Welcome

Bulkley Morice Wildfire Resilience Project – Workshop 3

Why you're here

- Land managers
- Representative of governments and interests in the area
- Project success relies on your input

"Identify the range of wildfire problems and the type of information that will support land managers …"

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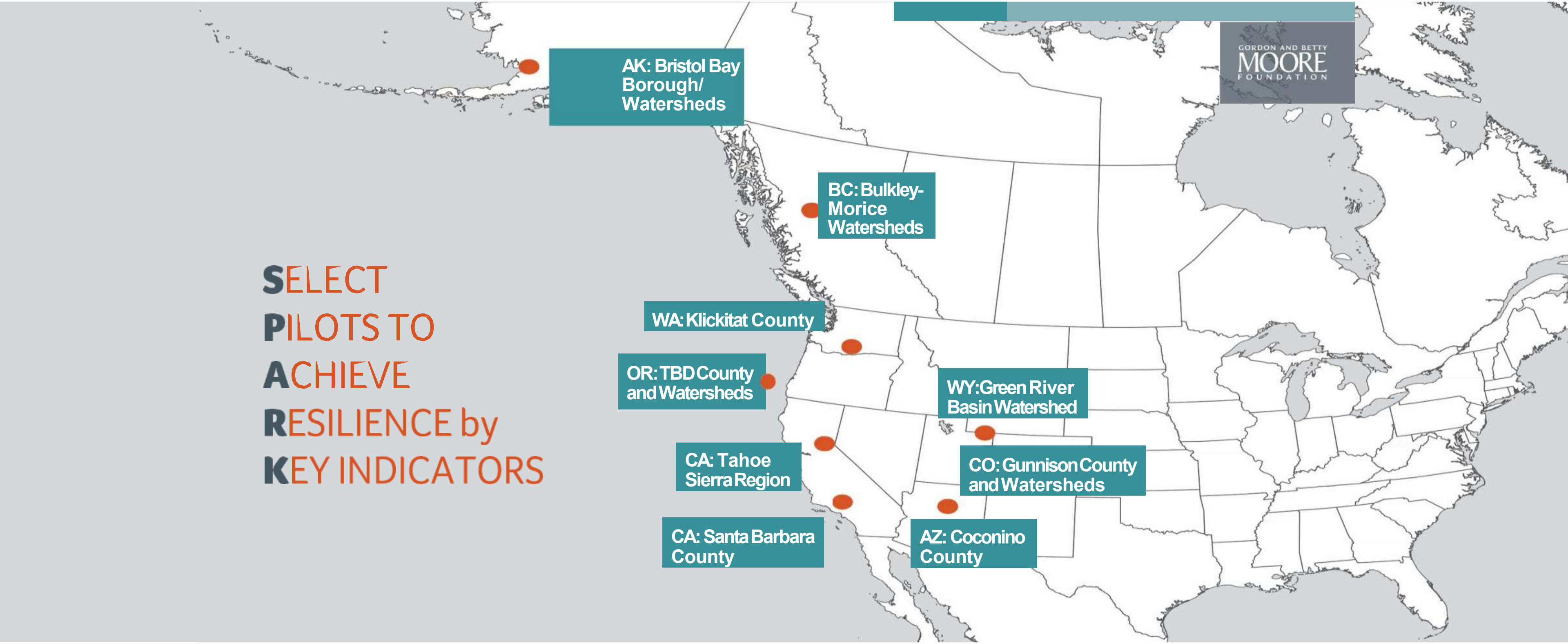
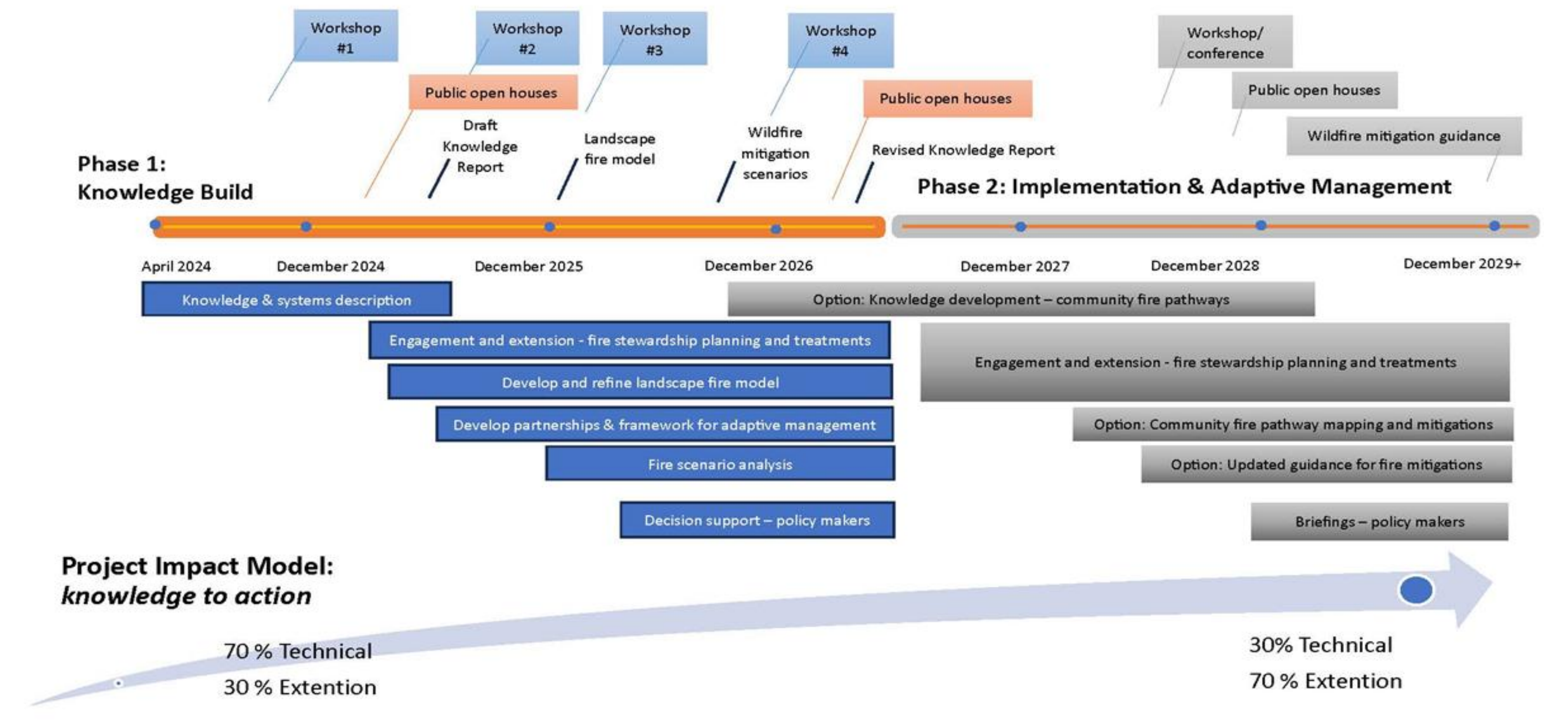


Project timeline and phases 2024 – 2030



Agenda

8:15-8:30 AM	Arrival and coffee
8:30-9:00 AM	Welcome and introductions
9:00-9:30 AM	Knowledge foundation – presentation and discussion
9:30-10:00 AM	How the TEF model works. A deeper dive into how the model simulates wildfire behaviour
10:00-10:20 AM	Break
10:20-12:OO PM	How the TEF model works, *presentation continued*. Small group discussions about modelling wildfire hazard
12:00-1:00 PM	Lunch
1:00-2:15 PM	Present and discuss the current conditions wildfire hazard map
2:15-3:00 PM	Present and discuss how climate change may affect wildfire hazard
3:00 - 3:20 PM	Break
3:20-4:00 PM	Learning scenarios: Design and purpose
4:00-4:20 pm	Steering committee direction: Round table to hear from each steering committee member
4:20-4:30 pm	Wrap up, next steps, next workshop

- Build the knowledge foundation
- Understand the strengths and limits of the BuMo wildfire model (TEF)
- Review the beta version of the current conditions hazard maps
- Present and discuss the design and purpose of learning scenarios

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Lessons from Jasper

2024 Jasper Wildfire

- 33,000 ha burned
- 359 structures destroyed.
- 25,000 people evacuated
- $880m insured losses

Sources:
- "FP Innovations: Jasper Wildfire Community Impact Research;
- Canadian Forest Service: Jasper Wildfire Complex 2024 Reconstruction

The monster of Jasper

With more than 32,500 hectares burned, the Jasper Wildfire Complex is the most devastating to hit the national park in more than a century

CBC News: August 10, 2024

Jasper Fire Regime:

A pattern of frequent, mixed-severity fires maintained a diverse vegetation mosaic with lower fuel loading and susceptibility to large crown fires

Before the 19th century, fire was frequent, driven by both lightning and Indigenous burning practices.

Jasper images: Top 1900's. Bottom 2025.

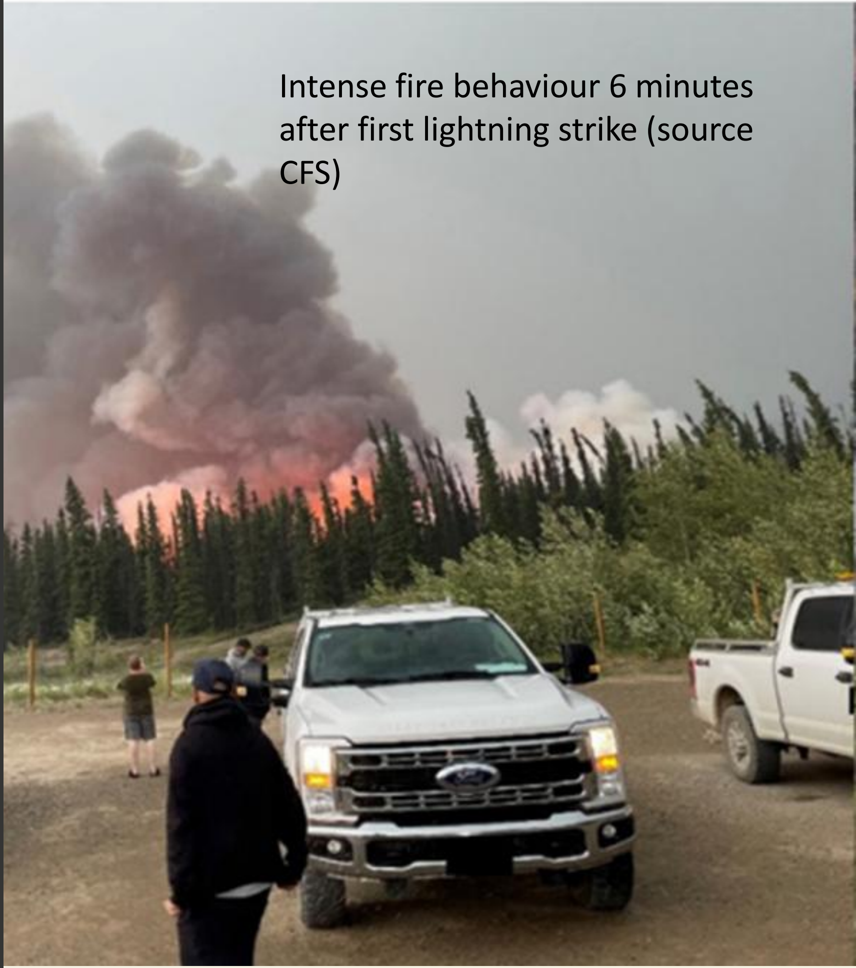
2024 Wildfire Behaviour:

Lightning ignited multiple strikes.

Preceded by a month-long drought.

Crown fire activity was observed within 10 minutes: no opportunity for direct suppression.

Fire exhibited severe to extreme fire behaviour in the following days.



Intense fire behaviour 6 minutes after first lightning strike (source CFS)

Key contributing factors:

- Drought
- Rapid ignition and acceleration
- Continuous and MPB-affected fuels
- Sustained high-intensity plume-driven behaviour
- Convection column collapse
- Ember transport

Drought:

- Prolonged dry conditions increased the amount of fuel available.
- Near record fire weather values
- Nearly all surface fuels were available to burn, even in green stands

Mountain Pine Beetle:

- Extensive areas of 7-year-old grey attack stands
- Accelerated fuel drying increased the amount of dead dry fuel compared to green stands
- Fuel consumption and fire intensities in affected stands were 2–3 x higher than in green stands
- Longer burn periods
- Increased convection and plume development

There is some debate in the literature about the effects of mountain pine beetle mortality on fire behaviour.

In our ecosystems the evidence is fairly conclusive that it increases fire intensity.

Fuel Connectivity:

- Fire exclusion and suppression led to continuous fuels
- Some prescribed fire in the park, but not in the area of the fire
- Unbroken fuel continuity for over 25 km allowed unchecked fire growth down the valley

"Uninterrupted mature conifer forest created a wind-aligned corridor for fire spread in the upper Athabasca valley. Tree mortality caused by the mountain pine beetle (MPB) altered the structure and availability of the fuel complex. The loss of foliage caused accelerated drying of the surface fuels, and tree mortality led to an abundance of dry woody fuel, greatly increasing fuel consumption and fire intensity."

(CFS)

Fire Severity and Size:

- Most of the fire burned at high (27%) and extreme (52%) fire severity
- Caveat: severity is difficult to assess
- Severity was consistent with the pattern of severity in other extremely large fires in the montane regions of western Canada

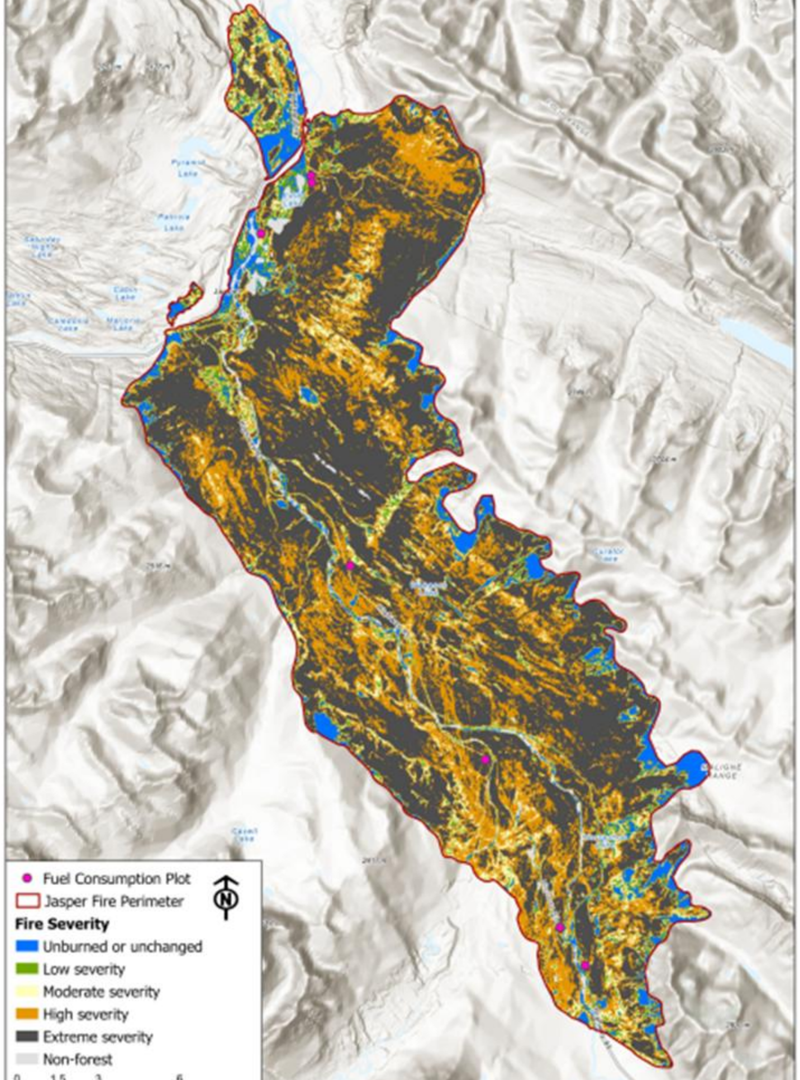


Figure 28. Example plot photo showing extreme fuel consumption from the Jasper Wildfire Complex (Plot JP11). Snags (trees dead before the fire) frequently exhibited complete loss of branch structure and deep bole charring. Density reductions of approximately 40–80% indicated that many dead trees were consumed nearly completely, whether while standing or after toppling. Coordinates and bearing information are provided by the Theodolite application.[7]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Key Insights:

- Under extreme fire behaviour, wildfire suppression is ineffective.
- Over a century of fire exclusion has shifted the landscape toward a more uniform, fire-prone structure, increasing the potential for large, uncontrollable fires
- Spread rate was much higher than expected from models

Key Insights: fuel treatment:

- 1500 ha of fuel treatments from 2003 to 2022
- Fuel treatments reduced fire intensity and ember transport
- Roads, railway, etc. disrupted fuel continuity
- Some aspen stands reduced fire intensity but did not stop the fire

<u>Result:</u> Improved ability for structural firefighters to respond, but….<u>treatments did not stop the fire</u>.

“Jasper National Park had implemented more extensive fuel mitigation efforts around its townsite than any other Canadian community affected by a wildland fire disaster. Fuel treatments, along with natural and artificial fuel breaks (rivers, lakes, highway, railway, golf course, deciduous forest patches) likely reduced fire intensity and ember impingement in the wildland community interface, reducing the threat to safety and improving defensible positions for structural firefighters; this likely decreased structure loss in the townsite and surrounding areas.” (CFS)

Key Insights: Fuel treatment and crown fraction burned

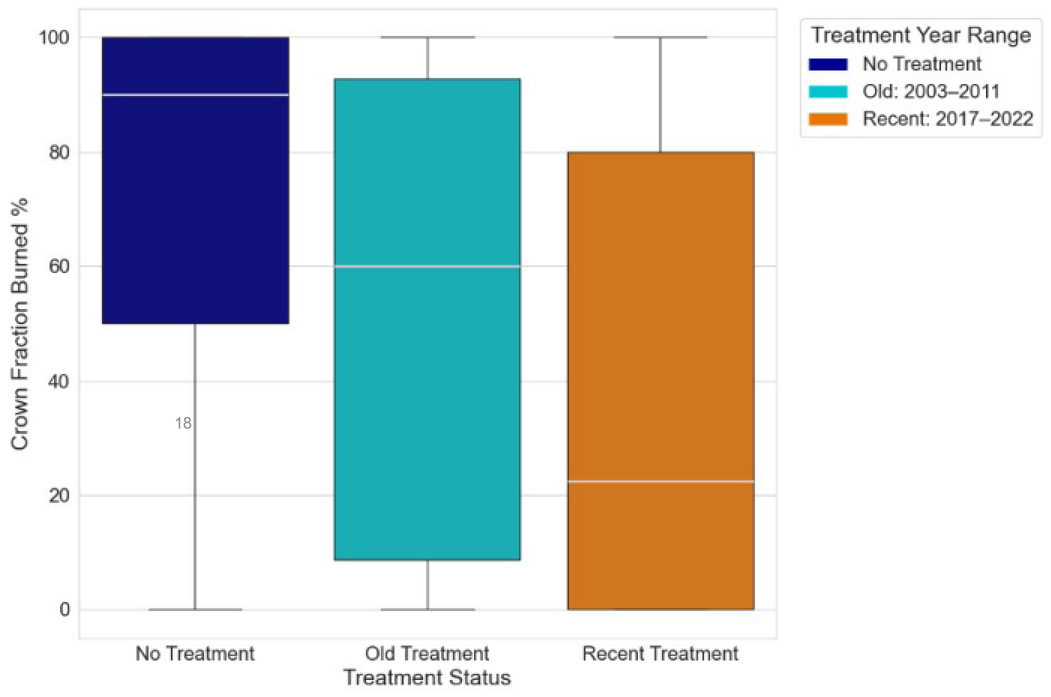


Figure 26. Distribution of crown fraction burned (%) across treatment types

Community Impact Research (FPI):

Within Jasper townsite:

- Convective column collapsed and long-range spotting caused embers to ignite structures directly (i.e. combustible roofs) and indirectly (vegetation around homes).
- Strong winds then drove structure-to-structure spread
- Once structure-to-structure ignition began, suppression resources were overwhelmed.

Outside the townsite:

- continuous fuel pathways allowed wildland fire to ignite structures directly.

