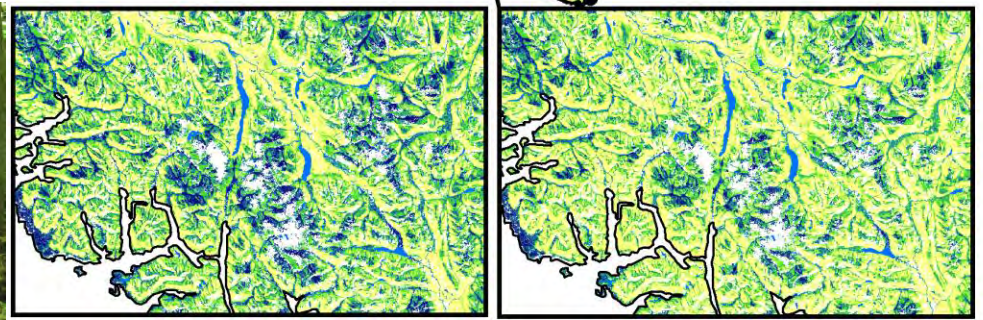


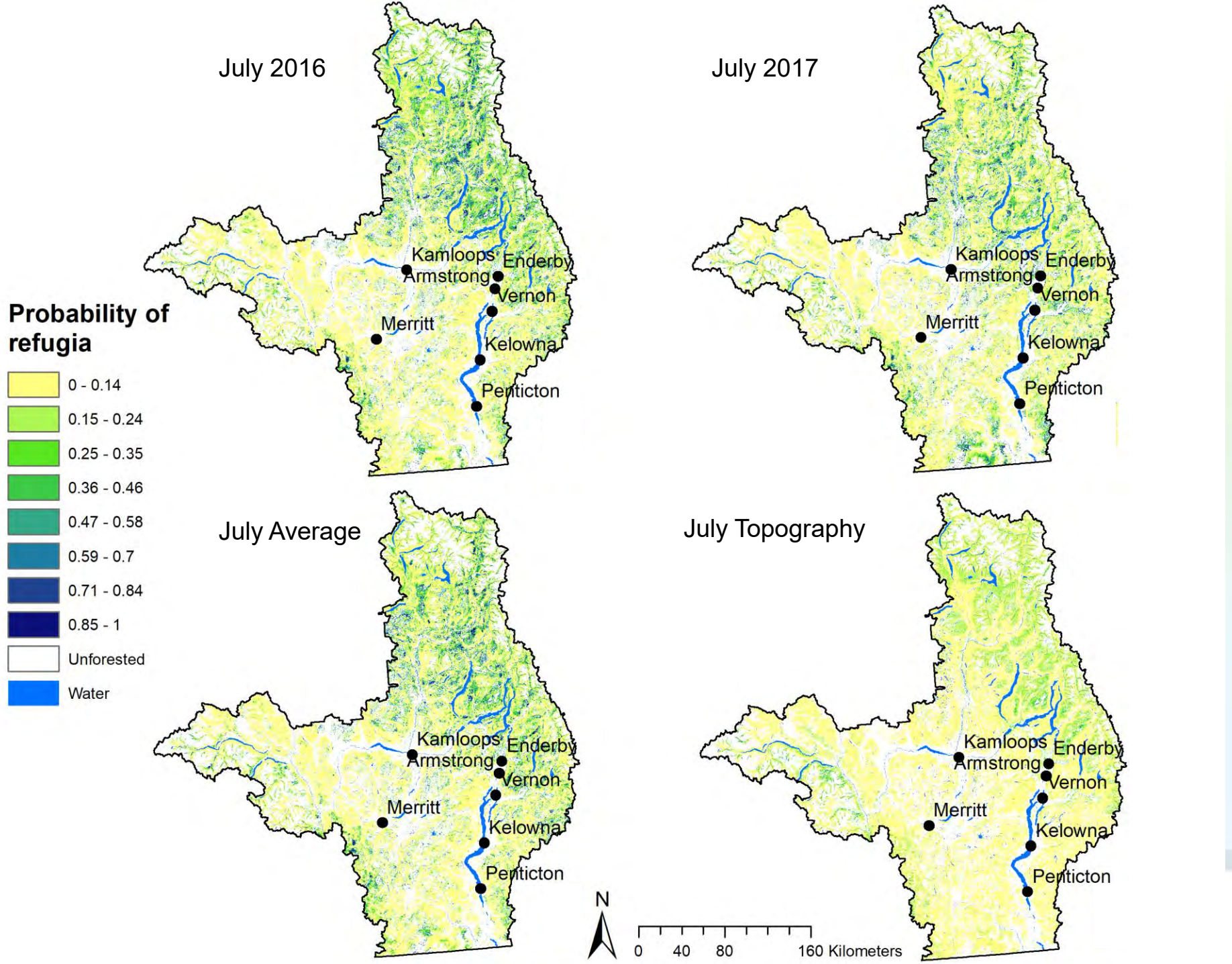
July 2016



July 2017

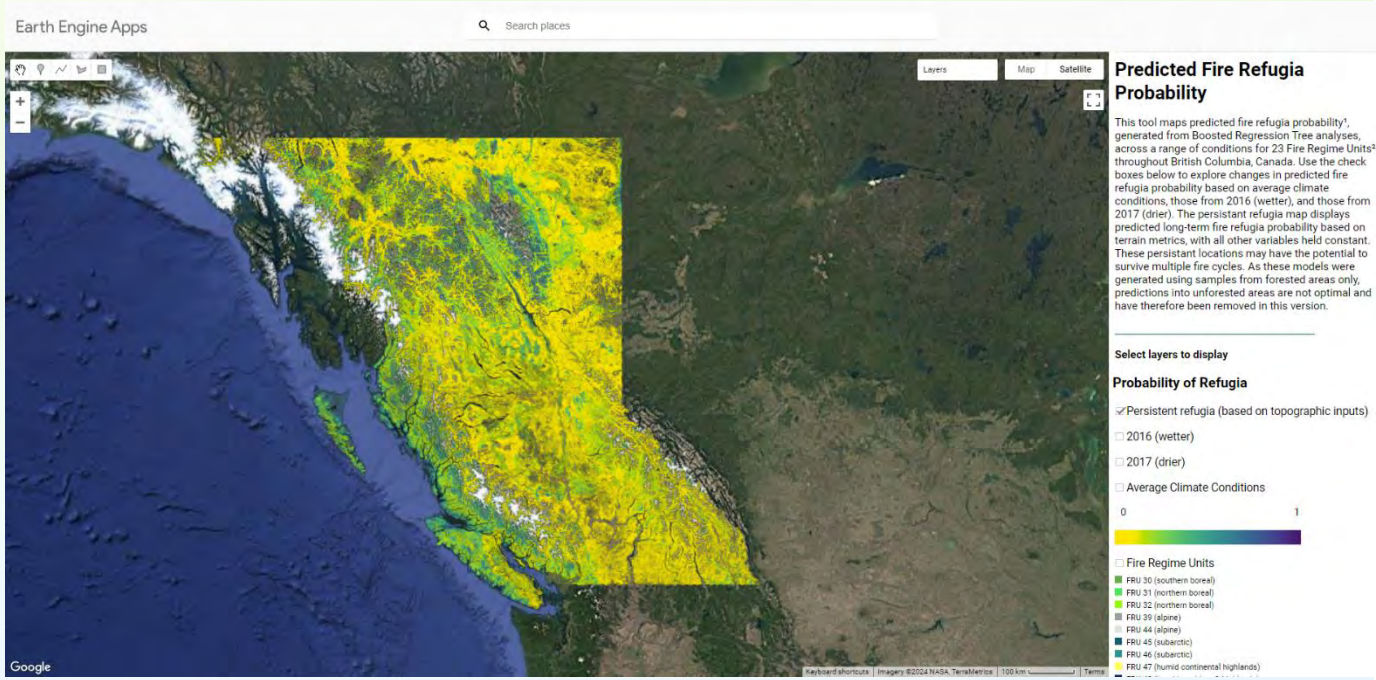





July 2016
July 2017
July Average
July Topography
Probability of refugia
0 - 0.14
0.15 - 0.24
0.25 - 0.35
0.36 - 0.46
0.47 - 0.58
0.59 - 0.7
0.71 - 0.84
0.85 - 1
Unforested
Water
Kamloops
Enderby
Armstrong
Vernon
Merritt
Kelowna
Penticton
N
0
40
80
160 Kilometers

Google Earth Engine App

- Publicly available web app
- Work in progress!
- [“Predicted Fire Refugia Probability Across British Columbia”]



Predicted Fire Refugia Probability

This tool maps predicted fire refugia probability[1], generated from Boosted Regression Tree analyses, across a range of conditions for 23 Fire Regime Units[2] throughout British Columbia, Canada. Use