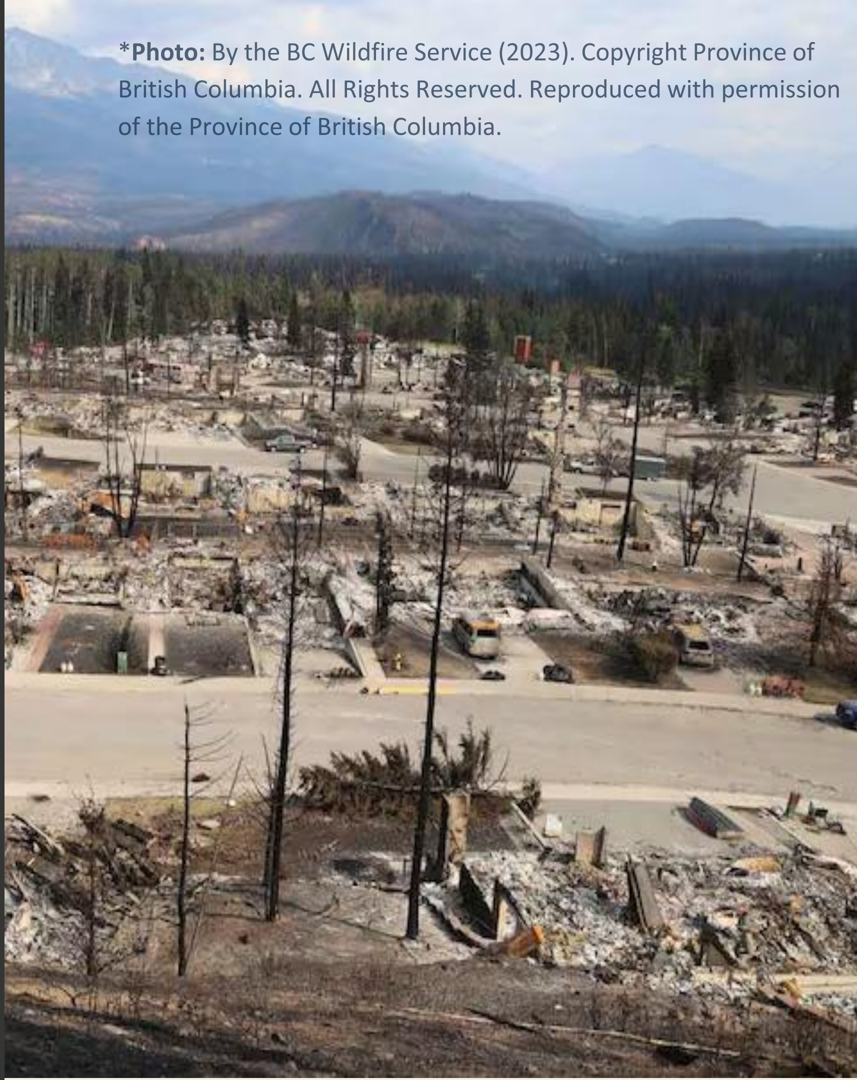
Key Insights

Factors in Jasper:

- Wooden roofing materials increase the risk of ignition.
- When the spacing between structures was less than 5m, the likelihood of structure-to-structure ignition was higher

Factors outside the townsite:

- Combustible roofing
- Proximity to another structure
- Continuous pathway of fuel
- Combustible material near the structure (mulch, trees, shrubs)
- Combustible materials under decks
- Long dead grass

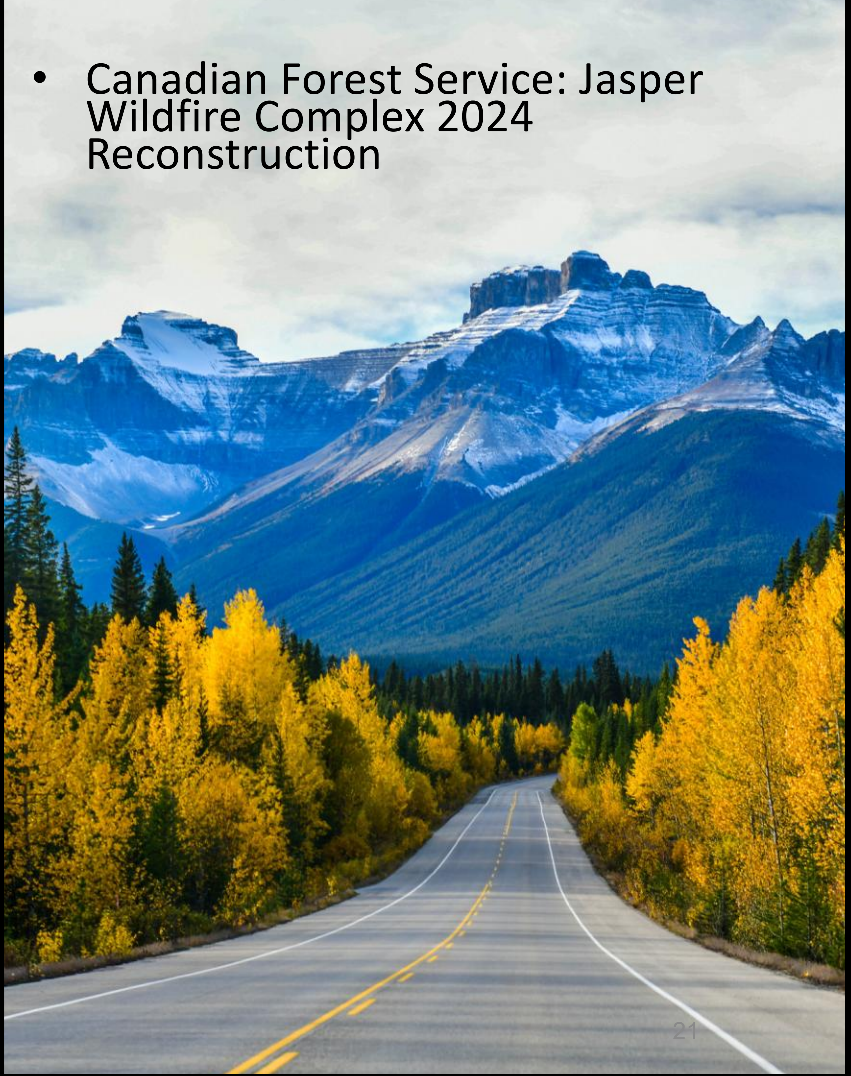


Conclusions:

Enhancing community resilience:

Wildfire disasters are driven by a common sequence of factors—*severe fire potential, extreme burning conditions, multiple ignitions within communities, and rapidly developing fire behaviour exceeding firefighting resources.*

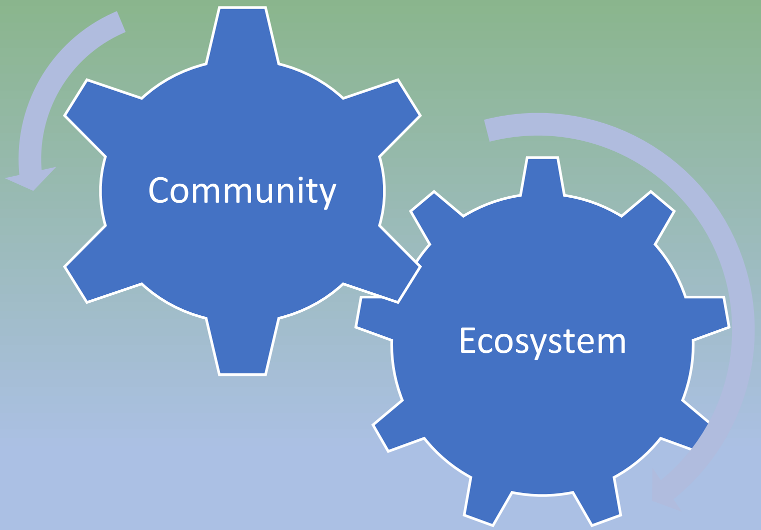
Strengthening resilience requires an integrated approach, including landscape risk assessment and management, increasing fire-resistance in the built environment, and effective pre-response planning.



Resilience: Two dimensions

Community dimension: Minimizing damage from wildfires to safety, property, and important ecosystem services such as water or timber.

Ecological dimension: Maintaining the ability of the ecosystem to recover from wildfire or to transition to a new acceptable state.



Socio-Ecological Resilience

Ecological dimension

Departure from the historic disturbance regime

- Assumption: The further the fire regime is from the historical regime, the greater the risk to ecosystem resilience.

Coming: Summary of the Fire Regime.

- What did it look like before settlement?
- What does it look like today?
- How has it changed, and what does that mean for resilience?
- Potential Indicator: Fire return interval
- Potential Indicator: Proportion of high-severity fire

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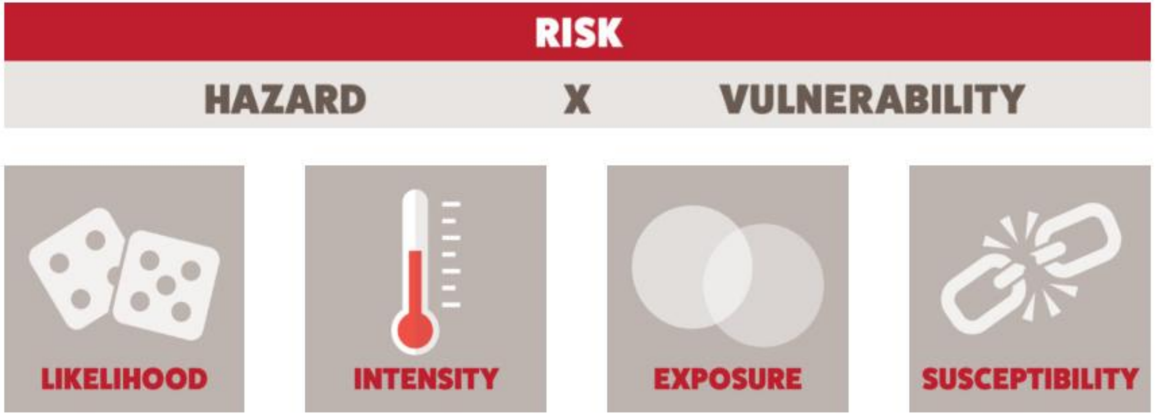
Community: Wildfire risk

A community's wildfire risk is the combination of likelihood and intensity (together called "hazard") and exposure and susceptibility (together called "vulnerability").



USDA Forest Service

Missing: Assessing Vulnerability

TEF Model: Assesses hazard

AGNI-NAR Wildfire Vulnerability Model

- Developed by Dr. Hussam Mahmoud:
- Designed to predict wildfire propagation and structural damage in the wildland–urban interface (WUI).
- Helps communities, engineers, and policymakers understand which buildings are likely to ignite or survive during a wildfire.
- Used to assess community-level wildfire risk by modelling how fire spreads from vegetation into neighbourhoods.
- Guidance for risk mitigation

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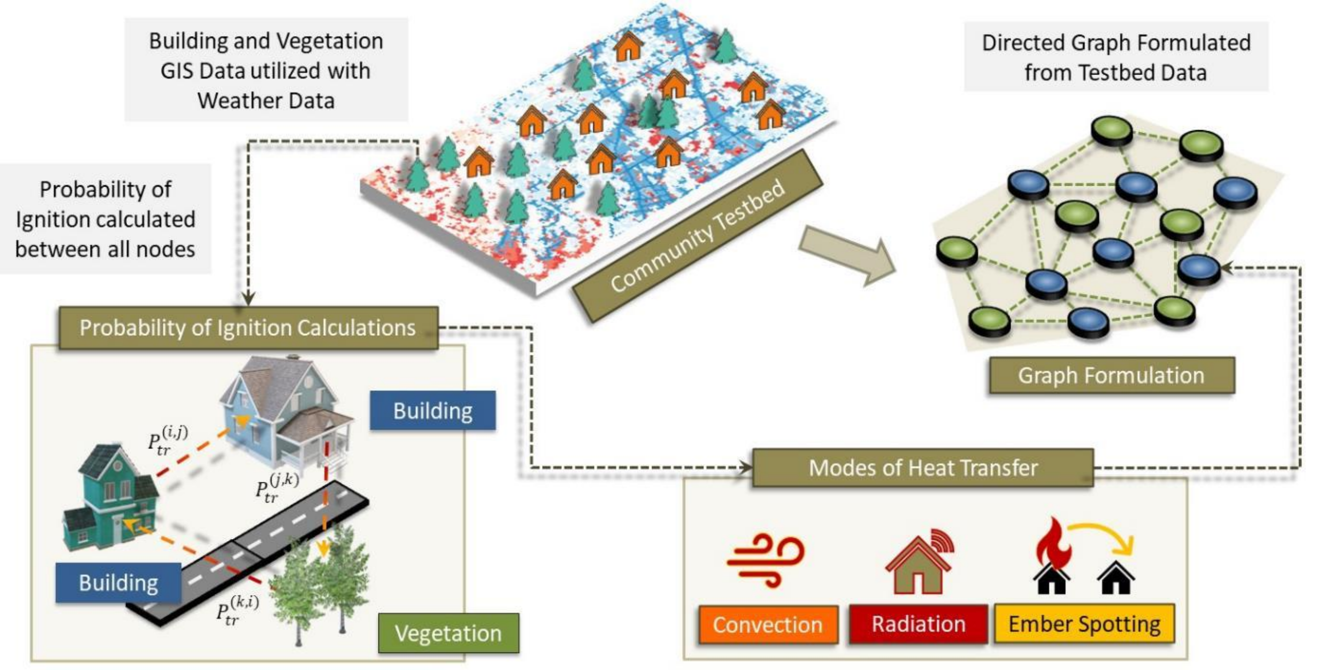
Graph Theory Application: AGNI-NAR

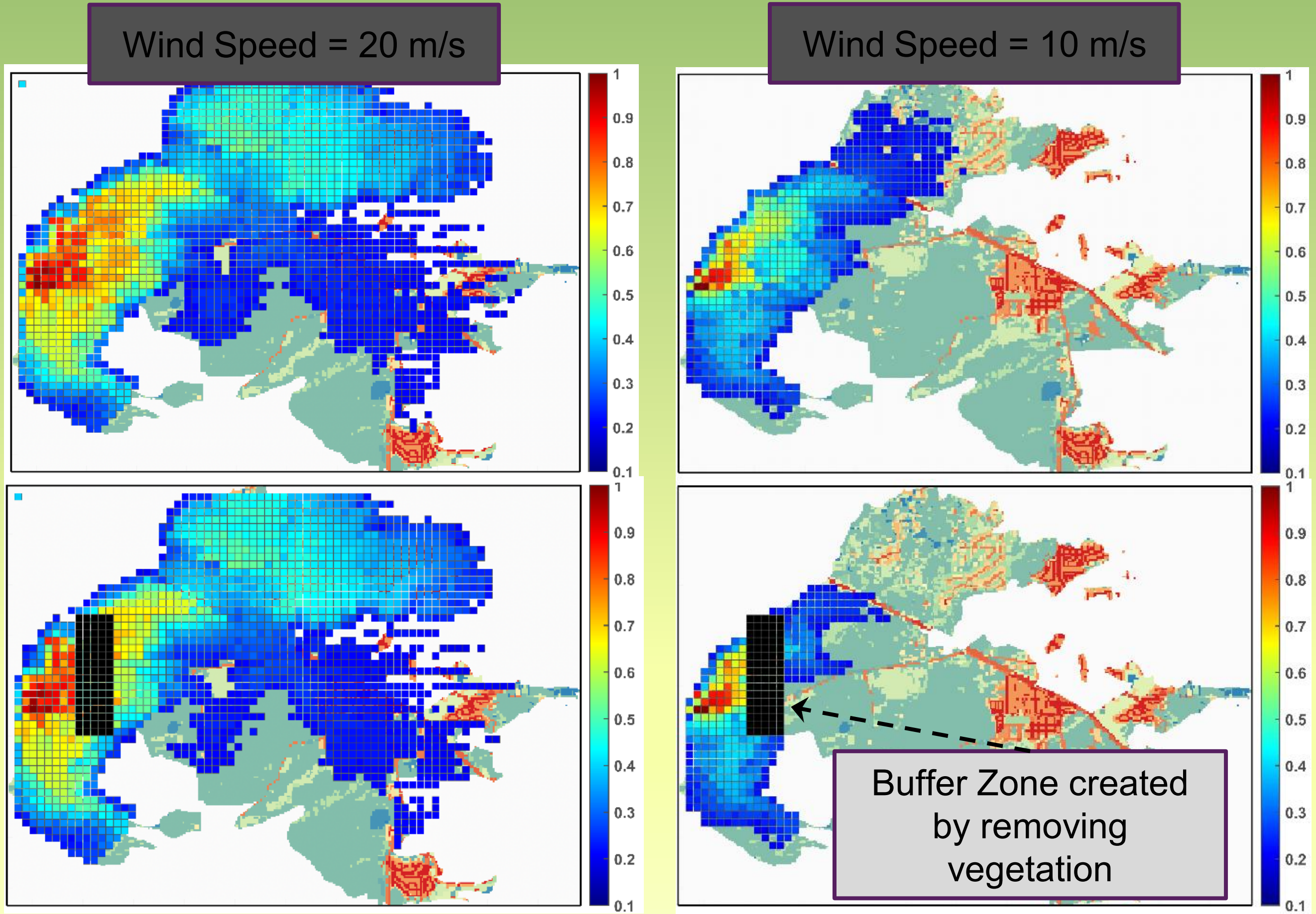


Two analysis

- Most probable path (**MPP**) to calculate highly transmissible wildland vegetation and fire boundary.
- Relative venerability (**RV**) to determine likelihood of damage for a given fire boundary.

Need data on topography, vegetation, buildings, **wind, and home-ignition zone**

Wildfire Mitigation (Marshall Fire)



Wildfire boundary shown after introduction of a buffer zone created by removing vegetation areas

The results demonstrate that the effectiveness of the buffer zone reduces significantly at higher wind speeds

Vulnerability Modelling for the Bulkley Morice

Next steps:

- Identify up to 3 communities to test the application of the model
- Discuss process with communities in early winter 2026
- Apply model summer/fall of 2026

Landscape Level Fuel Treatment Effectiveness

Fuel treatments often focus on the individual stand

Treatment effectiveness is not binary; it depends on the fire weather.

Landscapes are too large to treat at a stand level.

We need to obtain a landscape effect

Example:

Some stands are effective at resisting recent wildfires

- Dense stands between 20 and 40 years had much lower fire severity and often did not burn.
- May be related to stand structure and wind penetration.

But did they achieve the landscape level effect?

Image: 2018 Nadina Fire

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Landscape Level Treatments

- Size matters
- Design matters

Emerging hypothesis: Strategically placed fuel breaks, of the right size and with the right treatments, can improve suppression effectiveness and reduce fire behaviour.

PODs are one way to apply this strategy

Potential Operational Delineation (PODs)

PODs are sub-landscape level units bound by features that are designed to inhibit fire spread or decrease fire behavior.

- concept developed to pre-plan for wildfire prevention and suppression activities
- spatial units defined by potential control features, such as roads and ridge tops, within which relevant information on forest hazard, ecology, and fire potential can be summarized
- combine local fire knowledge with advanced spatial analytics to help managers develop a common understanding of risks, management opportunities, and desired outcomes to determine fire management objectives.

(Lakes FLP)

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Potential Operational Delineations

- POD concept being developed as a product for Bulkley Morice
- Can be used in multiple places
  - Fire Management Planning (suppression)
  - Fuel management strategies (MoF, communities)
  - Forest Landscape Planning
  - Others?

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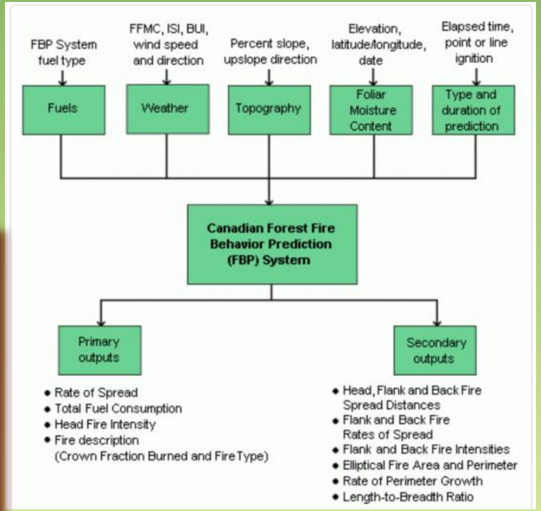
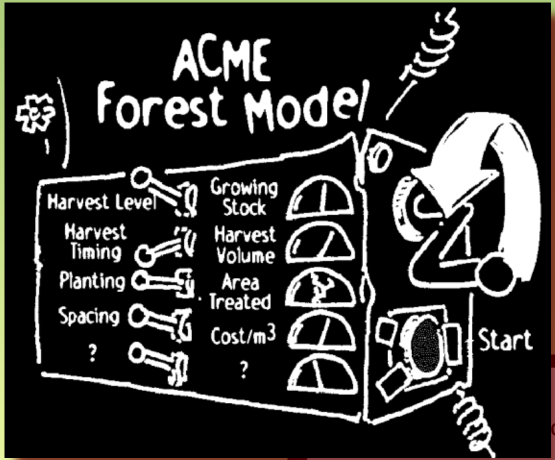
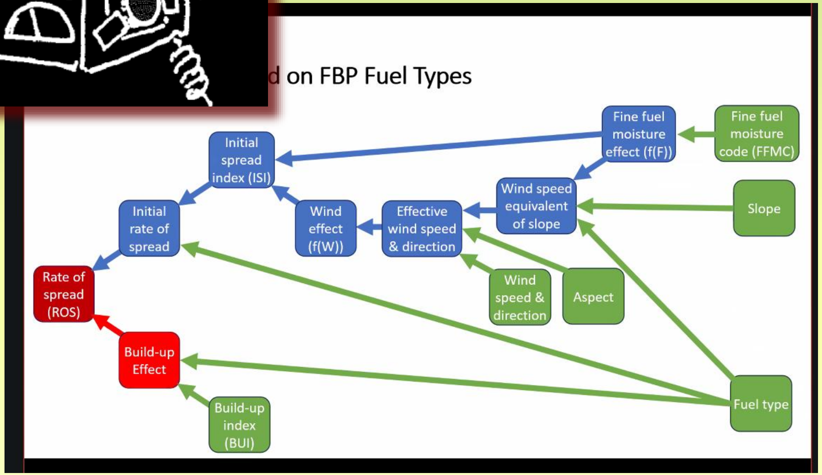
Time-Based Empirical Fire Model – *how it works*

Modelling Wildfire

- Ignition
- Spread
- Fuel
  - FBP system - Canadian Forest Fire Behavior Prediction System Empirical – modelled from imagery and field observations
  - Hybrid
- Weather
  - Slope, Aspect
  - Wind speed and direction
  - FFMC (Fine Fuel Moisture Code), BUI (Build-up Index)
- Extinguishment



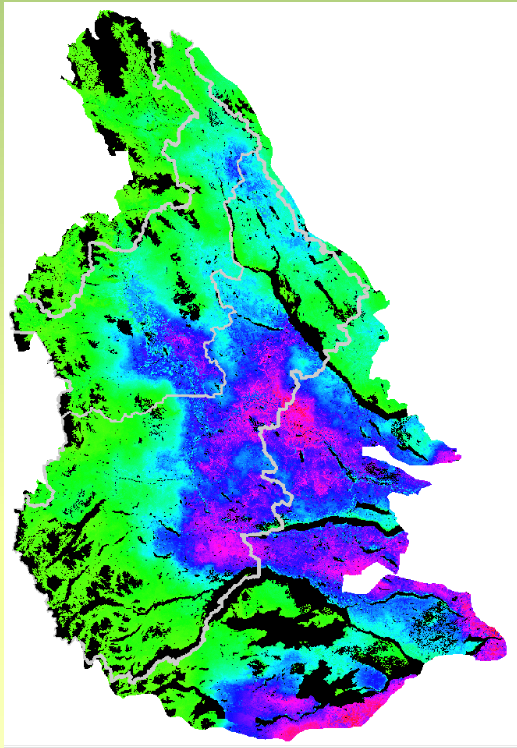




Wildfire Hazard - Core

Likelihood

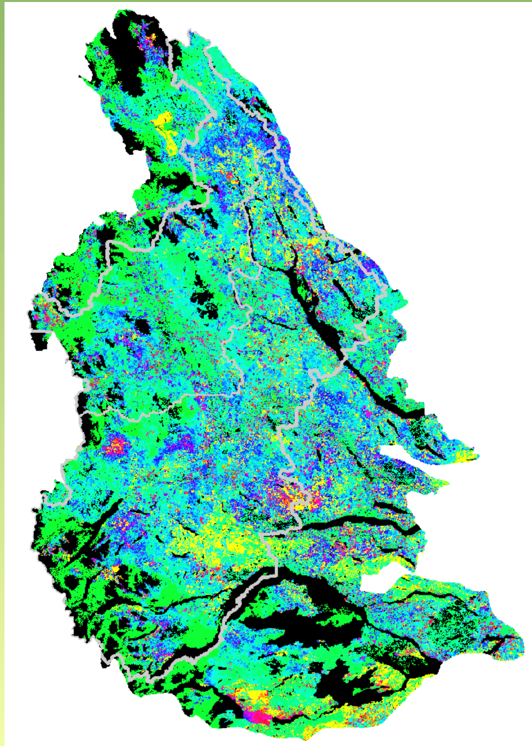
Simulation of 10,000 fires to estimate how many times a 1-hectare cell burns



Intensity

Function of:

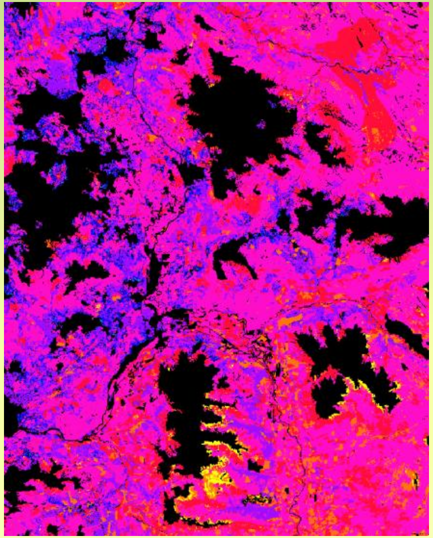
- Heat
- Fuel consumed
- Rate of spread



Wildfire Hazard - Supplemental

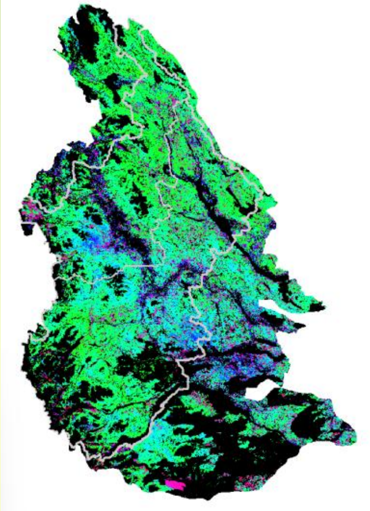
Rate of Spread

- How fast a fire moves
    - Function of Weather, Topography and Fuels



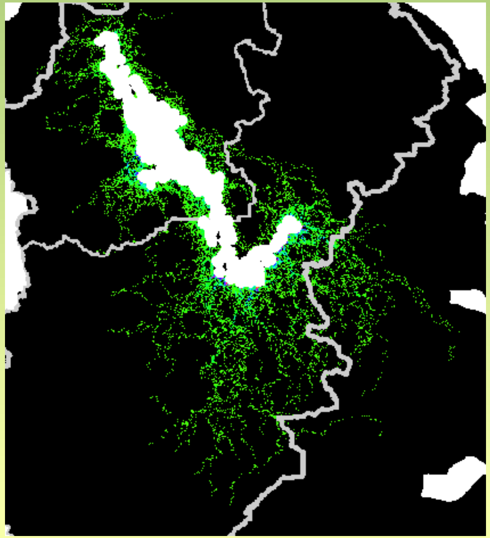
Crown & Surface Fraction Burned

- Magnitude of effect on forest canopy and surface



Fire Pathways

- How often fire enters the Wildfire Urban interface



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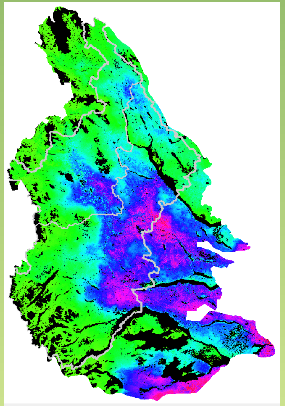
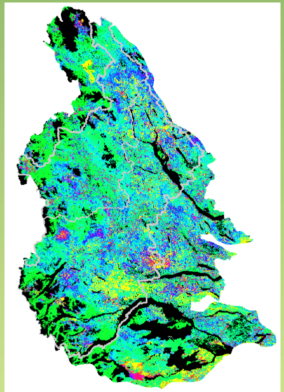
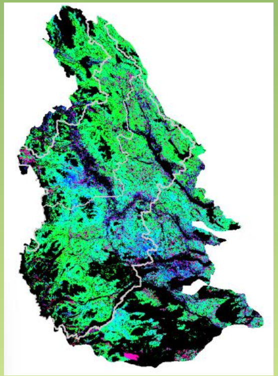
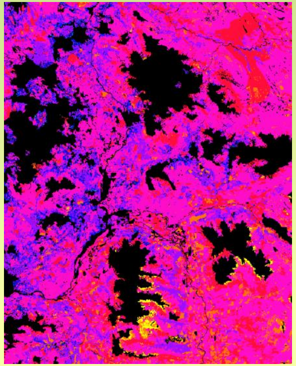
BuMo Wildfire Hazard - Framework

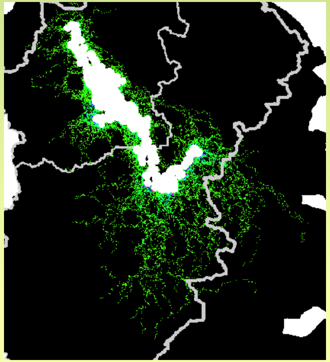
- Combination of factors:
    - **Likelihood** – times burned
    - **Fire pathways** – community and value exposure to fire
    - **Fire intensity**- informs wildfire management and impacts
    - **Rate of spread** – how fire could move
    - **Crown and surface fraction burned** – informs management strategies











TEF Model Components - Fuel Types

- Fire Behaviour Prediction (FBP) Fuel Types
  - Basis for wildfire management
  - Developed Nationally
  - Poor correspondence between field assessment and FBP types
  - But it is the basis of wildfire management in BC!

Baron et al. 2024

- Empirical Fuel Types
  - Satellite-based burn severity mapping correlated with landscape elements
  - Fuel flammability a function of past fire
  - Require local calibration
  - In development, not operationalized

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Influence of fuel on fire behaviour

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Outline

- Context Fire modelling and CFFDRS
- Fire Weather
- Fuels
- Fire Behaviour Prediction
- Options for modelling fuels

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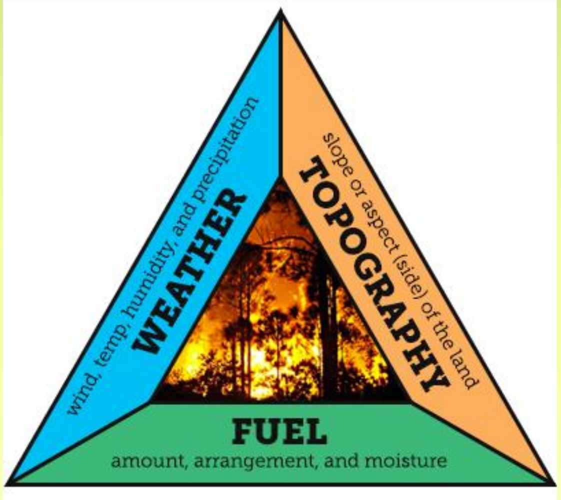
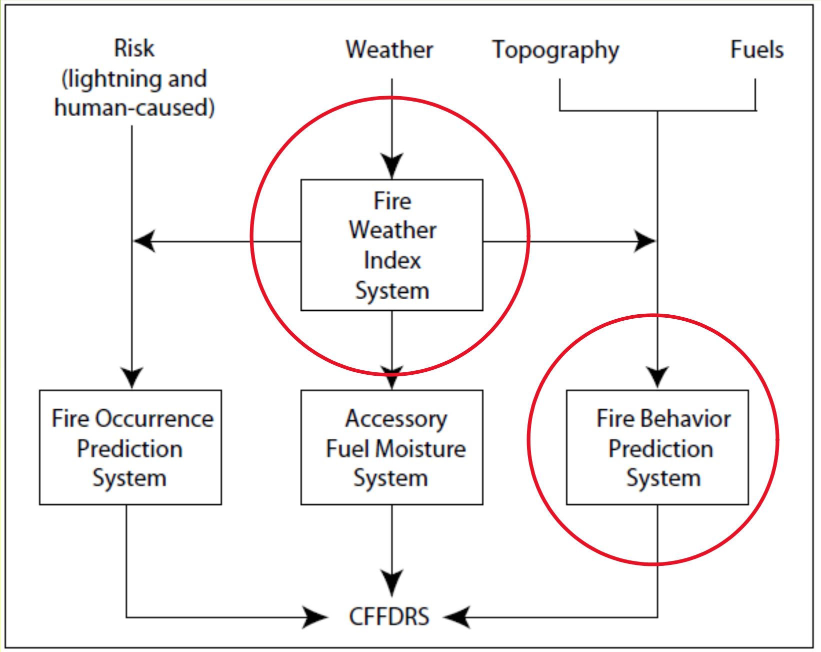
Fire modelling in BuMo

- TEF simulates daily fire spread over the season
  - Based on the Canadian Fire Behaviour Predict System (FBP).
  - Integrates weather, fuels and terrain over landscape
  - Fast, flexible
  - Repeated simulations give burn probability

- Daily fire behaviour depends on
  - Fire weather
  - Fuels
  - Topography



Canadian forest fire danger rating system



Lawson and Armitage (2008) Weather guide for the Canadian Forest Fire Danger Rating System. CFS Northern Forestry Centre.

Canadian forest fire danger rating system

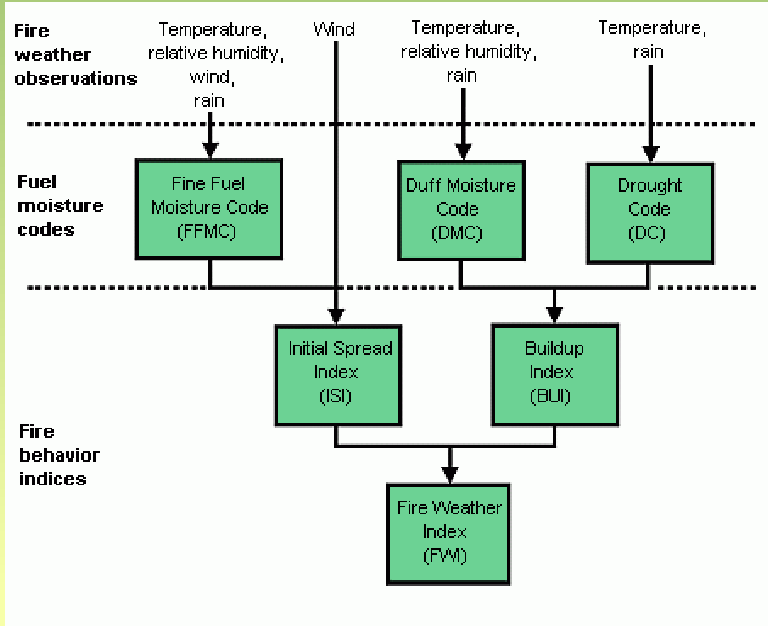
Researchers

- Measured response of fuel moisture to weather
  - Temperature, precipitation, relative humidity
  - Wind
- Created weather indicators to predict fuel moisture (FWI)
- Measured response of fire to fuel moisture in different fuels
- Predicted fire spread and intensity in different fuels as a function of weather (FBP)

Good work but BC is complicated

- 409 experimental fires
  - Measure fuels
  - Measure weather at burn site
  - Measure open-wind and in-stand-wind during fire
  - Rate of spread and fuel consumption
- 125 wildfires
  - Subset of available info
- 16 fuel types

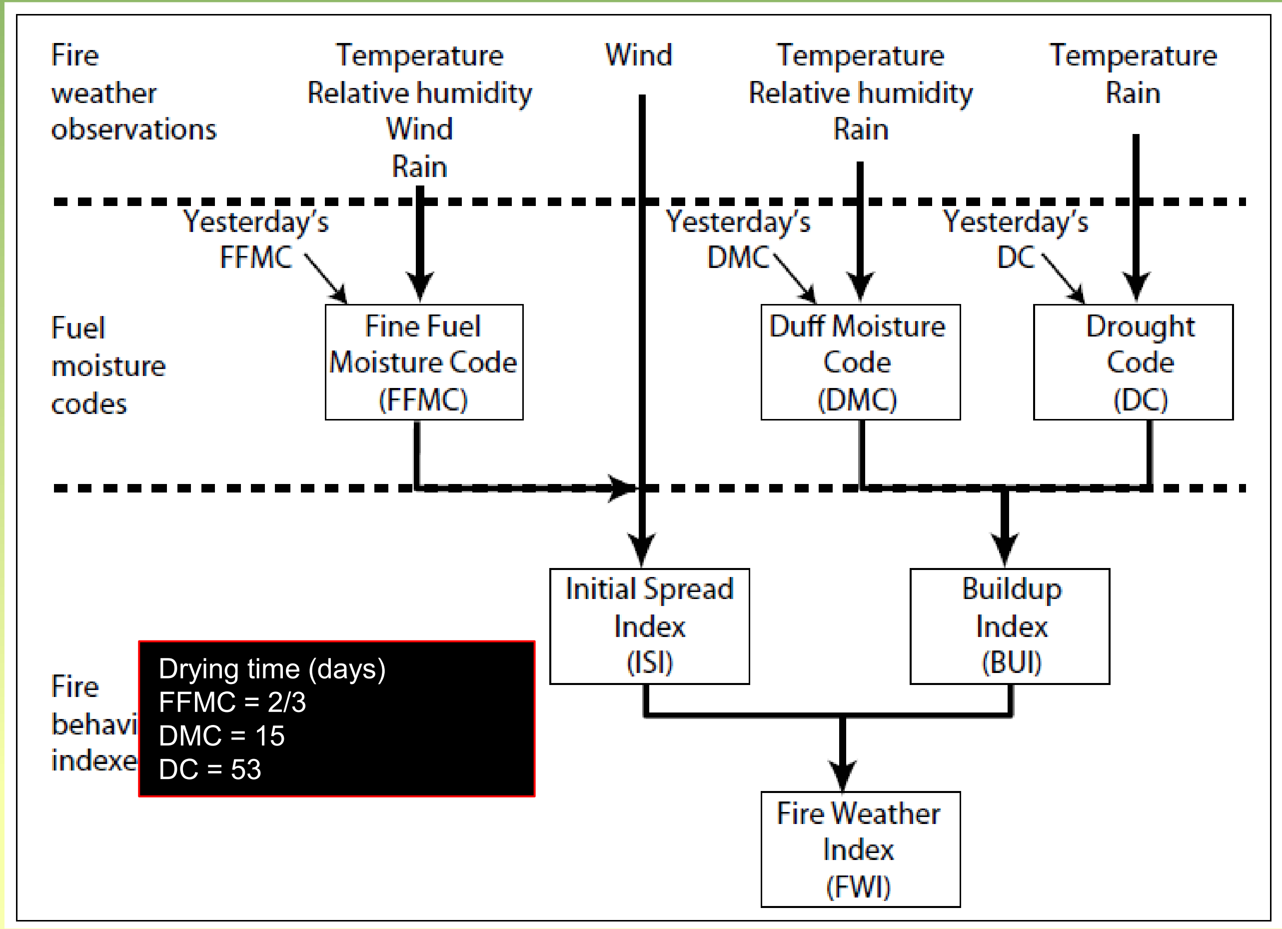
Fire weather index/indices



FWI = relative measure of potential intensity of fire in a mature pine stand on flat ground

https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi

- ISI is a generalized (fuel-free) indicator of fire rate of spread
- BUI is a generalized (fuel-free) indicator of combustible fuel and relates to heat generated
- FWI rates intensity



Lawson and Armitage (2008) Weather guide for the Canadian Forest Fire Danger Rating System. CFS Northern Forestry Centre.

FWI ~ calibrated to C3

- FWI = relative measure of potential intensity of fire in a mature pine stand on level ground

Stocks et al (1989). Canadian forest fire danger rating system: an overview. *The Forestry Chronicle*, *65*(4), 258-265.

Moisture codes and fire weather indices	Low	Moderate	High	Very High	Extreme
BUI	<20	20-40	40-60	60-90	>90
FFMC	<63	63-84	84-88	88-91	>91
ISI	<2	2-5	5-10	10-15	>15
FWI	<5	5-10	10-20	20-30	>30

Big fires burn at higher FWI danger ratings

In Canada only 3% of fires are > 200 hectares and account for about 97% of area burned

Big fires (> 200 ha) from 1959 to 1999 had

- ISIs ranging from 10 to 16
- BUI values from 50 to 92.