the check boxes below to explore changes in predicted fire refugia probability based on average climate conditions, those from 2016 (wetter), and those from 2017 (drier). The persistant refugia map displays predicted long-term fire refugia probability based on terrain metrics, with all other variables held constant. These persistant locations may have the potential to survive multiple fire cycles. As these models were generated using samples from forested areas only, predictions into unforested areas are not optimal and have therefore been removed in this version.

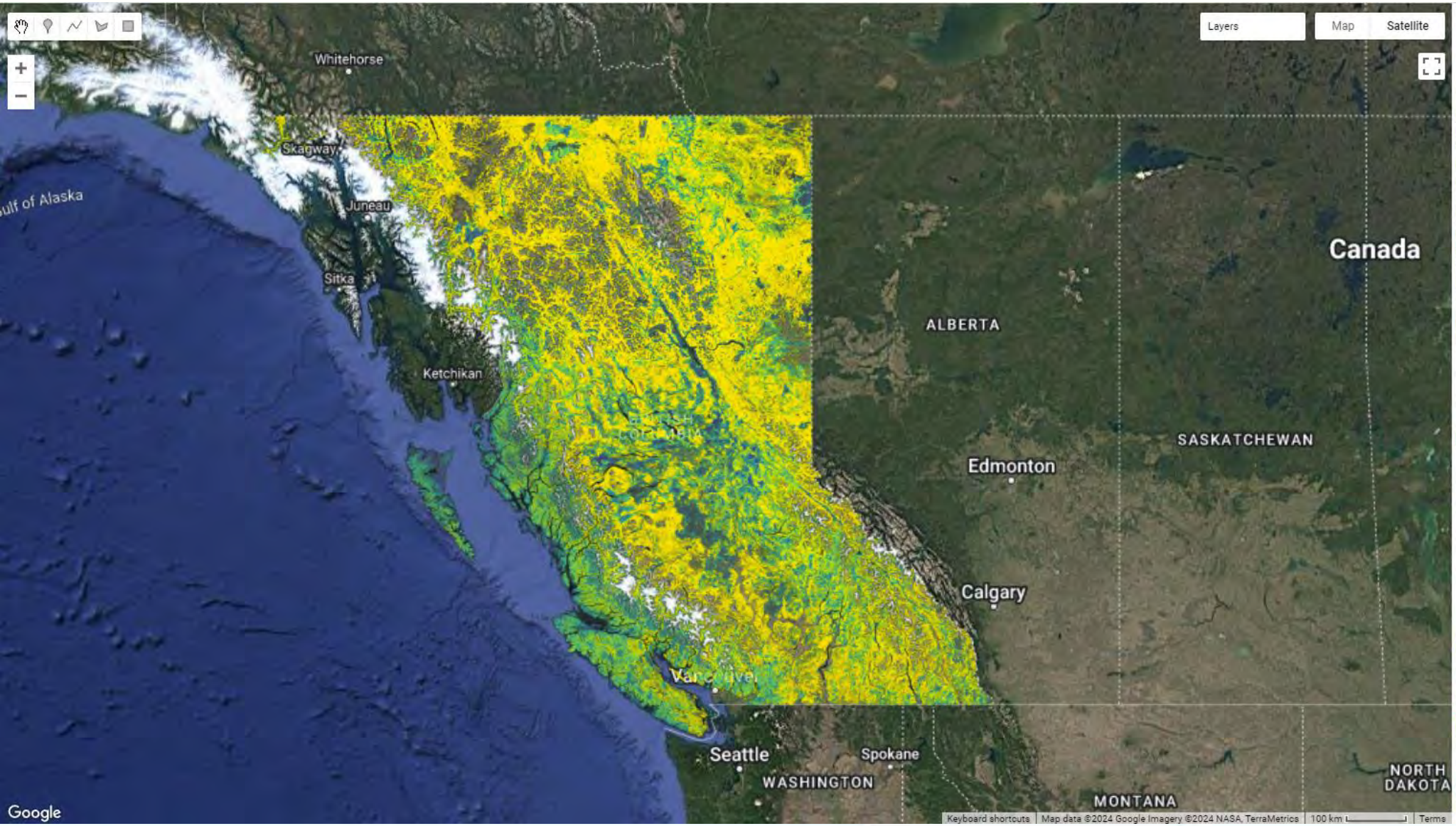
Select layers to display

Probability of Refugia

- ☐ Persistent refugia (based on topographic inputs)
- ☐ 2016 (wetter)
- ☐ 2017 (drier)
- ☐ Average Climate Conditions