Moisture codes and fire weather indices	Low	Moderate	High	Very High	Extreme
BUI	<20	20-40	40-60	60-90	>90
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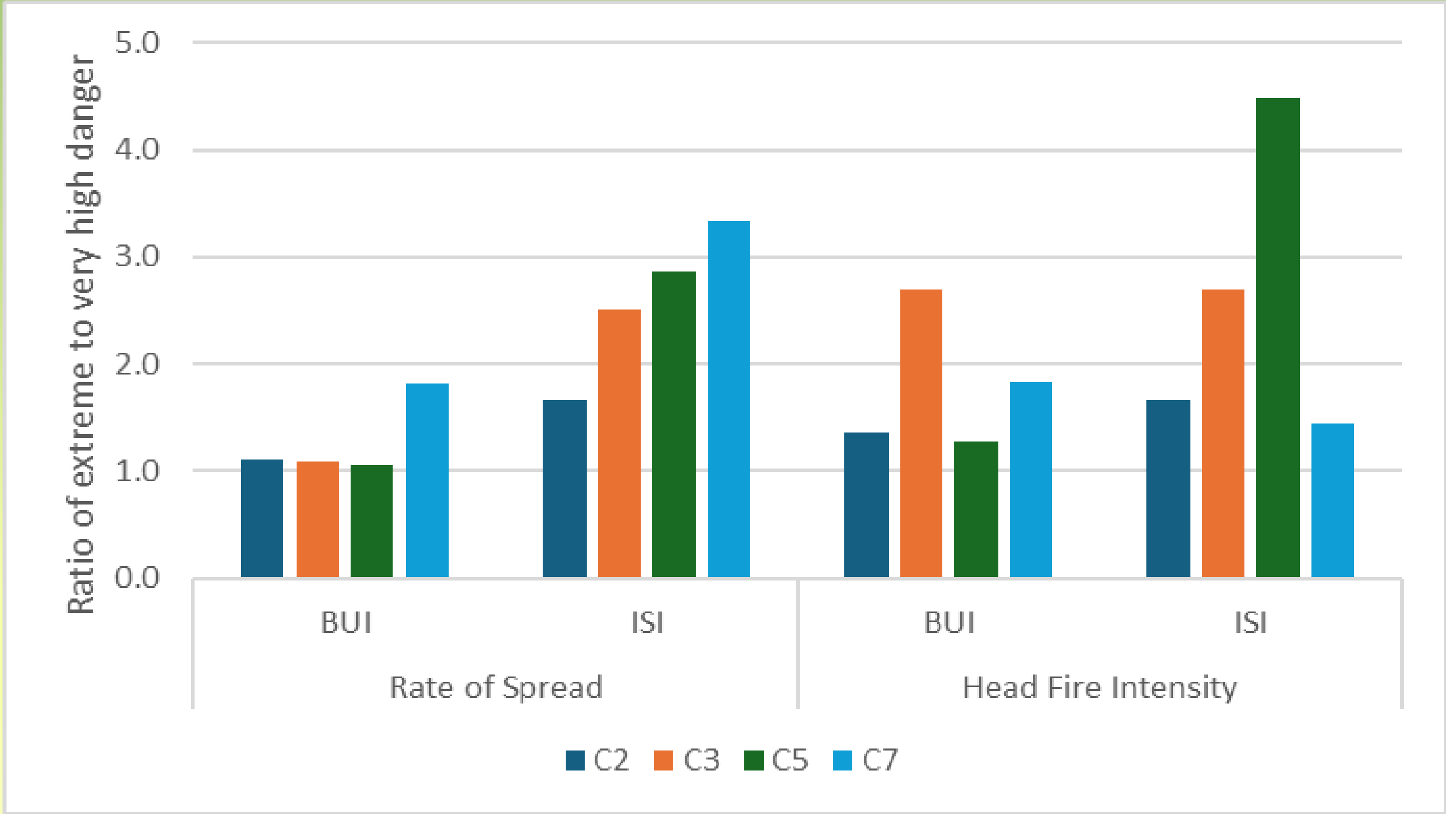
National Wildland Fire Situation Report, using CNFDB data https://cwfis.cfs.nrcan.gc.ca/report

Amiro et al. (2003, November). The weather of large fires in the Canadian boreal forest. In Proceedings of the 5th Symposium on Fire and Forest Meteorology. American Meteorological Society, Boston, Massachusetts, USA Orlando, Florida.

ISI is more influential than BUI



Foliar moisture matters

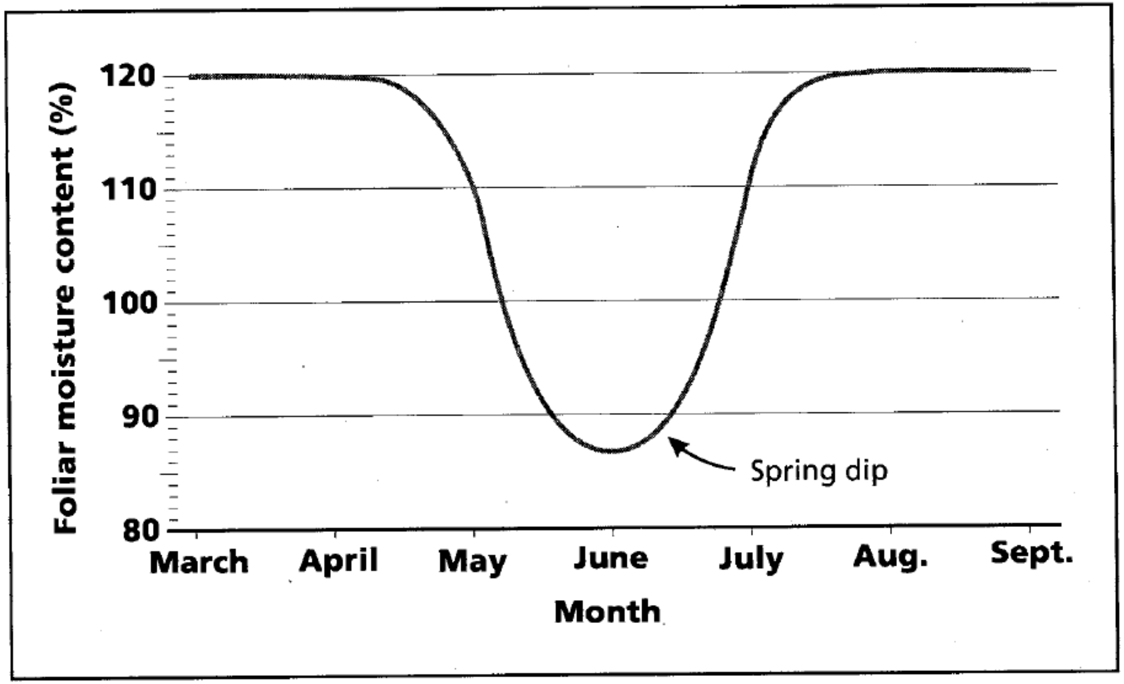


Figure 6. Conceptual example of the seasonal trend in the foliar moisture content of conifer foliage.

Hirsch, K.G. 1996. Canadian Forest Fire Behavior Prediction (FBP) System: user's guide. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. Special Report 7. 122 p.

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Fuels and fire behaviour

- What constitutes fuel in a stand?
- What are the different fuel types?
- How do they burn differently?

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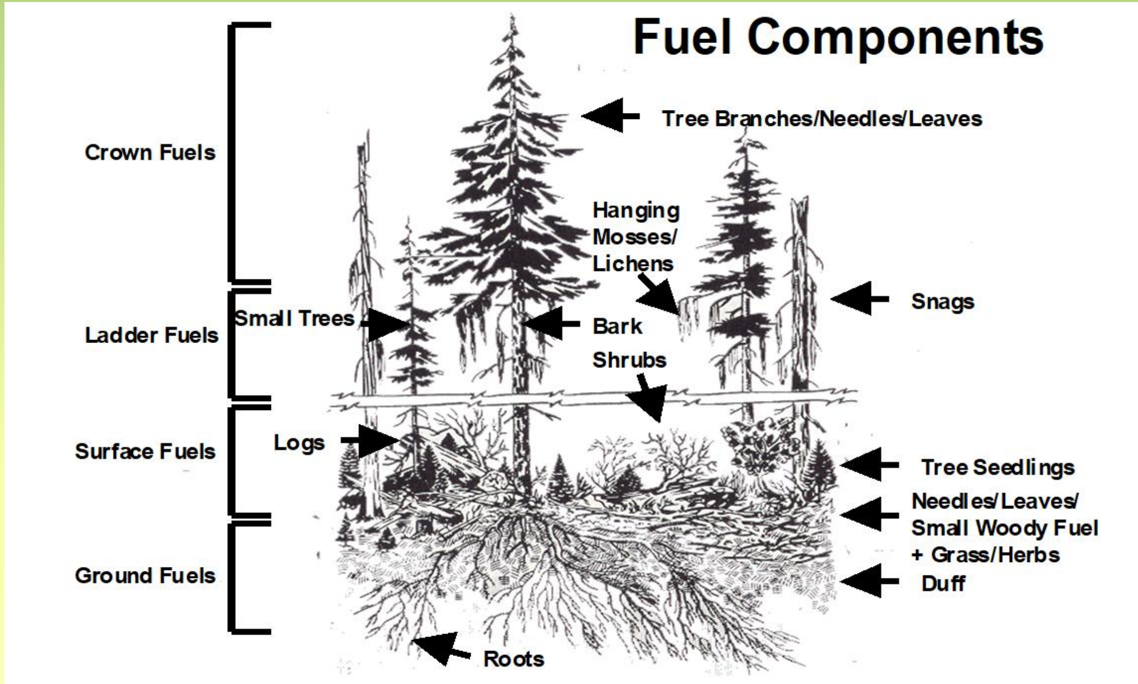
Fuel is the dry portion of live and dead organic matter

About 10-20% of forest biomass burns in a fire

- Live trees are wet inside
- Large pieces of dead wood and deep organic layers take a long time to dry out
- Small stems, branches and needles burn easily (trees, shrubs, herbs)
- Needle chemistry affects flammability

Stand structure influences fuel

- Amount and connectivity matter



CFS FBP fuel types

Table 4. Fuel types in the FBP System

General category	Fuel type	
Coniferous	C-1	Spruce—Lichen Woodland
	C-2	Boreal Spruce
	C-3	Mature Jack or Lodgepole Pine
	C-4	Immature Jack or Lodgepole Pine
	C-5	Red and White Pine
	C-6	Conifer Plantation
	C-7	Ponderosa Pine/Douglas-fir
Deciduous	D-1	Leafless Aspen
Mixedwood	M-1	Boreal Mixedwood—Leafless
	M-2	Boreal Mixedwood—Green
	M-3	Dead Balsam Fir/Mixedwood—Leafless
	M-4	Dead Balsam Fir/Mixedwood—Green
Slash	S-1	Jack or Lodgepole Pine Slash
	S-2	Spruce/Balsam Slash
	S-3	Coastal Cedar/Hemlock/Douglas-fir Slash
Open	O-1a	Matted Grass
	O-1b	Standing Grass

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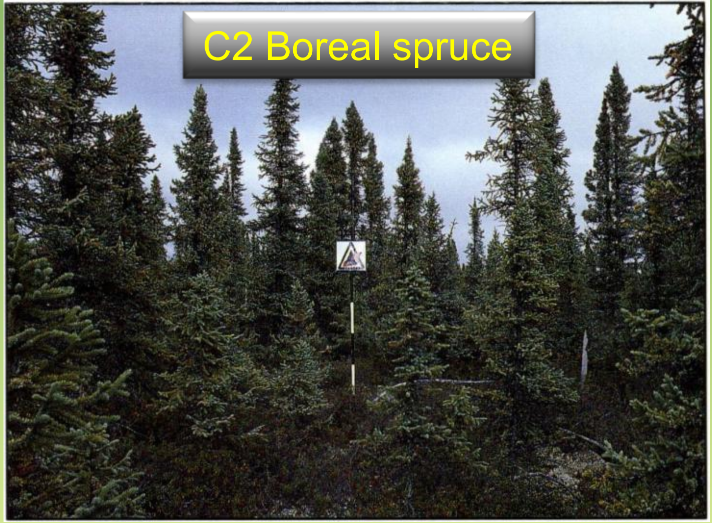
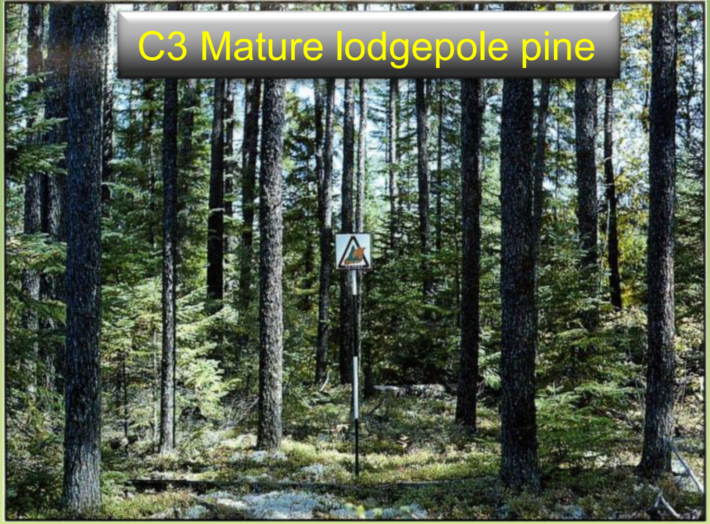

C2 Boreal spruce


C3 Mature lodgepole pine


C5 Red and white pine

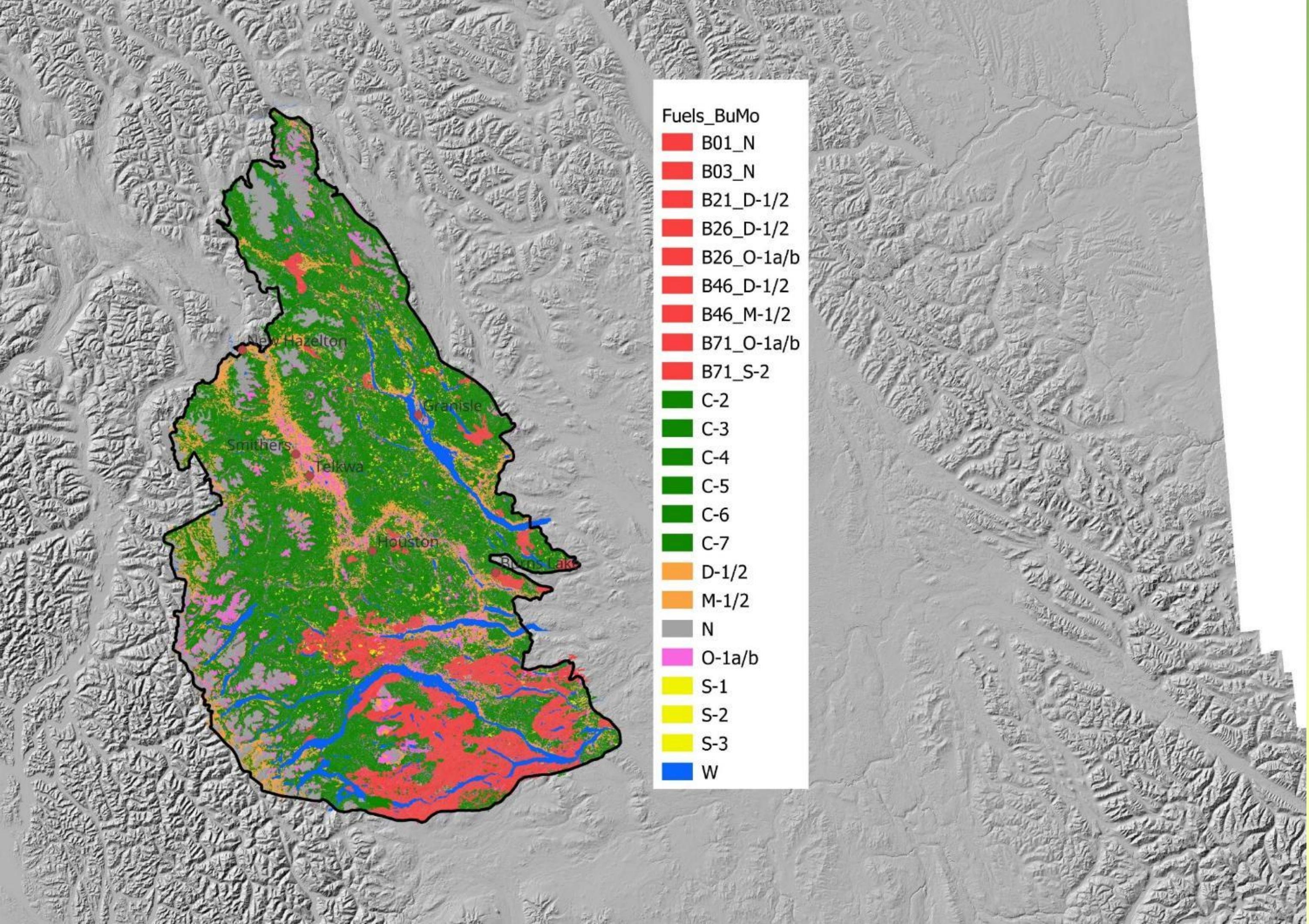

C7 Ponderosa—Douglas-fir


S1 Pine slash


S2 Spruce/fir slash


C4 Immature pine

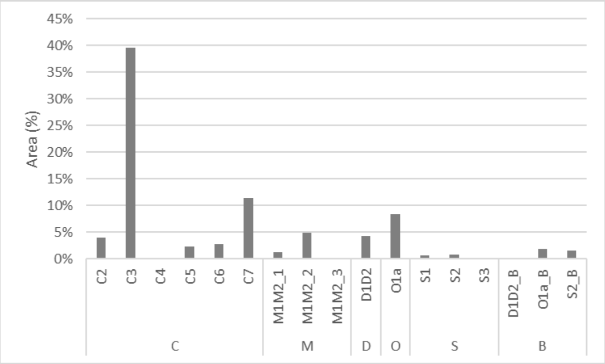

C6 Plantation
https://cwfis.cfs.nrcan.gc.ca/background/fueltypes/s2

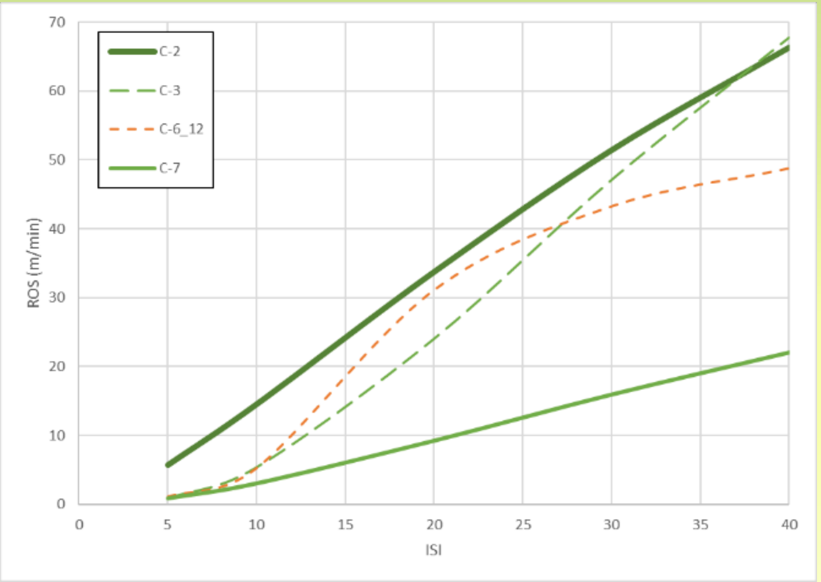


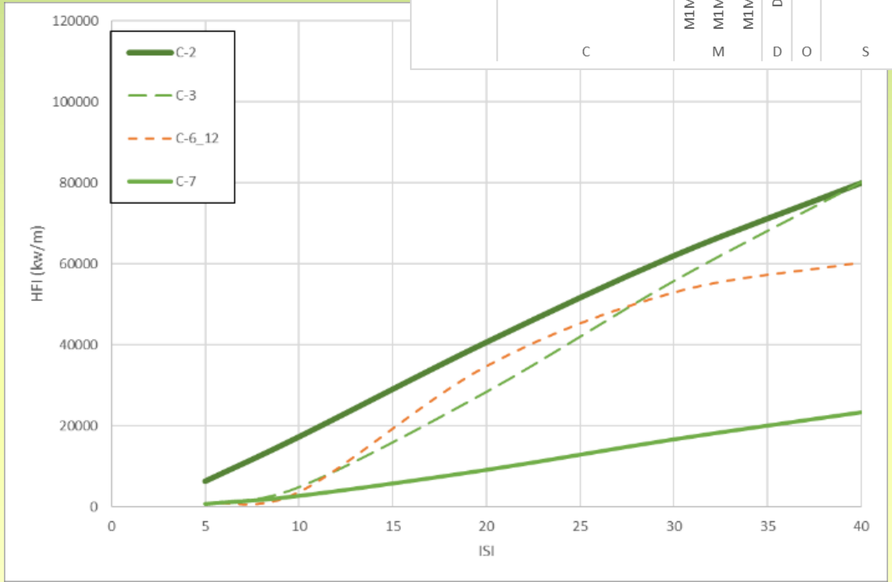
Bulkley Morice WILDFIRE RESILIENCE PROJECT