0 — 1

- ☐ Fire Regime Units
  - FRU 30 (southern boreal)
  - FRU 31 (northern boreal)
  - FRU 32 (northern boreal)
  - FRU 39 (alpine)
  - FRU 44 (alpine)
  - FRU 45 (subarctic)
  - FRU 46 (subarctic)
  - FRU 47 (humid continental highlands)



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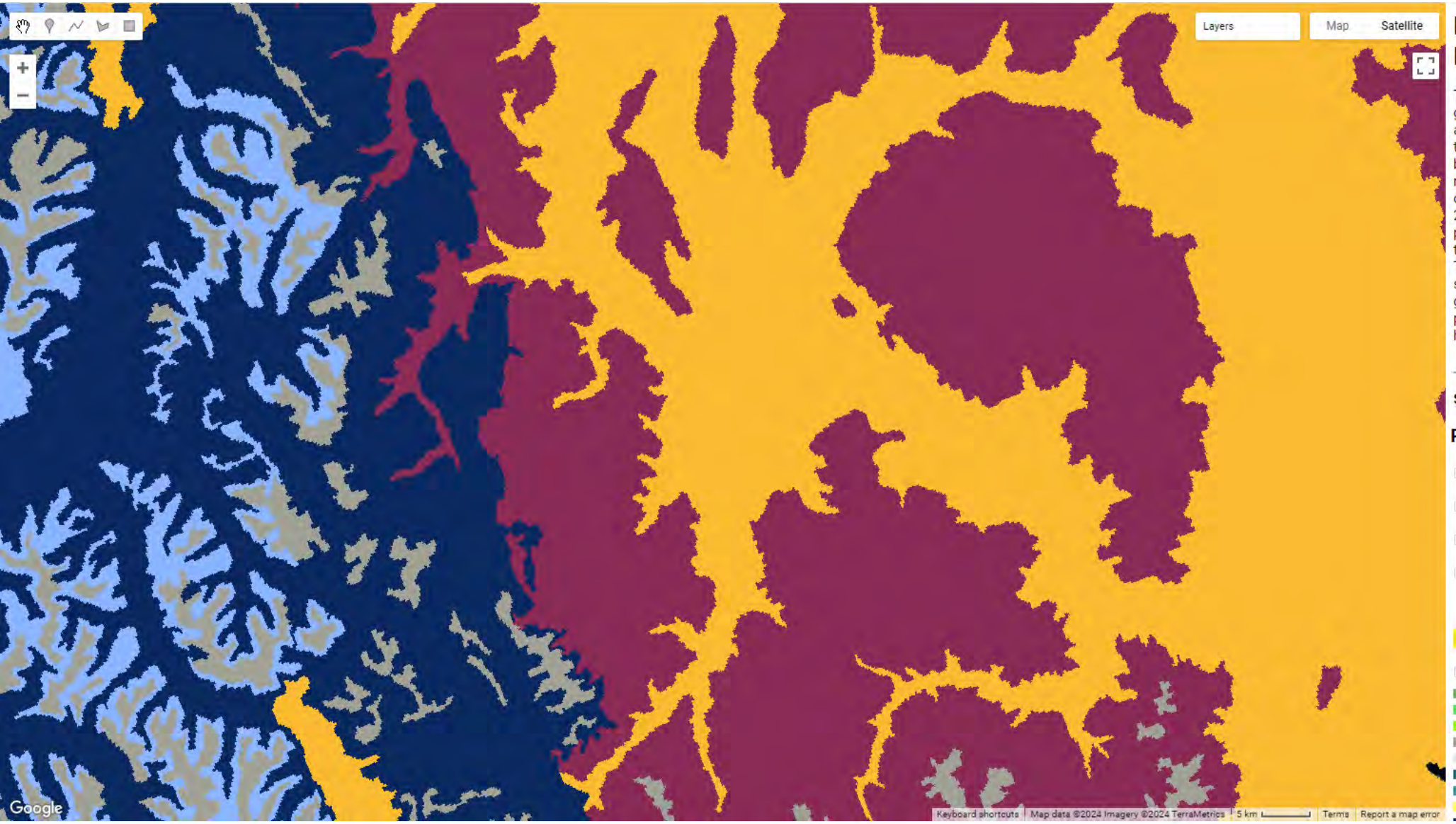