Fire behaviour depends on fuel and weather

ISI is ~1.5 to 2 x more influential than BUI

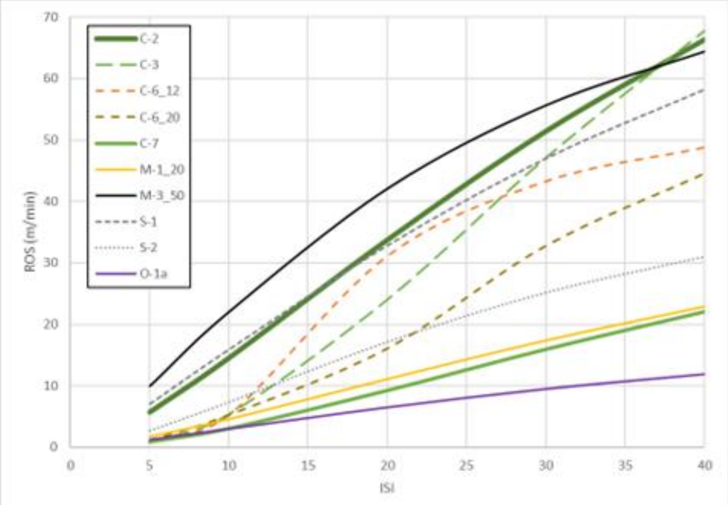


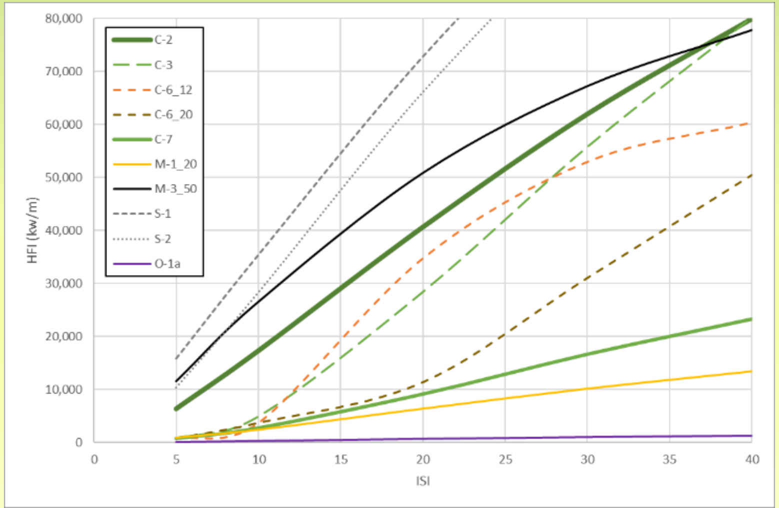




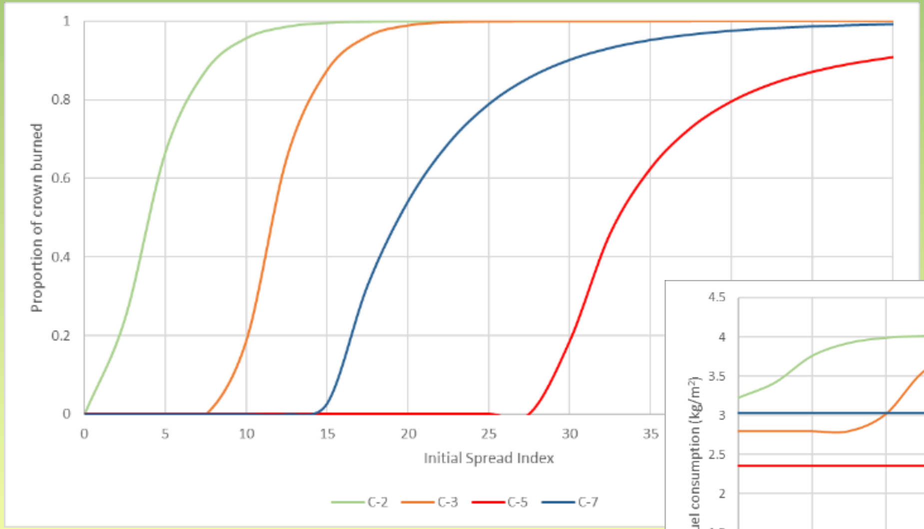
Fuel responses

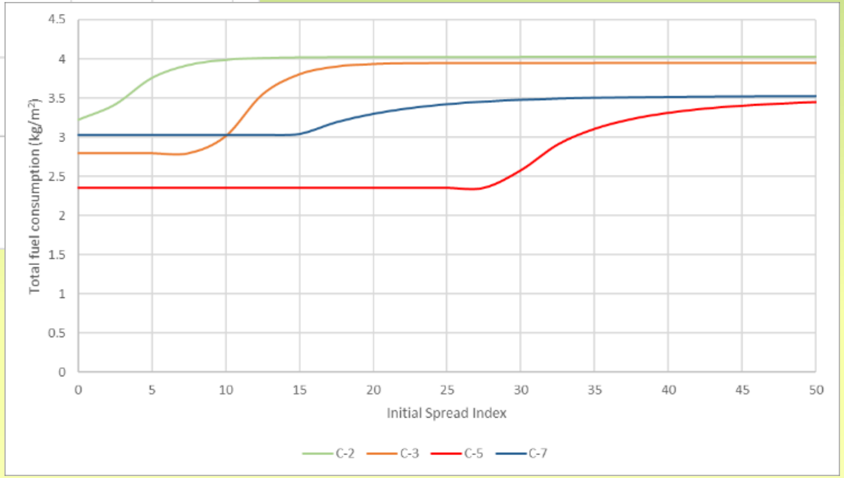
	Relative spread or intensity class				
	V. Low	Low	Moderate Or Variable	High	V. High
ROS	O1a live	C7, C5, M1 (20% conifer)	C3, C6, **S2**	C2, **S1**	M3 (50% dead), **O1a cured**
Intensity	O1a live	C7, C5, M1 (20% conifer), **O1a cured**	C3, C6	C2	M3 (50% dead), **S1, S2**





Crown fire varies with fuel





Default assignment of BC stands to fuel types

Leading species	Crown closure, stocking and dead MPB*	AgeClass_A (0 – 10)**	AgeClass_B (7 – 15+)	AgeClass_C (10 – 30+)	AgeClass_D (> 30)	CFS Fuel
Pl	N/A	0 to 7				S1
	Sparse		7 +			C7
	D/O		7 to ~10			O1
	D/O stocked			~10 to ~30		C3
	D/O overstocked (>8000 sph)			~10 to ~30		C4
	D/O with < 50% MPB				~30 +	C3
	D/O with > 50% MPB				~30 +	C2
Sx	N/A	0 to 7				S2
	Sparse		7 +			C7
	D/O		7 to ~15			O1
	Dense			~15 +		C2
	Open			~15 +		C3
Sb_Sw	N/A	0 to 10				S2
	Sparse		10 +			M1_30
	Dense		10 +			C2
Bl	Sparse	0 +				C7
	D/O	0 +				C3
Hw	Any	0 +				C5

1) Default classification scenario

Fuel Type	Stand Attributes*
S1 (slash with pine)	• post-logging pine stands ≤ 7 years
S2 (slash with spruce)	• post-logging Sb, Sw (≤ 10 years) and Sx (≤ 7 years)
C2 (boreal spruce)	• open/dense stands of Sw/Sb > 10 years; • dense Sx > 4m tall (~15yr) • open/dense Pl > 12m tall (~30yr) with MPB < 50%
C3 (mature lodgepole pine)	• open Sx > 4m tall (~15yr) • open/dense Bl • open/dense Pl (< 8000 stems/ha) and 4-12m tall (~10 – 30 yr) • open/dense Pl > 12m tall (~30yr); same with ≤ 50% MPB
C4 (immat. lodgepole pine)	• open/dense Pl (> 8000 stems/ha) and 4-12m tall (~10 – 30 yr)
C5 (red and white pine)	• Mature Hw
C7 (Ponderosa pine—Douglas-fir)	• sparse Pl > 7 year • sparse Sx > 7 years • sparse Bl
M3 65% conifer	• Open/dense Pl and > 12m (~30yr) and MPB > 50%
M1/M2 30% conifer	• Sparse Sb/Sw > 10 years
O1 (grassland)	• Open/dense Pl > 7 years and < 4m tall (~10yr) • Open/dense Sx < 4m tall (~15 yrs)

Misclassification?

- 25% of C2 (boreal spruce) has MPB-kill; may be OK for spread but underestimate intensity
- Only 20% of C3 (lodgepole pine fuel) is Pl leading; mostly Sx and Bl; 5% of C3 has MPB-kill
- D1D2 (aspen) may underestimate spread and intensity for aspen on drier sites
- O1a (grassland) spread and intensity depend on curing; may burn hot in spring and late summer/fall

2) Reclassification scenario

Fuel type	Modification
C2 (boreal spruce)	Move beetle killed stands (> 30%) to M3_50
C3 (mature Jack or lodgepole pine)	Move fir and spruce leading to C2 Move MPB kill (> 30%) to M3_50 Move MPB kill (10-30%) to C2
C4 (immature Jack or lodgepole pine)	Leave as is (or move AC 1 < 10 yr to S1).
C5 (red and white pine)	Leave as is (mostly Hw)
C6 (conifer planation)	Assign to C6_12 (Do this later: No site prep → C6_12; Site prep or wildfire → C6_20)
C7 (Ponderosa pine—Douglas-fir)	Leave as is (Or Assign Age < 10 to S2)
M1M2 (mixedwood)	Treat as M1M2 with 50% conifer
D1D2 (aspen)	Treat as M1M2 with 20% conifer
S1 and S2 (slash: pine, spruce)	Leave as is
Burned (D1D2, O1a, S2)	Leave as is
O1a	Leave as is
M3_50	New for beetle kill.

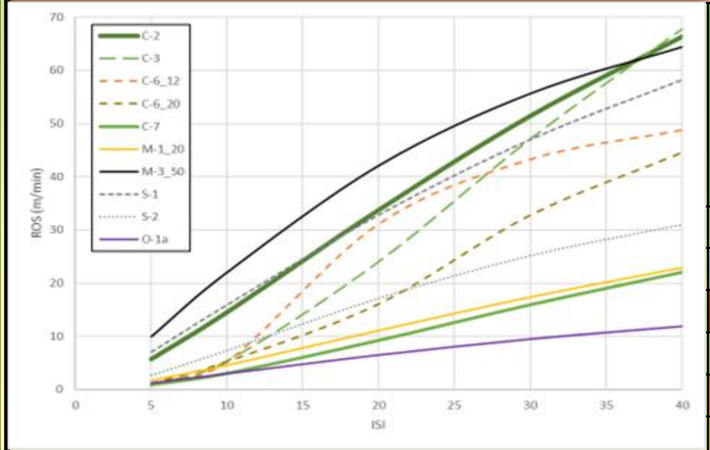
BuMo-specific hypotheses

- Recent clearcuts burn well
- Stands with beetle-kill burn well
- Old growth may burn less than mature
- Deciduous stands inhibit fire spread
- Dense young stands resist fire
- Burned areas inhibit fire for 20+ years
- Site preparation, including broadcast burning, inhibits fire for 20+ years
- Thinning treatments with pruning and debris removal (especially underburning) resist fire in some ecosystems

Bulkley Morice WILDFIRE RESILIENCE PROJECT

3) New hypotheses scenario

Stand Age				
0-10	10-20	20-50	50-120	>120
High Slash (S1) -Historic logging	**Canopy Closing** (S2)	**Dense Canopy** (C6 12m CBH)		
Low Slash (O1a) -Wildfire -Log & SitePrep	**Canopy Closing** (C7)	**Dense Canopy** (C6 20m CBH)		
		Open Canopy Conifer (C2)	**Open/Dense Canopy Conifer** -Hemlock (C5) -Other Conifers (C2)	**Open/Dense Canopy Conifer** -Hemlock (C5) -Other Conifer (C3)
		Sparse canopy stands (<= 25% tree canopy; C7)		
		Thinned (and pruned and slash removed/burnt; C7)		
		Beetle killed (M3_50, 50% dead)		
		Mixedwood (M2_50; 50% conifer)		
		Broadleaf/Decid (M1_20, 20% conifer)		
Field or grassland (O1a, 50% cured)				



Time-based Empirical Fire (TEF) Model
Preliminary Application in the Bulkley-Morice Area

Andrew Fall, PhD
Landscape Systems Analyst
Gowlland Technologies Ltd.

Don Morgan, MSc

Dr. Phil Burton, PhD., Emeritus professor
UNBC

Dave Daust, MSc

Gen Perkins

And the whole team…

Bulkley-Morice Study Area

4.15 million ha (2.26 million ha in Bulkley and Morice TSAs)

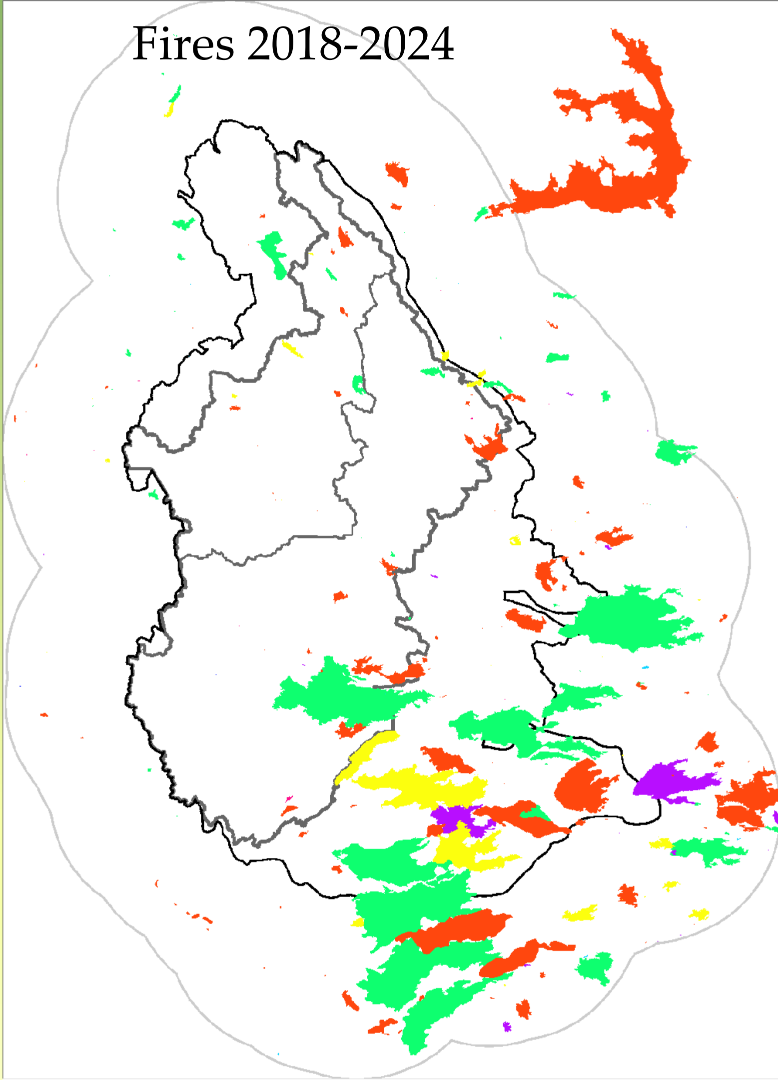
- Buffered by 50 km

Modelling wildfire?

- Why?
- How?
- What to do with model results?

TEF wildfire model

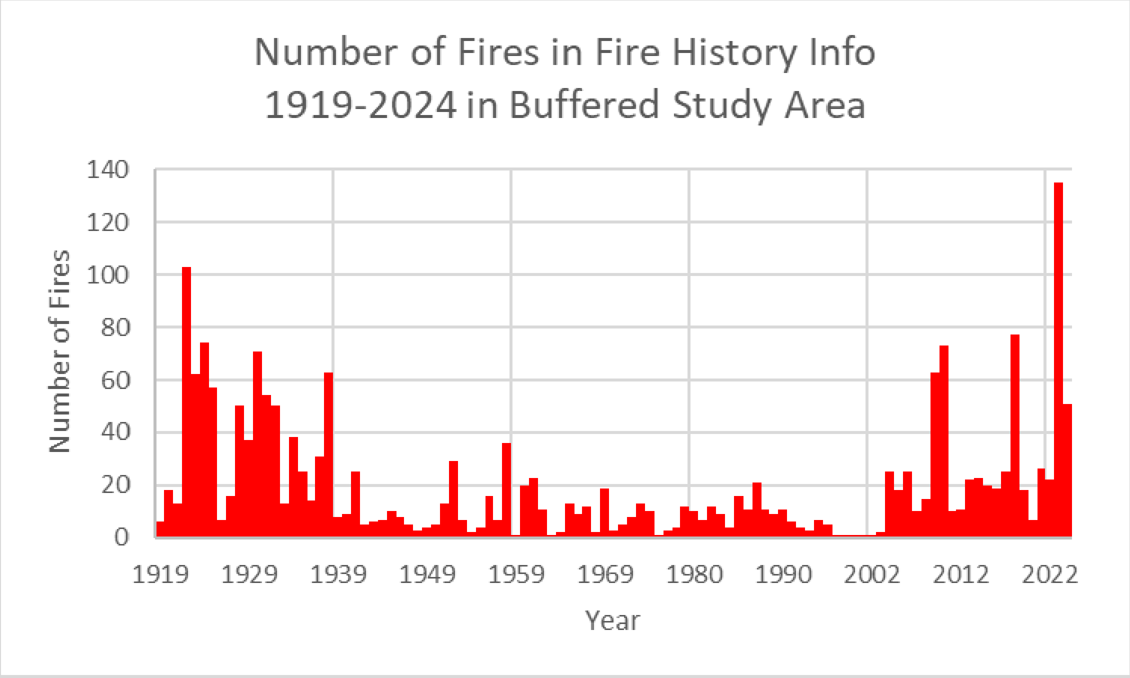
- Why a new model?
- How does it work?
- What can be done with it?



Bulkley-Morice Study Area

What's been going on with fires?

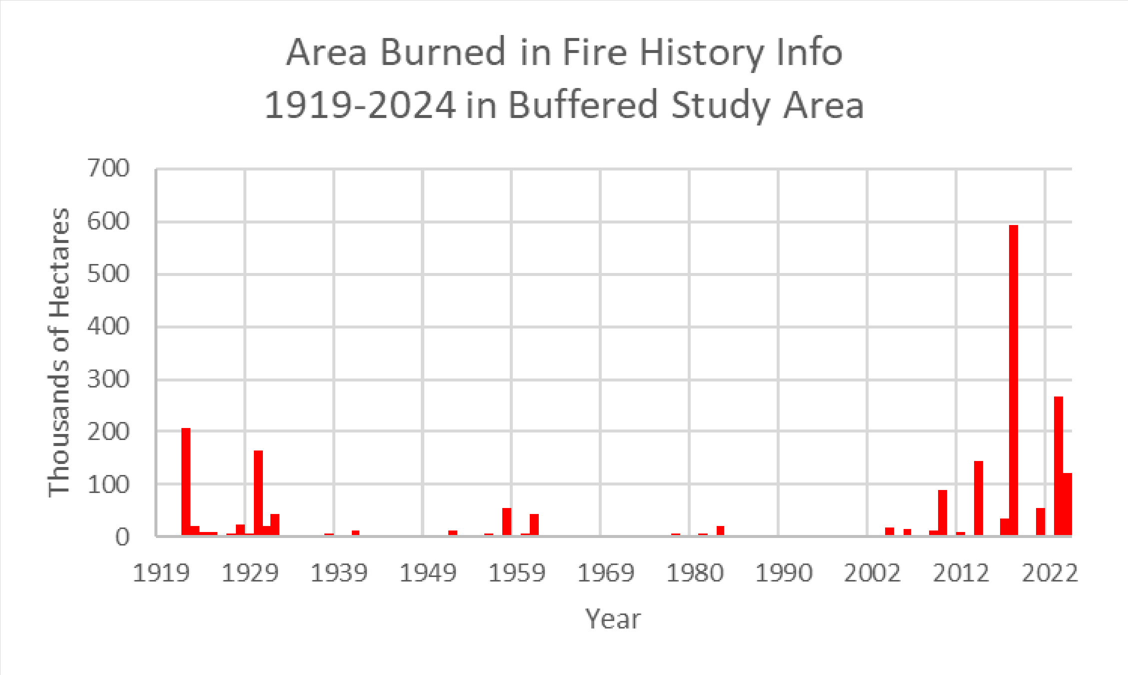
- There have always been many fires



Bulkley-Morice Study Area

What’s been going on with fires?

- But the area burned each year has varied dramatically

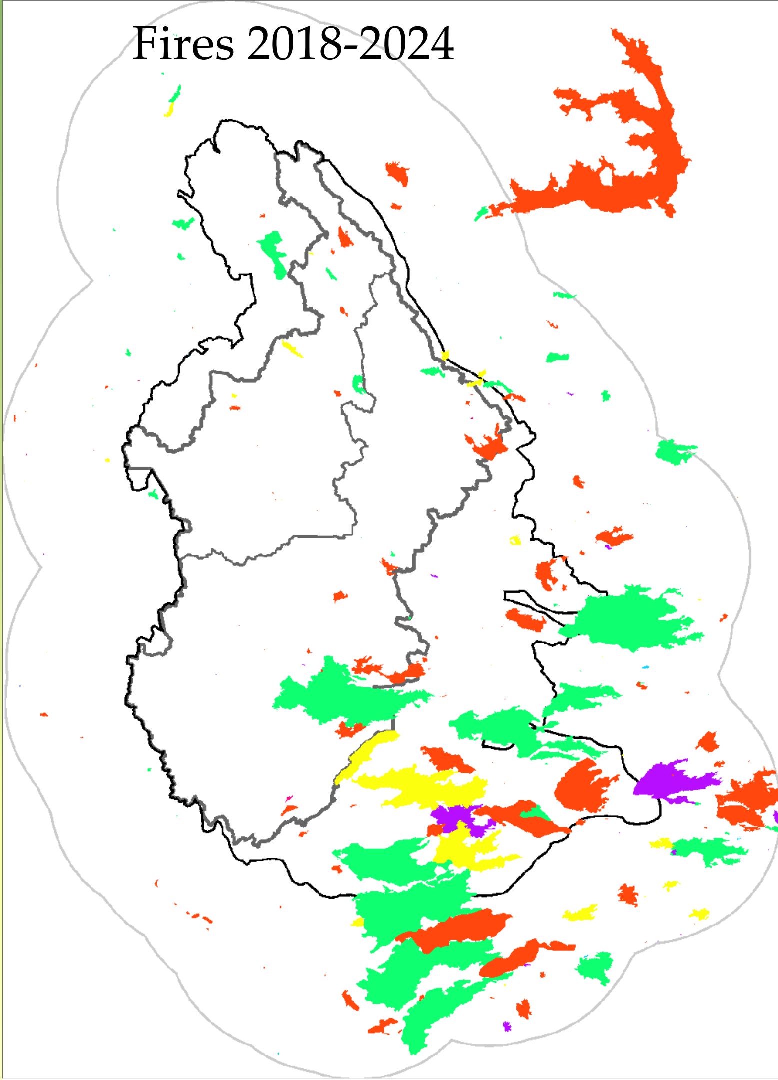


Why model Wildfire?

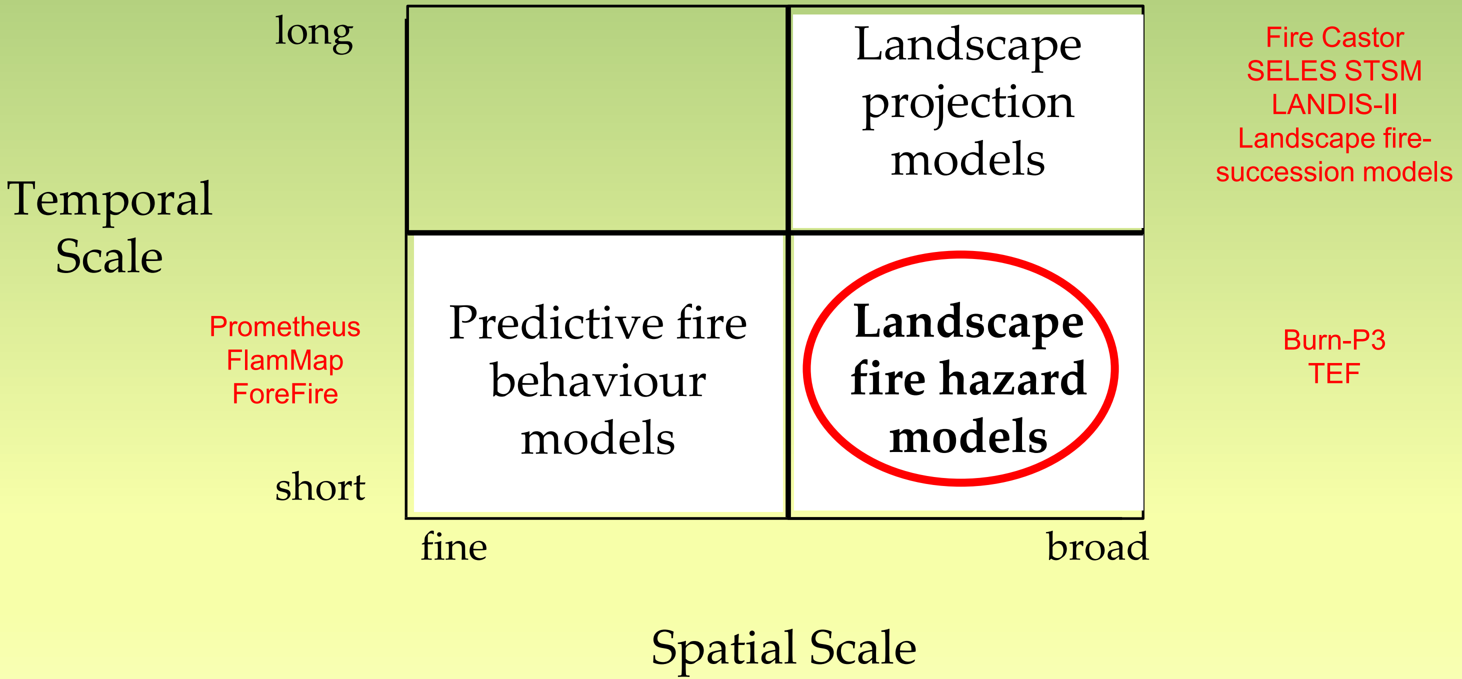
Fire models can be used:

- To assist fire suppression during a wildfire incident
- To assess wildfire hazard to communities and landscapes, including
  - potential for hazard reduction
  - potential effects of climate change
- To improve timber supply assessment
- To help understand potential impacts on values
  - old growth, wildlife habitat, water quality, economy, etc.
- To help identify potential macro fire refugia under climate change

➢ **NO SINGLE MODEL CAN ADDRESS ALL OF THESE**



Fire Model Types



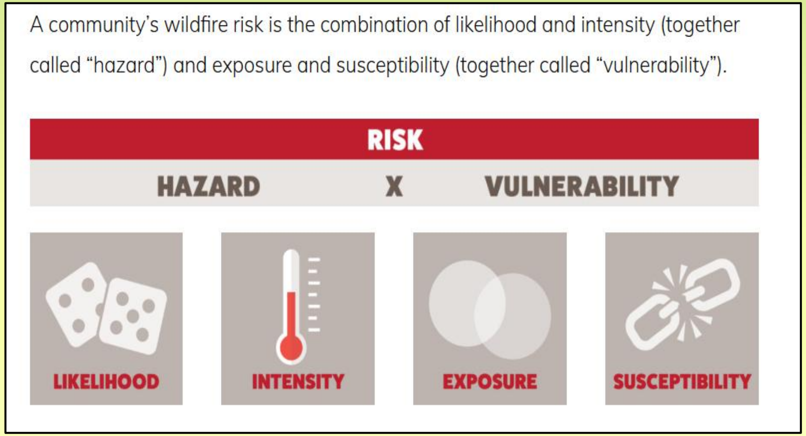
Landscape Wildfire Hazard Models

Designed to assess wildfire relative likelihood and hazard over large areas but a short time frame (years to decades)

- May assist with tactical planning (e.g. Forest Landscape Planning)
- May assist with hazard reduction planning

Can be applied with relatively modest effort and locally available data

(also called *Burn Probability Modelling* – see Parisien et al. 2019, *Int J Wildland Fire* 28:913-926)



Time-based Empirical Fire (TEF) Model Preliminary Application in the Bulkley-Morice Area

- **TEF model design and inputs**
- Set up and evaluation in the BuMo Study Area

- Assessing likelihood and hazard
- Comparison with other approaches

- Assessing potential effects of climate change

Features Common to Fire Models

Ignition: how many fire starts and where?

- TEF: focus on a single ignition

Spread: how fast does a fire spread and where?

- TEF: Based on fuel type (FBP or empirical), historical weather and topography

Extinguishment: how and when does a fire stop?

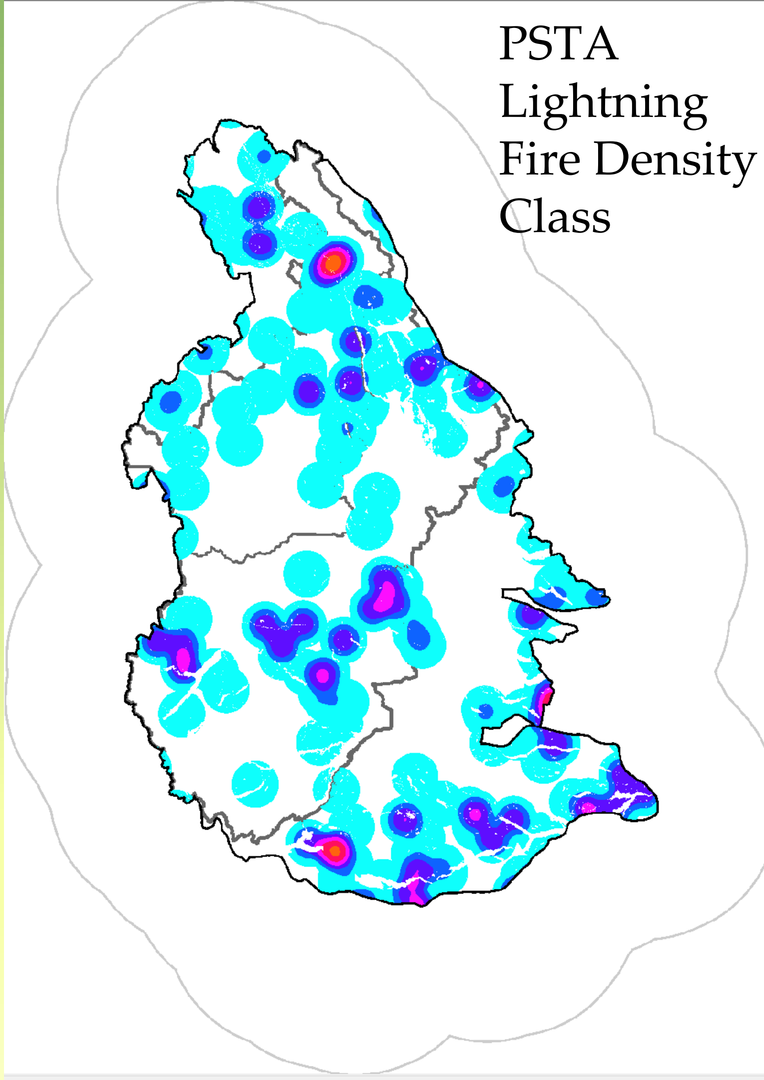
- TEF: After a “duration” in days set when the fire starts

Fire Ignition

Ignition represents a “fire escape” from a given source (e.g. lightning, human)

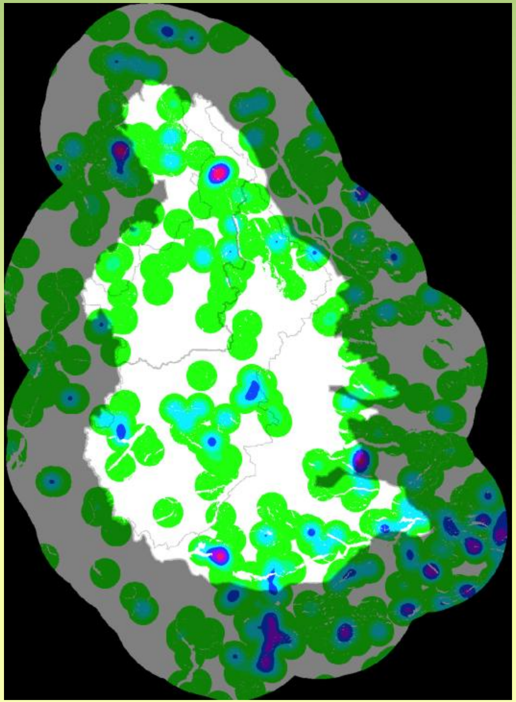
Each fire can be started either:

- In a defined location (e.g. historic fires)
- Stochastic based on a relative probability of ignition input layer:
  - Natural fires
  - Human fires



Fire Ignition: Lightning-caused

PSTA
Lightning Fire
Density

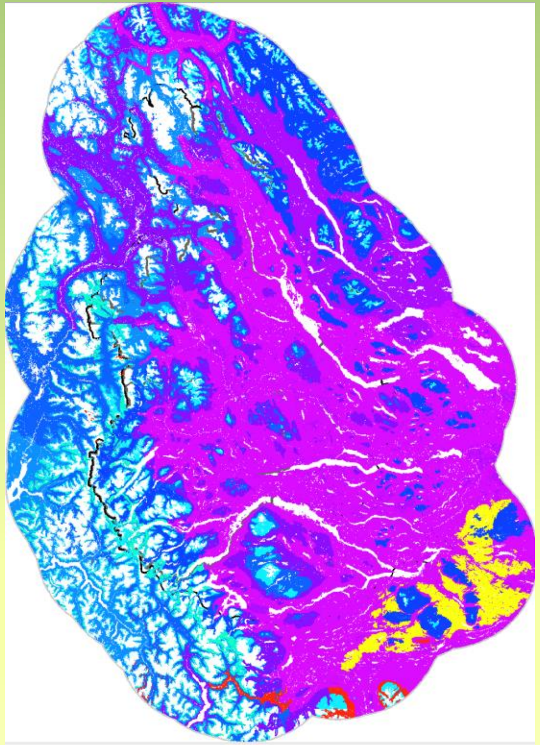


Assessed by:

Historic Natural
Fire Regime and

Natural
Disturbance Type

Relative
ignition
likelihood



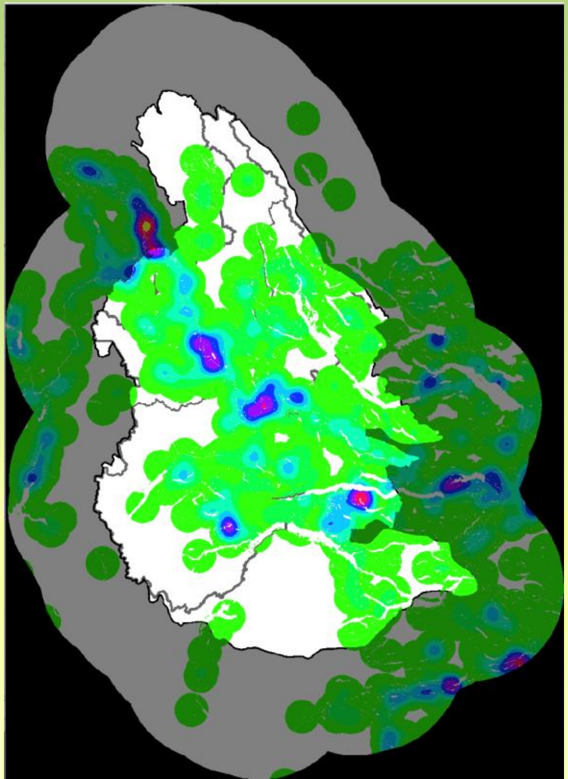
Light blue: ~50% random
Blue: below random
Purple: ~random
Pink: above random
Yellow: ~200% random

Fire Ignition: Human-caused

PSTA
Human Fire Density

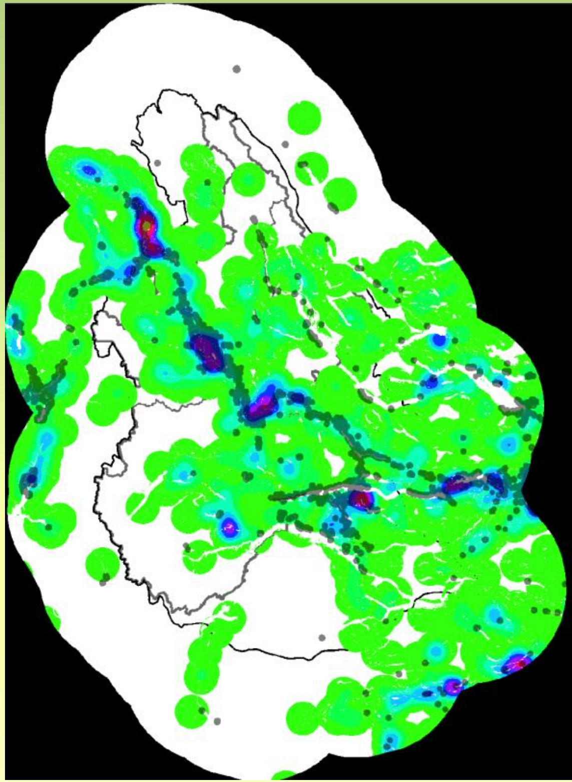
Assessed by:

Wildland Urban Interface (WUI)



Shading using WUI

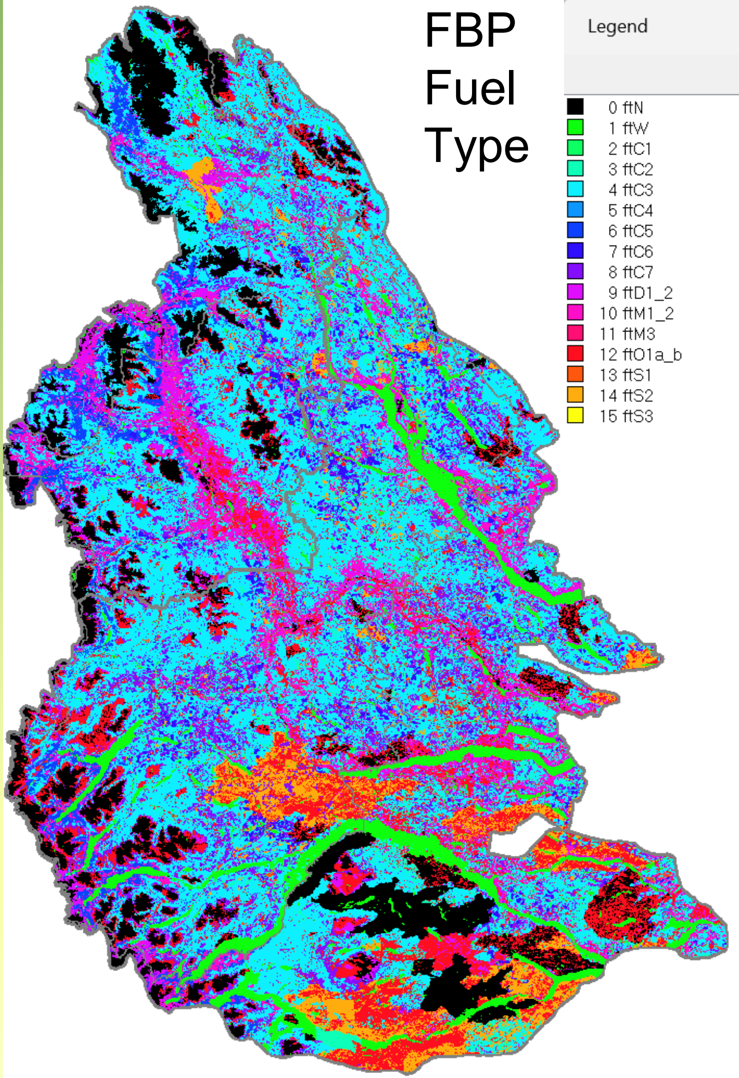
Mean fire density
- In WUI: 13.6
- Outside WUI: 3.2



Fire Spread

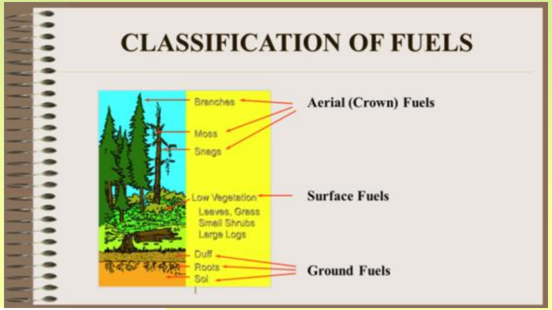
- TEF has been updated so that the modelled rate of fire spread can be driven either by:
  - FPB (Fire Behaviour Prediction) Fuel Type, or
  - Fire Susceptibility
    (e.g. as produced using Random Forests from field data)

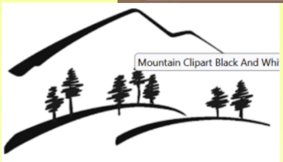
- Spread is also driven by topography, wind and fire weather:
  - Slope, aspect
  - Daily wind speed and direction
  - Daily fine fuel moisture code and build-up index



Rate of spread
based on FBP Fuel Types

Rate of spread (ROS)