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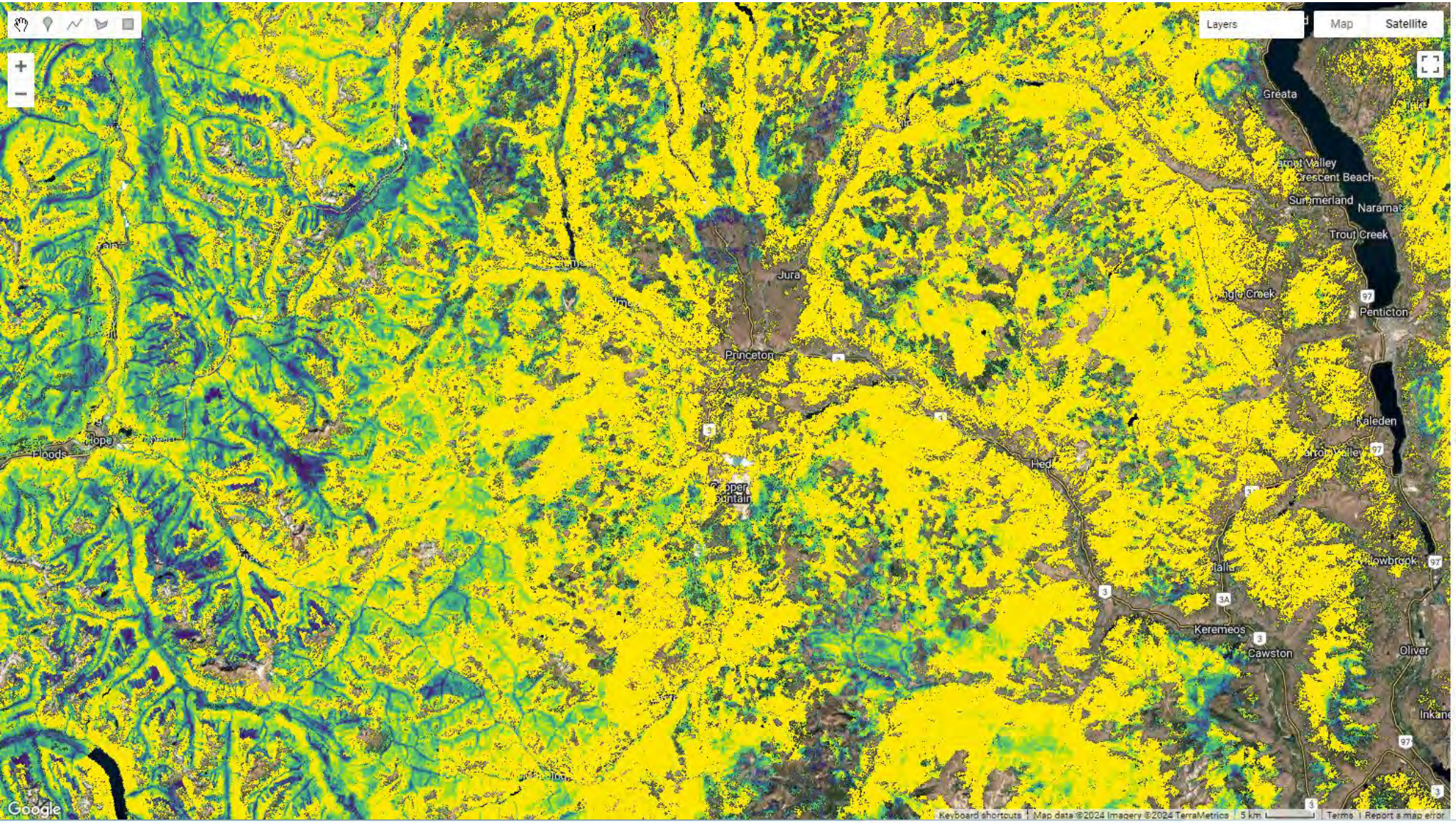

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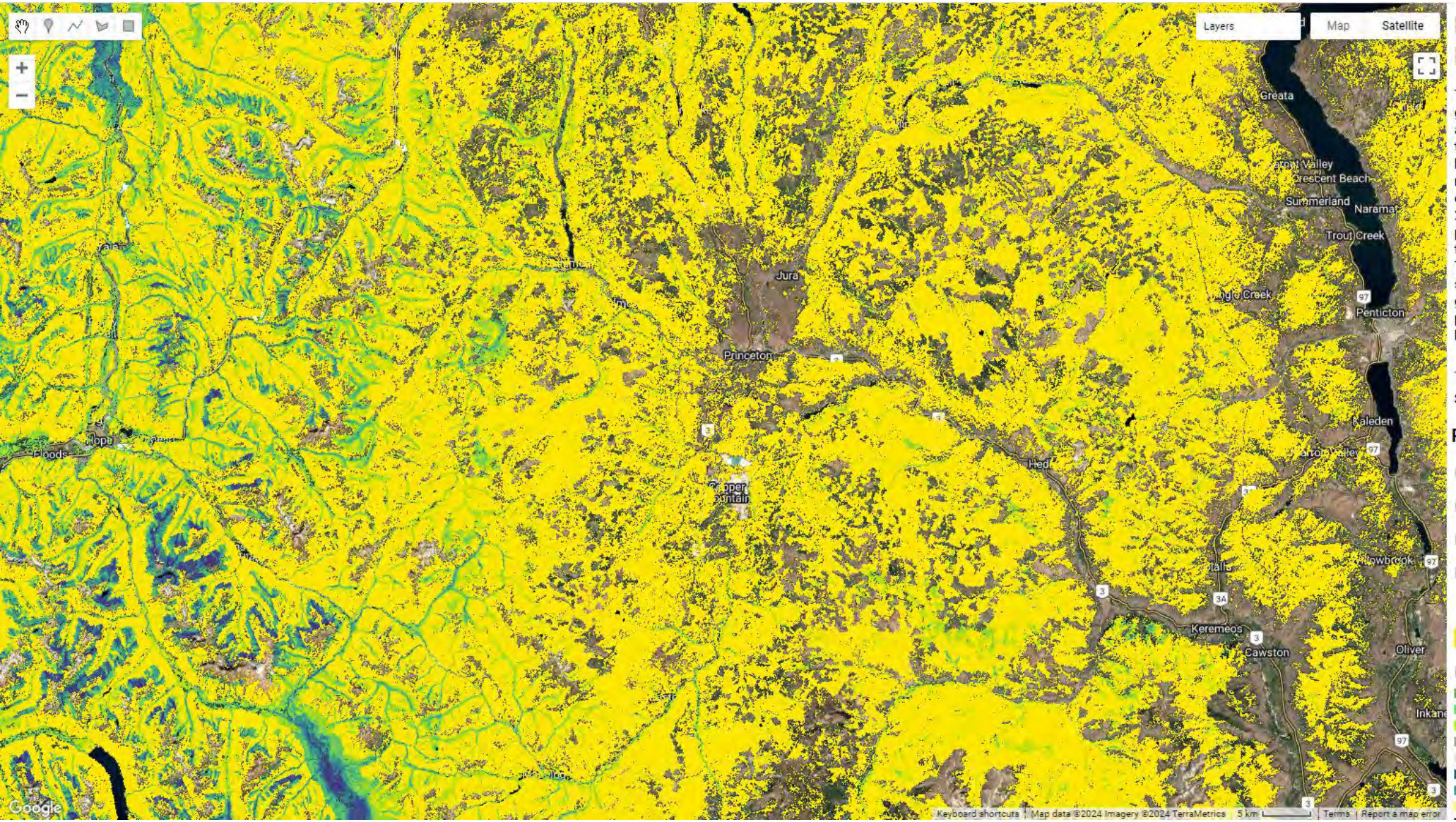
  - FRU 47 (humid continental highlands)



Predicted Fire Refugia Probability

This tool maps predicted fire refugia probability[1], generated from Boosted Regression Tree analyses, across a range of conditions for 23 Fire Regime Units[2] throughout British Columbia, Canada. Use the check boxes below to explore changes in predicted fire refugia probability based on average climate conditions, those from 2016 (wetter), and those from 2017 (drier). The persistant refugia map displays predicted long-term fire refugia probability based on terrain metrics, with all other variables held constant. These persistant locations may have the potential to survive multiple fire cycles. As these models were generated using samples from forested areas only, predictions into unforested areas are not optimal and have therefore been removed in this version.