Wind speed & direction

Fine fuel moisture

Prior weatherbuild-up

Fuel type

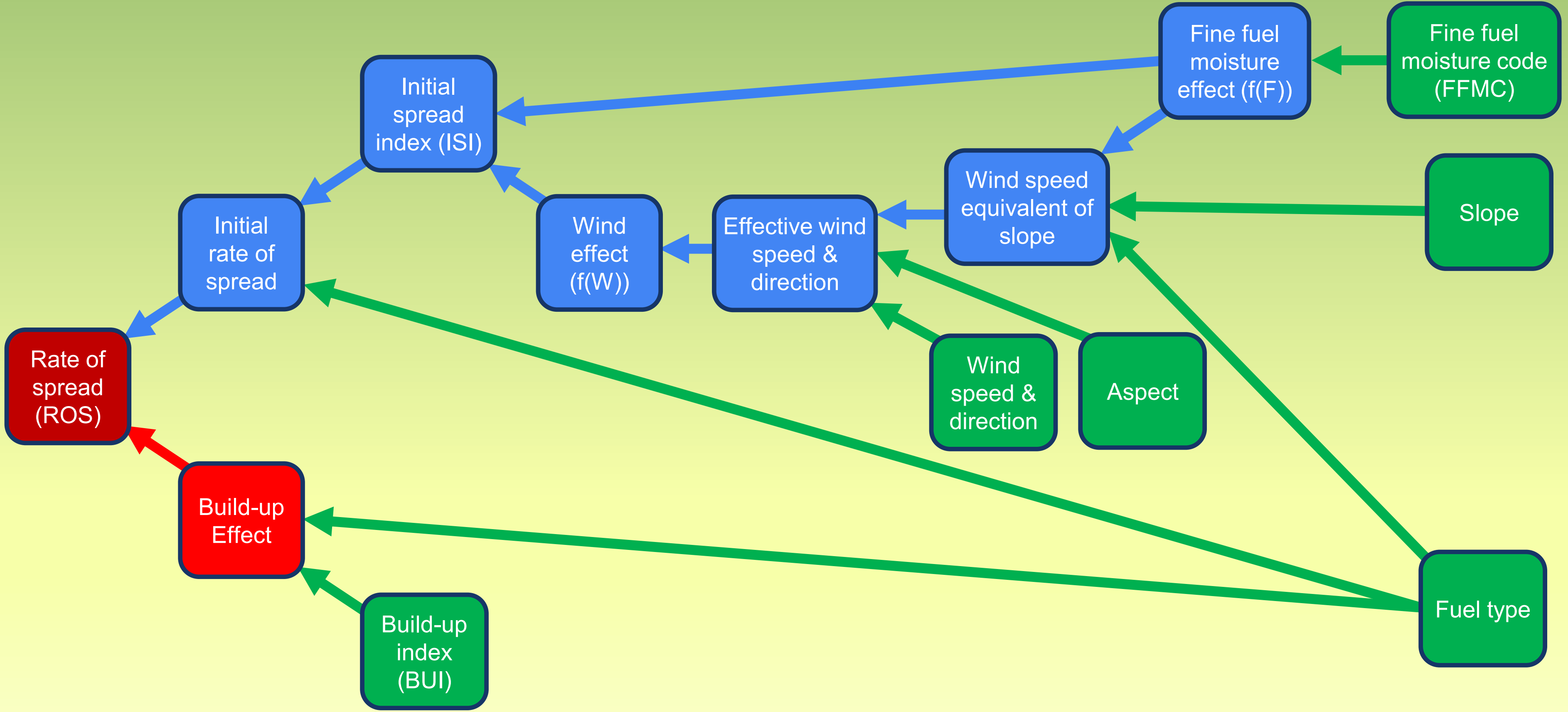
Slope & aspect

FASTER

Temporal change

SLOWER

Rate of spread based on FBP Fuel Types



Rate of spread based on FBP Fuel Types

$$ROS = RSI \times BE$$

$$BE = e^{\left[50 \times \ln(q) \times \left(\frac{1}{BUI} - \frac{1}{BUI_0}\right)\right]}$$

$$RSI = a \times \left[1 - e^{(-b \times ISI)}\right]^c$$

$$ISI = 0.208 \times f(W) \times f(F)$$

$$f(F) = 91.9 \times e^{(-0.1386 \times m)} \times \left[1 + \frac{m^{5.31}}{4.93 \times 10^7}\right]$$

where

$$m = \frac{147.2 \times (101 - FFMC)}{59.5 + FFMC}$$

$$f(W) = e^{0.05039 \times WSV}$$

If WS > 40, then

$$f(W) = 12 \times \left[1 - e^{-0.0818 \times (WSV - 28)}\right]$$

$$WSE = \frac{\ln\left[\frac{ISF}{0.208 \times f(F)}\right]}{0.05039}$$

$$WSX = \left[WS \times \sin(WAZ)\right] + \left[WSE \times \sin(SAZ)\right]$$

$$WSY = \left[WS \times \cos(WAZ)\right] + \left[WSE \times \cos(SAZ)\right]$$

$$WSV = \sqrt{WSX^2 + WSY^2}$$

$$SF = e^{3.533 \times \left(\frac{GS}{100}\right)^{1.2}}$$

$$RSF = RSZ \times SF$$

$$ISF = \frac{\ln\left[1 - \left(\frac{RSF}{a}\right)^{\frac{1}{c}}\right]}{-b}$$

Rate of spread based on FBP Fuel Types

$$ROS = RSI \times BE$$

$$BE = e^{\left[50 \times \ln(q) \times \left(\frac{1}{BUI} - \frac{1}{BUI_0}\right)\right]}$$

$$RSI = a \times \left[1 - e^{(-b \times ISI)}\right]^c$$

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$$WSV = \sqrt{(WSX^2 + WSY^2)}$$

$$WSE = \frac{\ln\left[\frac{ISF}{0.208 \times f(F)}\right]}{0.05039}$$

$$SF = e^{3.533 \times \left(\frac{GS}{100}\right)^{1.2}} \qquad GS < 60$$

$$RSF = RSZ \times SF$$

$$ISF = \frac{\ln\left[1 - \left(\frac{RSF}{a}\right)^{\frac{1}{c}}\right]}{-b}$$

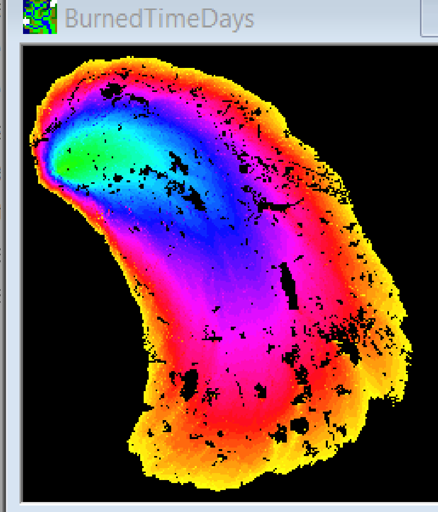
Fire Extinguishment

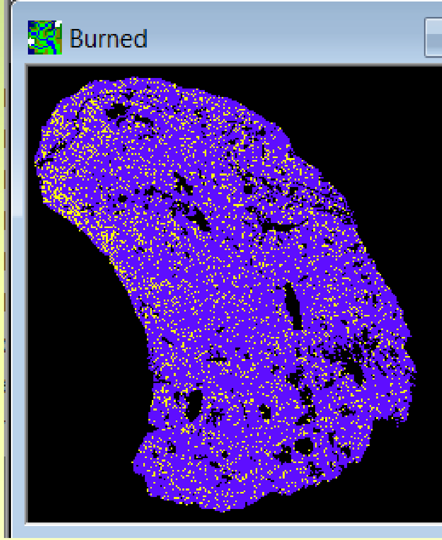
(1) Fires grow for a specific “duration” (days)

- Duration is picked from a distribution based on historic fires
- When the duration time is reached, TEF assumes fire stopping weather

(2) Fire growth may extinguish along individual cells along the active front (increasing likelihood when fire slows)

- May leave areas unburned “islands”
  Example: yellow = stopped cells





Assessing Relative Fire Likelihood and Hazard

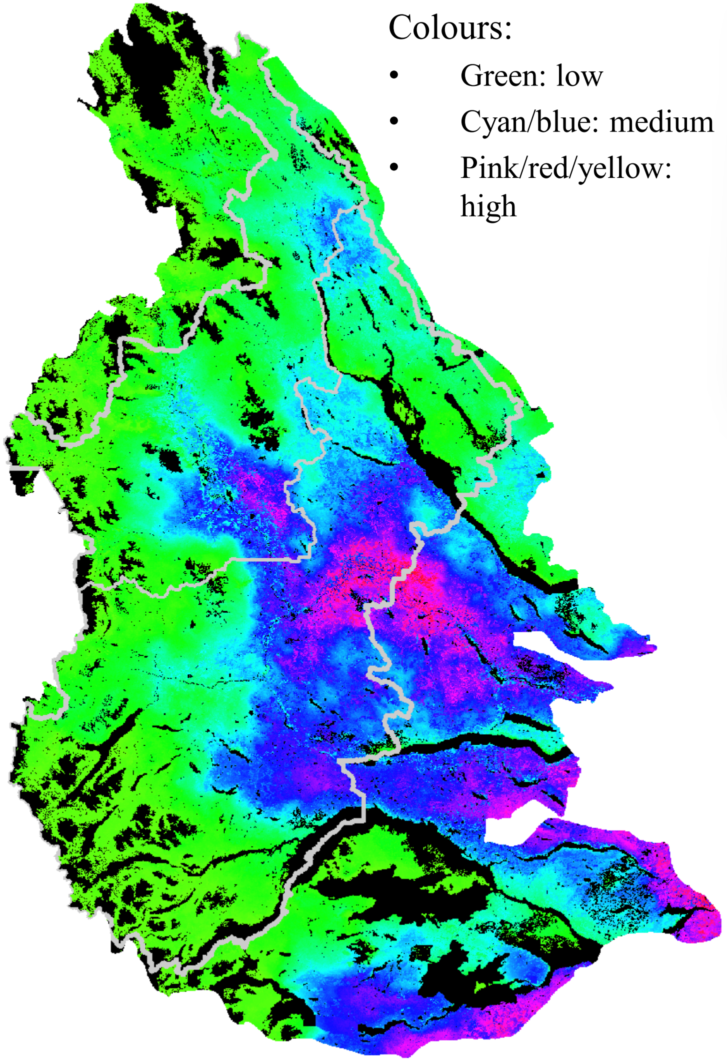
Fire Likelihood:

- Iteratively start many (e.g. 10,000) fires
- Accumulate averages:
  - Number of times each hectare burns (relative likelihood of a fire reaching that location)
  - Average rate of spread

Fire Hazard:

- Combine likelihood with estimated intensity

BUT BEFORE WE GET TOO FAR DOWN THE ROAD … we need to calibrate and evaluate TEF in the study area



Time-based Empirical Fire (TEF) Model
Preliminary Application in the Bulkley-Morice Area

- TEF model design and inputs
- **Set up and evaluation in the BuMo Study Area**

- Assessing likelihood and hazard
- Comparison with other approaches

- Assessing potential effects of climate change

Key Inputs and Uncertainties

Historic daily weather:

- April 1 until Oct 30 for years 2014-2024 (213 days)
- Wind direction and speed
- [IN PROGRESS: FFMC and BUI]

Fuel Types

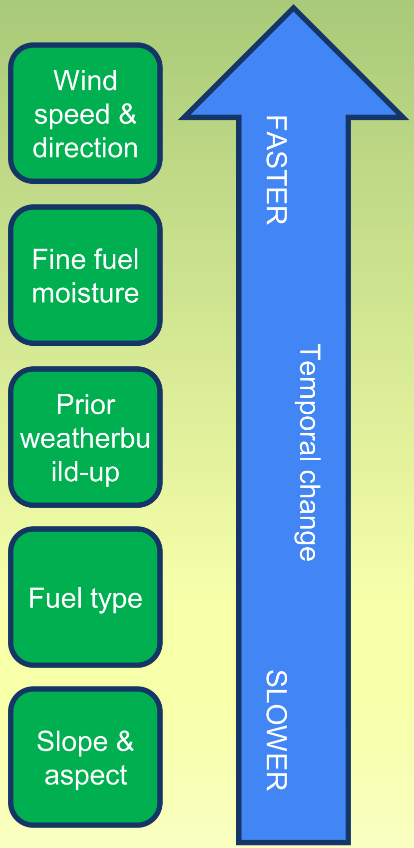
- 2023 and 2024
- Fast change following disturbance
  - Changes to grass types, slash types, deciduous, non-fuel

Grass curing factor:

- Important especially in the WUI

Spotting

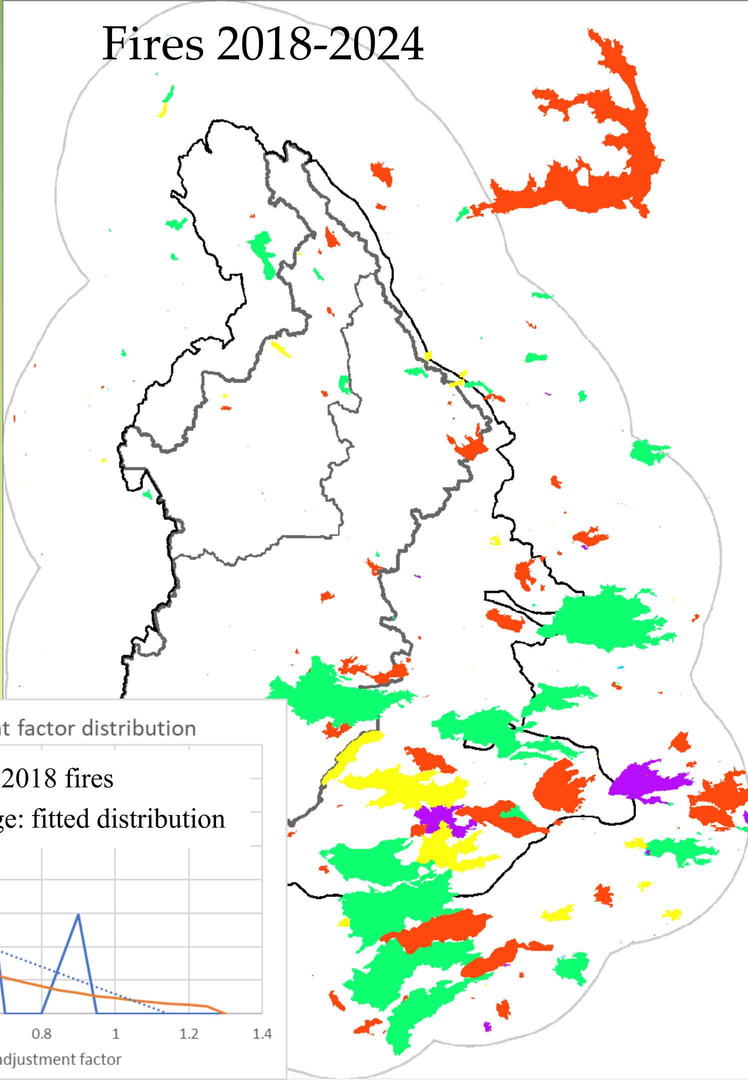
- Important to cross no/low fuel areas [UNDER REVIEW]

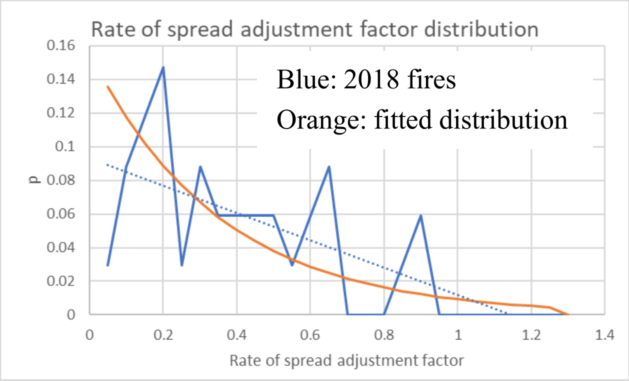


Calibration

Calibrate each 2018 fire ≥ 100 ha (n = 34)

- Match conditions as much as possible
  - Start location and date
  - Duration
  - Daily weather
  - [IN PROGRESS: 2017 Fuel Type layer]
- Fit “*rate of spread (ROS) adjustment factor*” to the closest match of resulting fire sizes to actual fire size
  - Represents uncertainty regarding factors not included
- Combine to produce a distribution of ROS adjustment factors
  - In main TEF runs: stochastically select from this distribution for each modelled fire

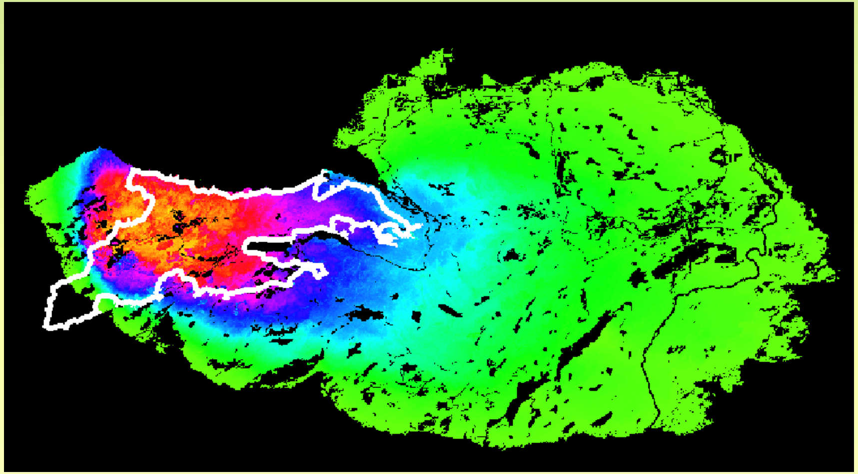


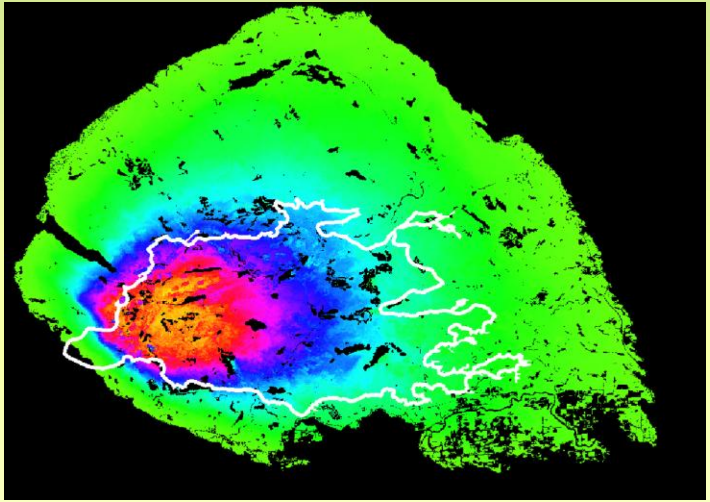


Calibration

Test calibration

- Run 1000 fires starting for each 2018 fire

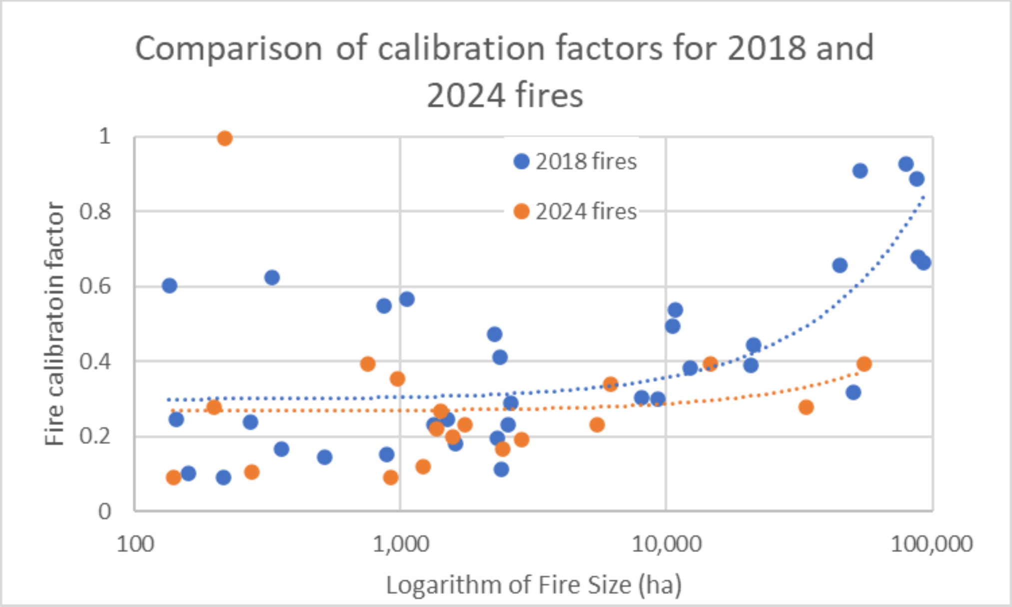


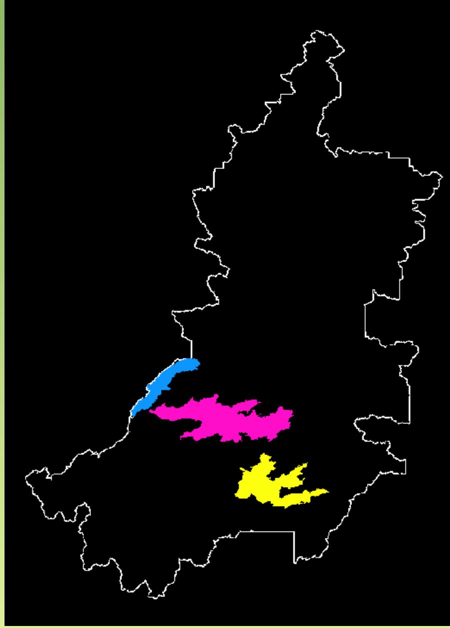


Validation: Test 1

Calibrate each 2024 fire ≥ 100 ha (n=19):