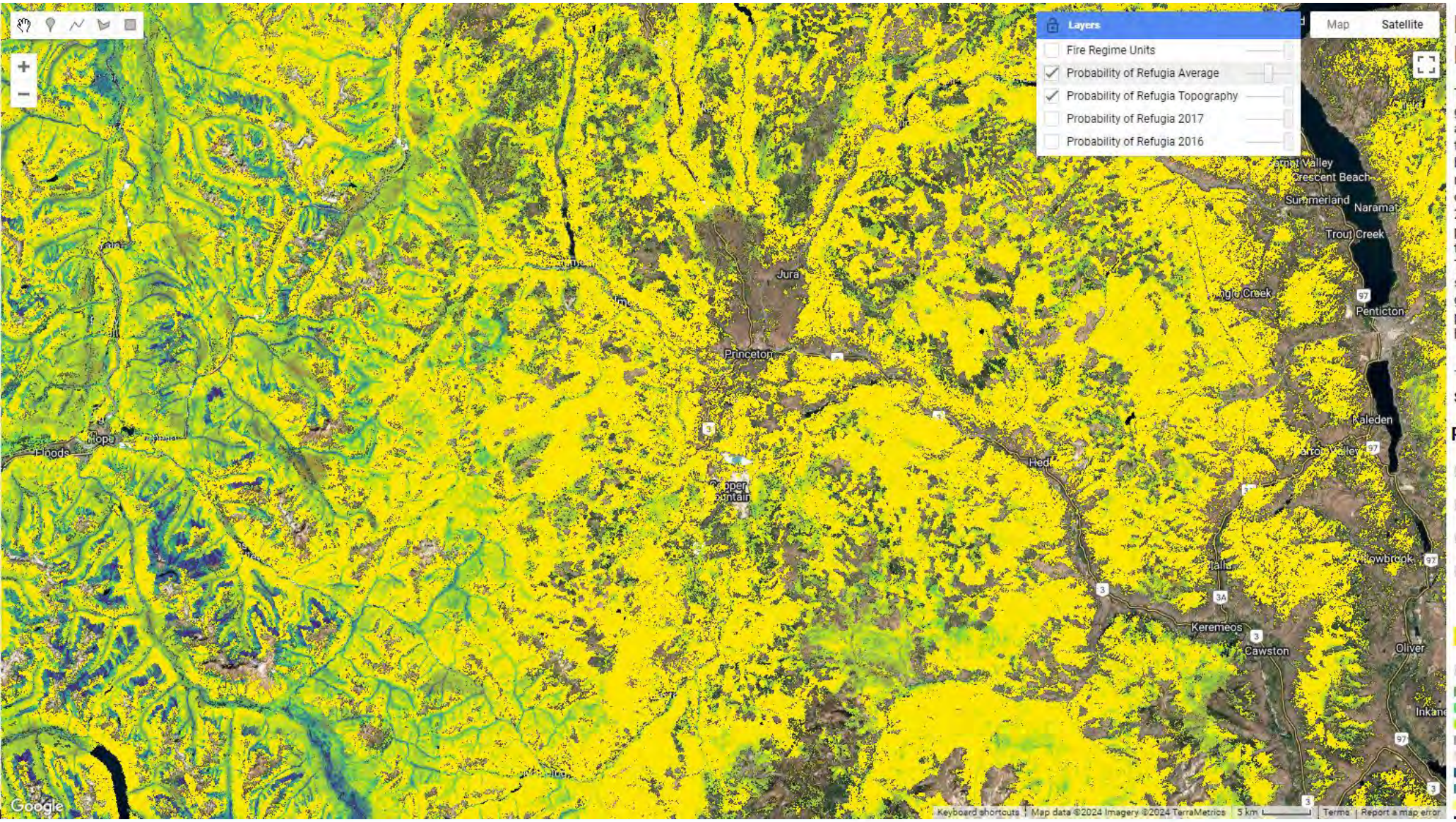
Select layers to display

Probability of Refugia

- [x] Persistent refugia (based on topographic inputs)
- [ ] 2016 (wetter)
- [ ] 2017 (drier)
- [ ] Average Climate Conditions

0 — 1

- [ ] Fire Regime Units
  - FRU 30 (southern boreal)
  - FRU 31 (northern boreal)
  - FRU 32 (northern boreal)
  - FRU 39 (alpine)
  - FRU 44 (alpine)
  - FRU 45 (subarctic)
  - FRU 46 (subarctic)
  - FRU 47 (humid continental highlands)



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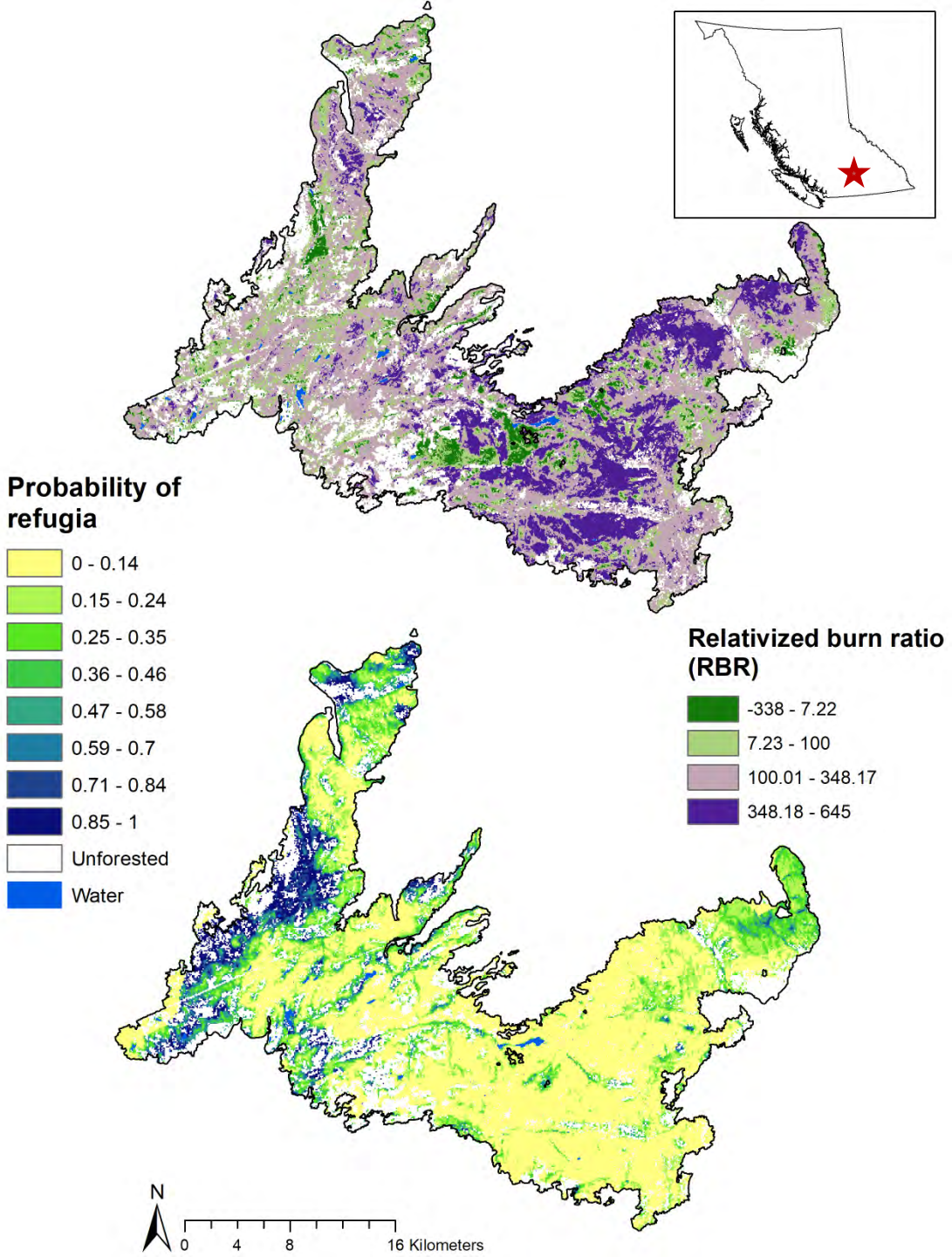
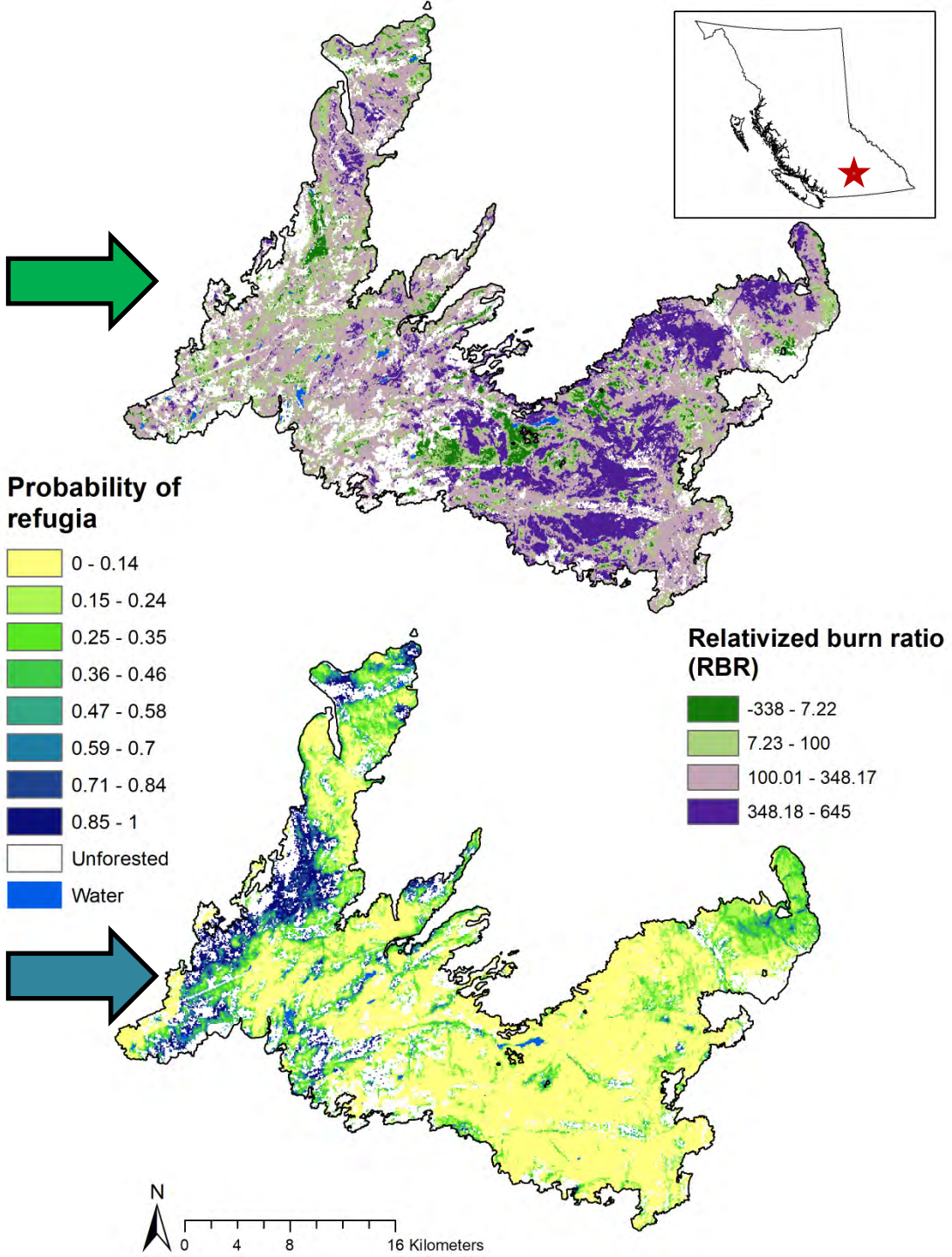
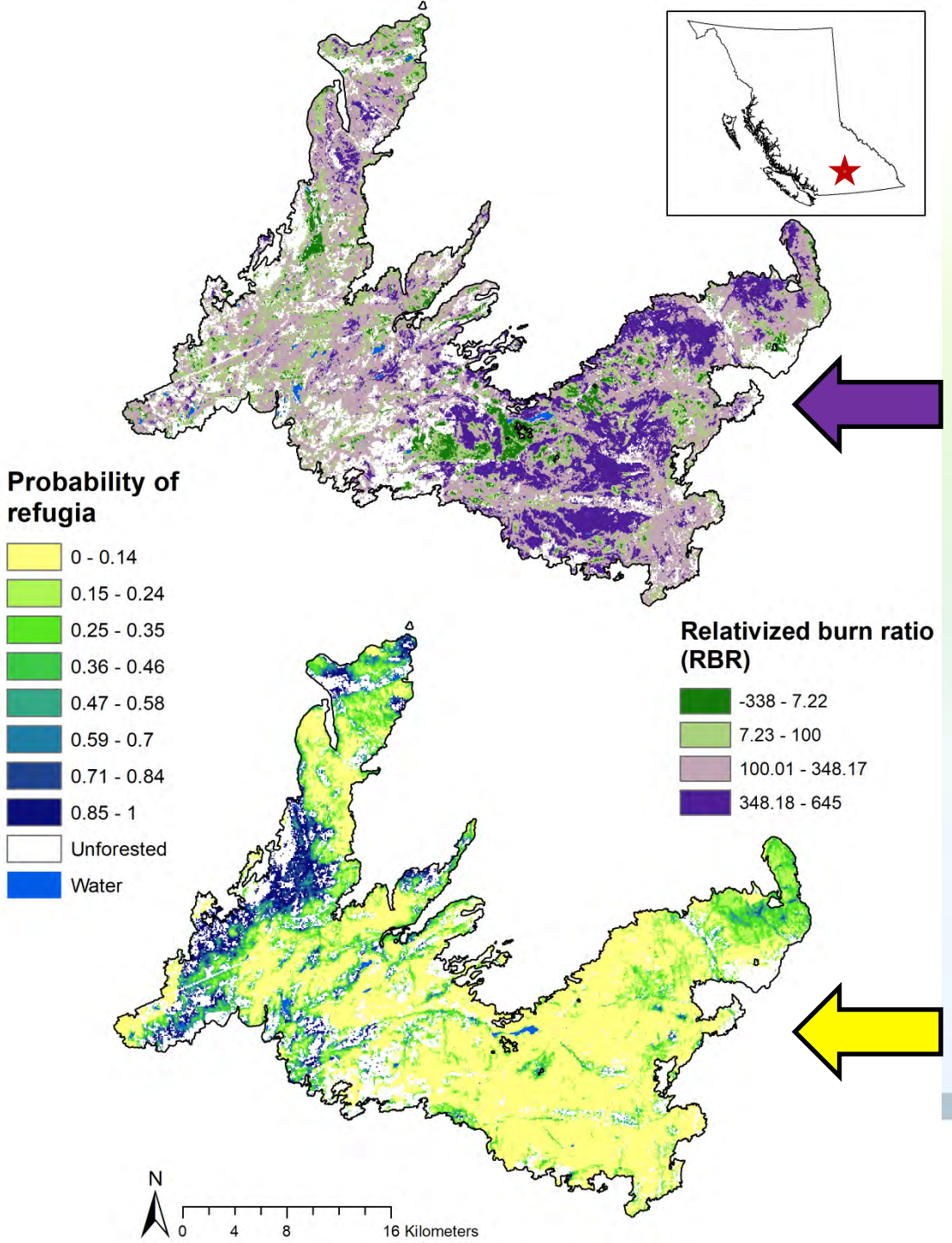
Actual vs. predicted fire

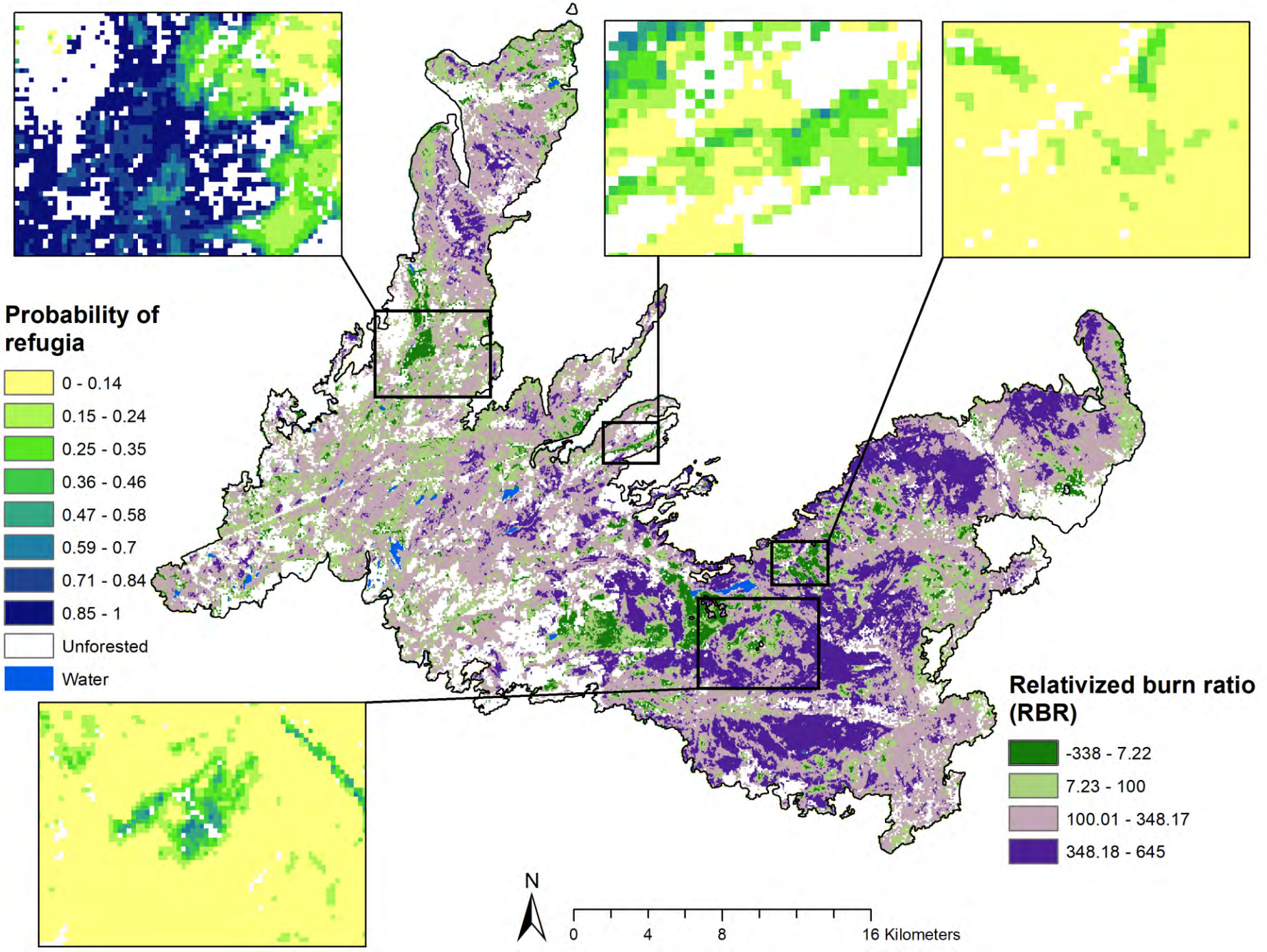


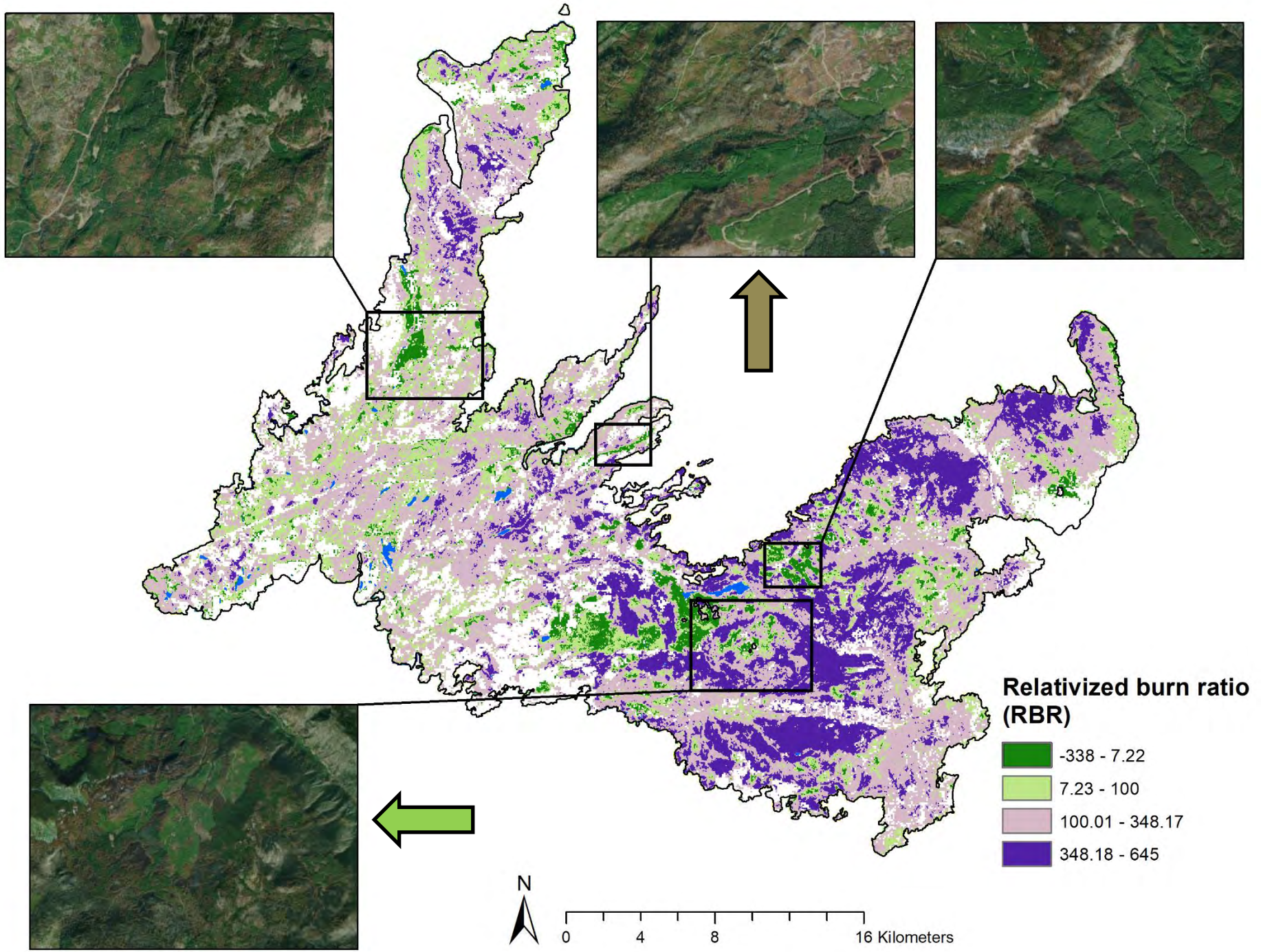
Actual vs. predicted fire



Actual vs. predicted fire




Probability of refugia
0 - 0.14
0.15 - 0.24
0.25 - 0.35
0.36 - 0.46
0.47 - 0.58
0.59 - 0.7
0.71 - 0.84
0.85 - 1
Unforested
Water
Relativized burn ratio (RBR)
-338 - 7.22
7.23 - 100
100.01 - 348.17
348.18 - 645
N
0
4
8
16 Kilometers


Relativized burn ratio
(RBR)
-338 - 7.22
7.23 - 100
100.01 - 348.17
348.18 - 645
N
0
4
8
16 Kilometers

Testing our predictions against recent fires

- Fires from 2020-2022 held back for testing
- Overall the models do quite well at predicting refugia in these fires
- They do an especially good job on fires from 2021, including those in the Okanagan
- First Nations Emergency Services Society (FNESS) did ground-truthing this summer

Conclusions

- Overall, bottom-ups were the strongest control
  - Fuels were of highest importance in the boreal and central interior
  - Phys. setting was of highest importance in alpine, coast, subarctic, wetbelt
- Bottom-up controls can be overwhelmed by extreme climate

Limitations

- Our models don't/can't explain everything
  - Fires are complex; lots of things happen by random chance and no prediction will be perfect
  - Our models don't predict in real time but suggest where refugia are more likely
- Daily fire weather not included in this study
  - But work from NWT shows it may not be a critical factor
- Fire regimes are changing
  - Especially true in Okanagan region

Importance for management

Conservation:

- Plant communities / seed sources
  - Promote biodiversity
- Safe havens / connectivity for species

Forest management:

- Refugia-informed harvesting

Community importance

- Thin fuels around high-value areas for protection
- Indigenous-led controlled burns
- Emulate fire in forestry practices
  - Diverse forest age, structure, and phase

Thank you!

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