- Compare calibration factors with those from base calibration





Validation: Test 2

Run TEF on recent fires not used for calibration

- 2024 fires ≥ 100 ha (19 fires)
- Match conditions as much as possible
  - Start location and date
  - Duration
  - Daily 2024 weather
  - 2023 Fuel Type layer
- Run 1,000 replicates
  - Pick ROS adjustment factor from distribution (results in variable outcomes)

Compare with a spread "null hypothesis"

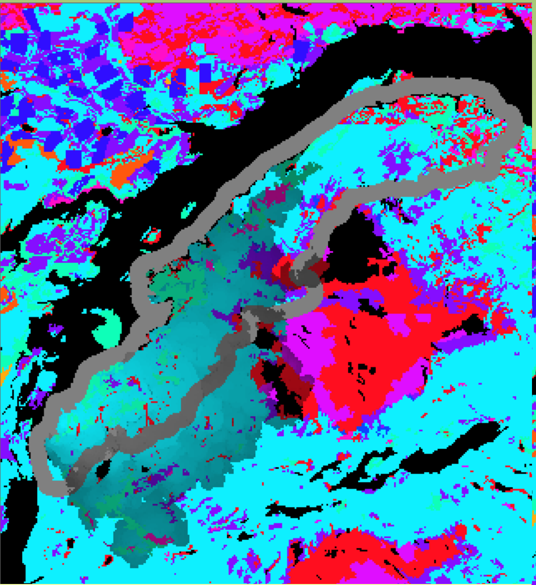
- Equal rate of spread in all directions

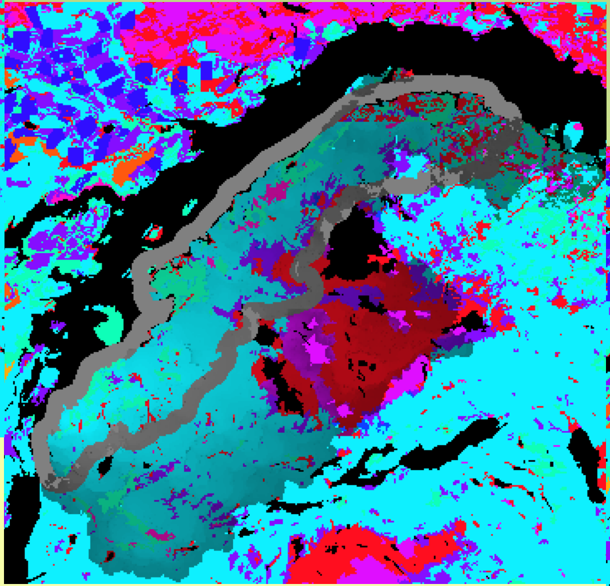
Bulkley Morice WILDFIRE RESILIENCE PROJECT

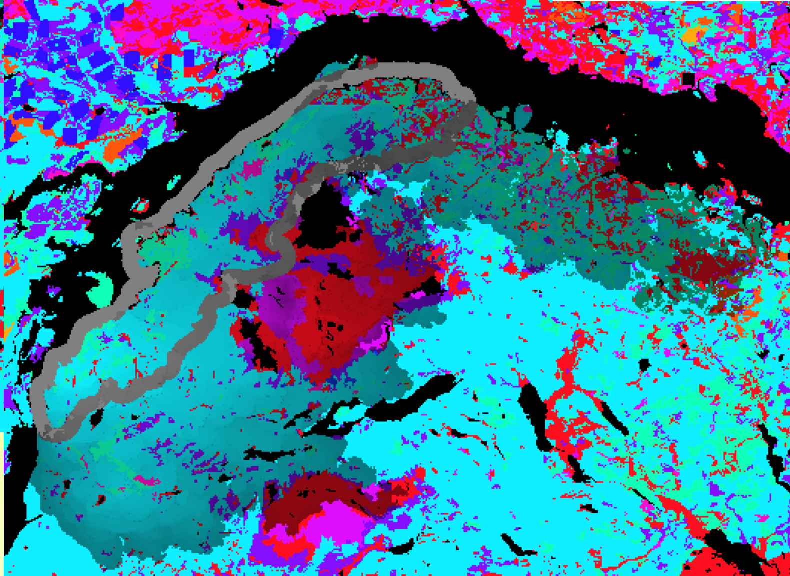
Validation: Test 2

Mount Wells Fire

Shading on 2023 Fuel Type



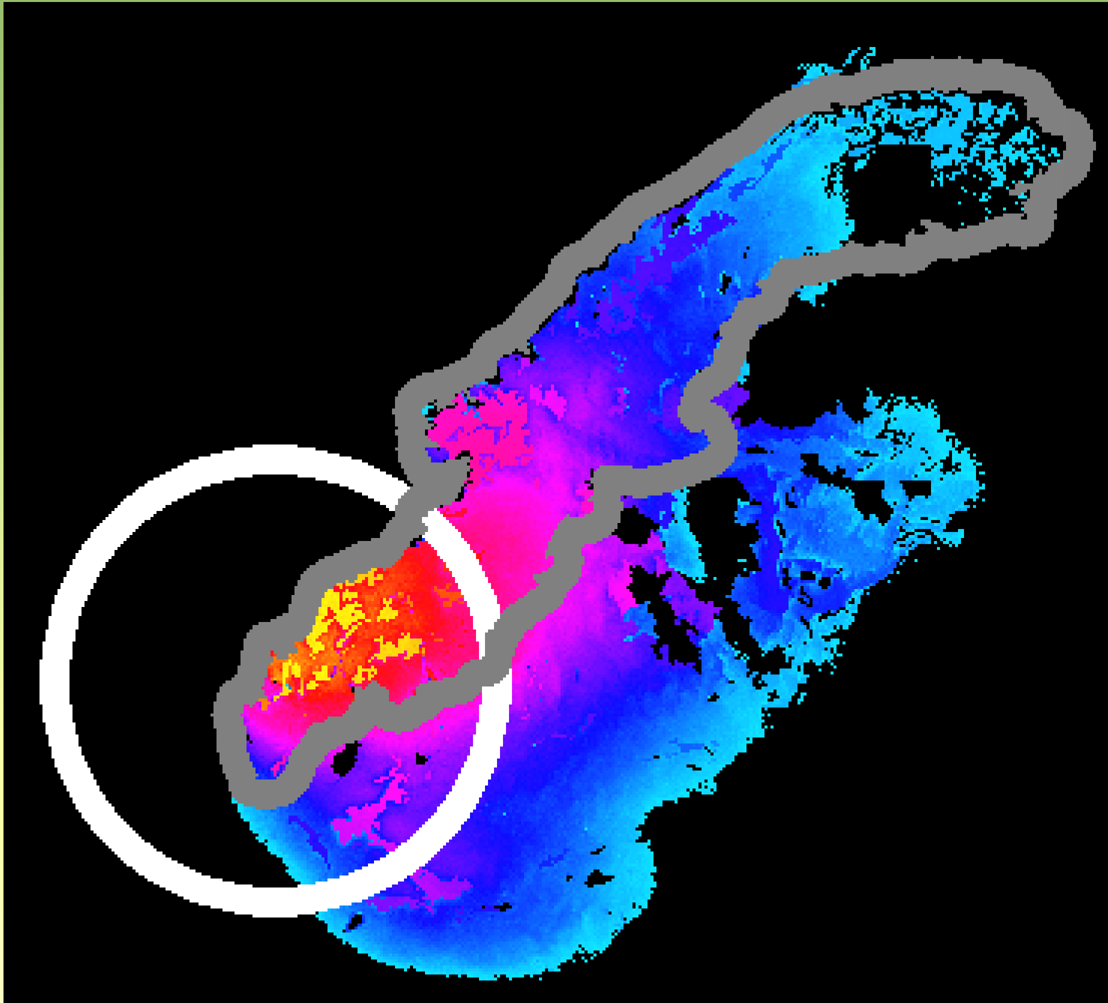




Validation: Test 2

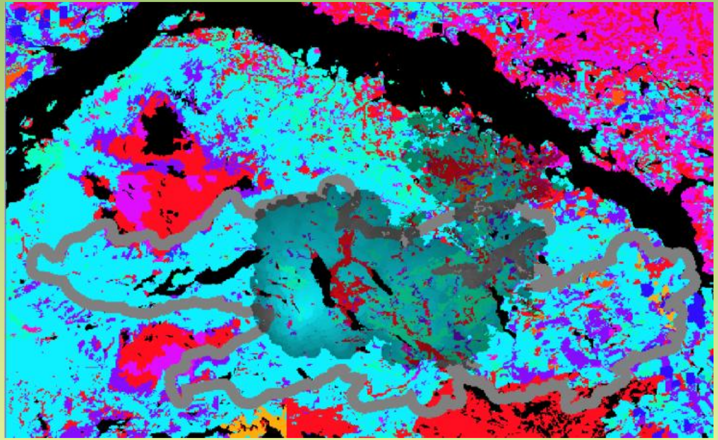
Mount Wells Fire

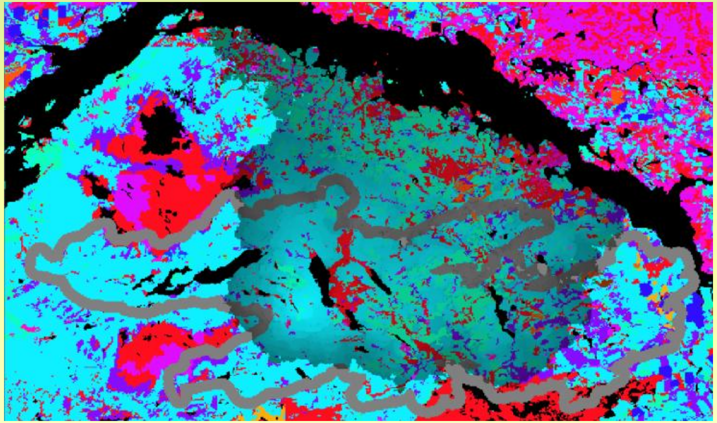
- The values shown consist of 50% of the total times burned (50th percentile)

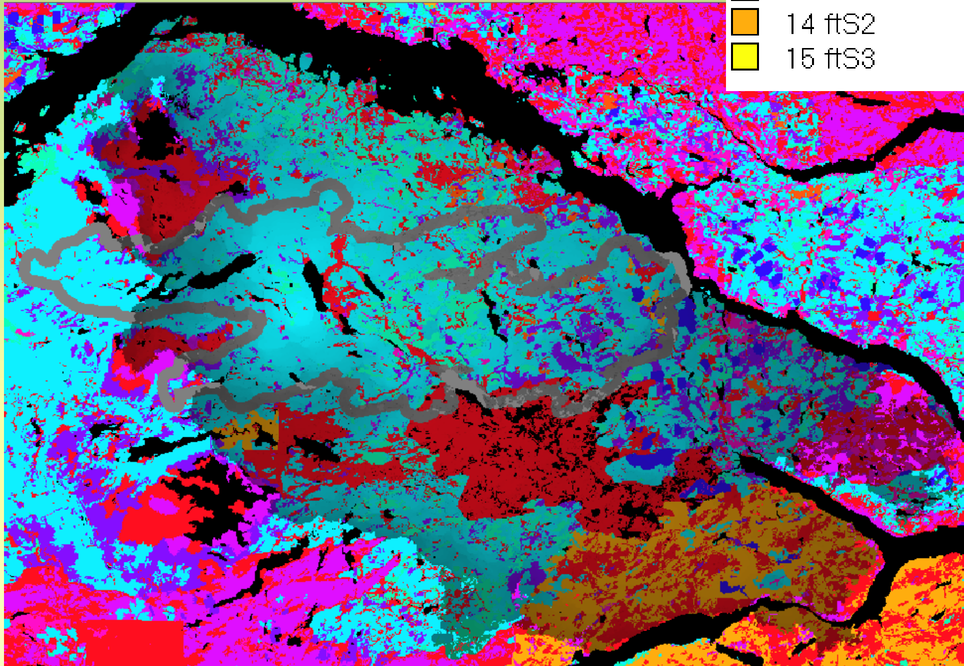


Validation: Test 2

Sabina Lake Fire
Shading on 2023 Fuel Type



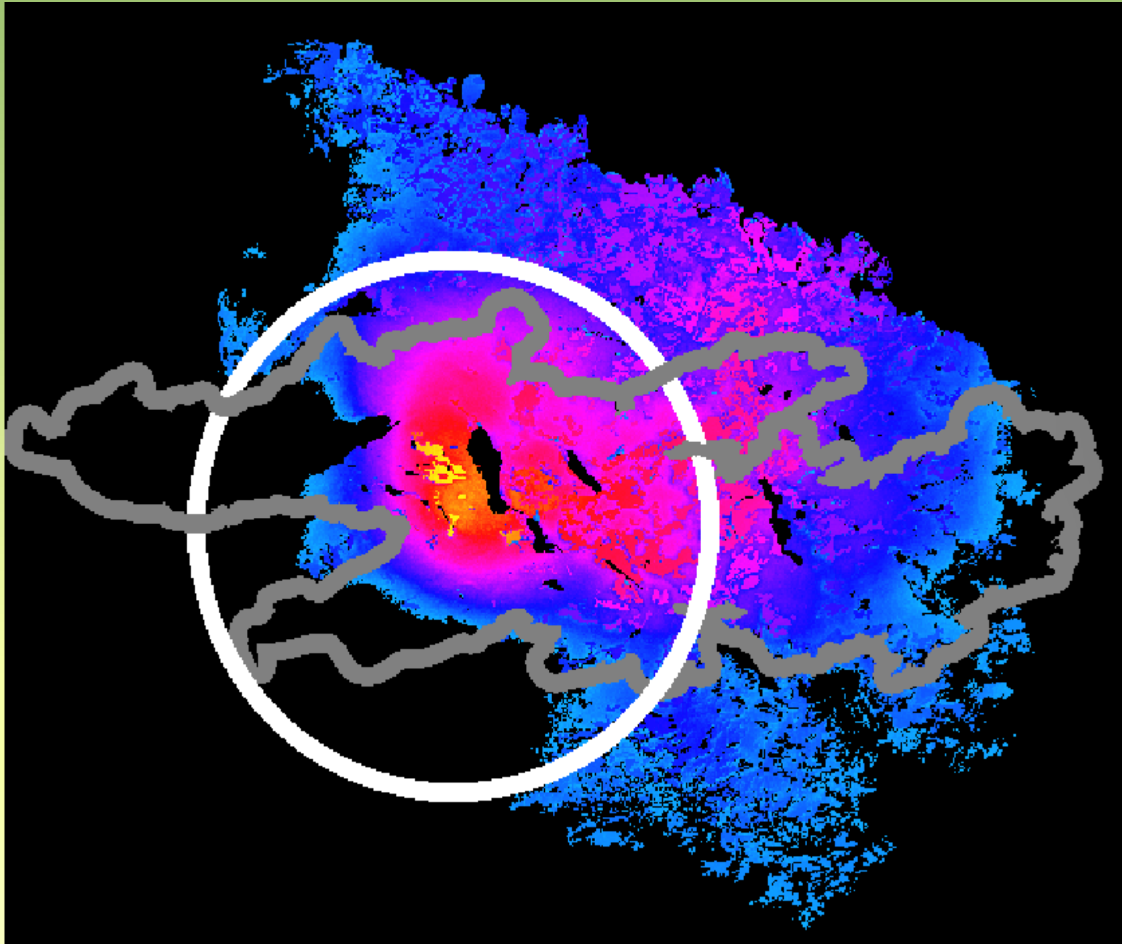




Validation: Test 2

Sabina Lake Fire

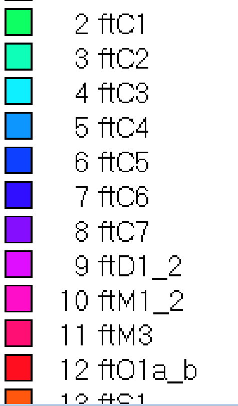
- The values shown consist of 50% of the total times burned (50th percentile)

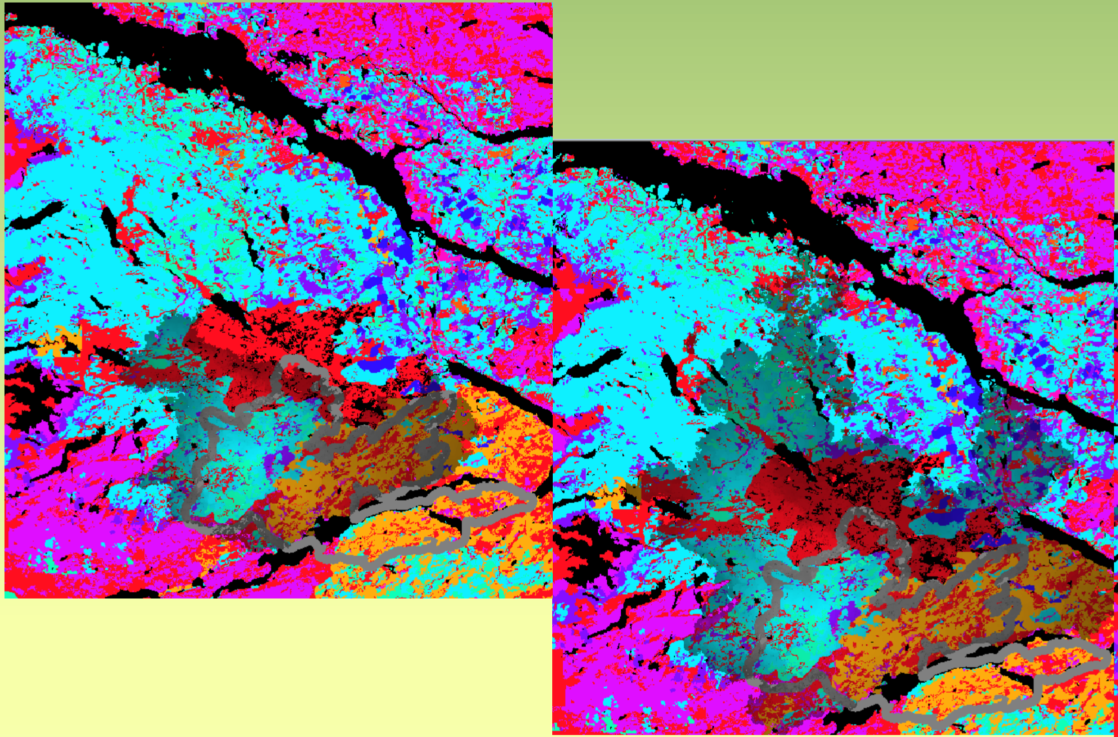


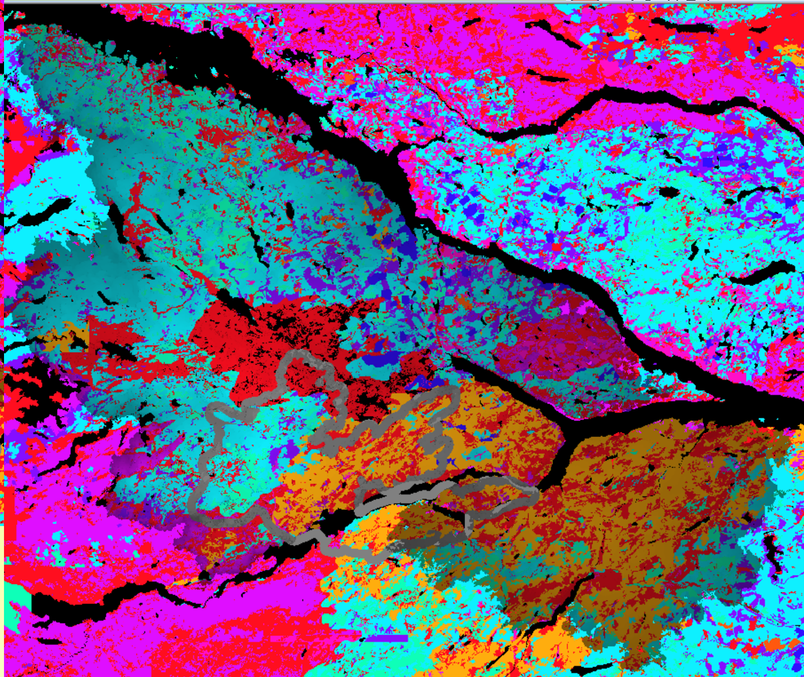
Validation: Test 2

Michel Creek Fire

Shading on 2023 Fuel Type



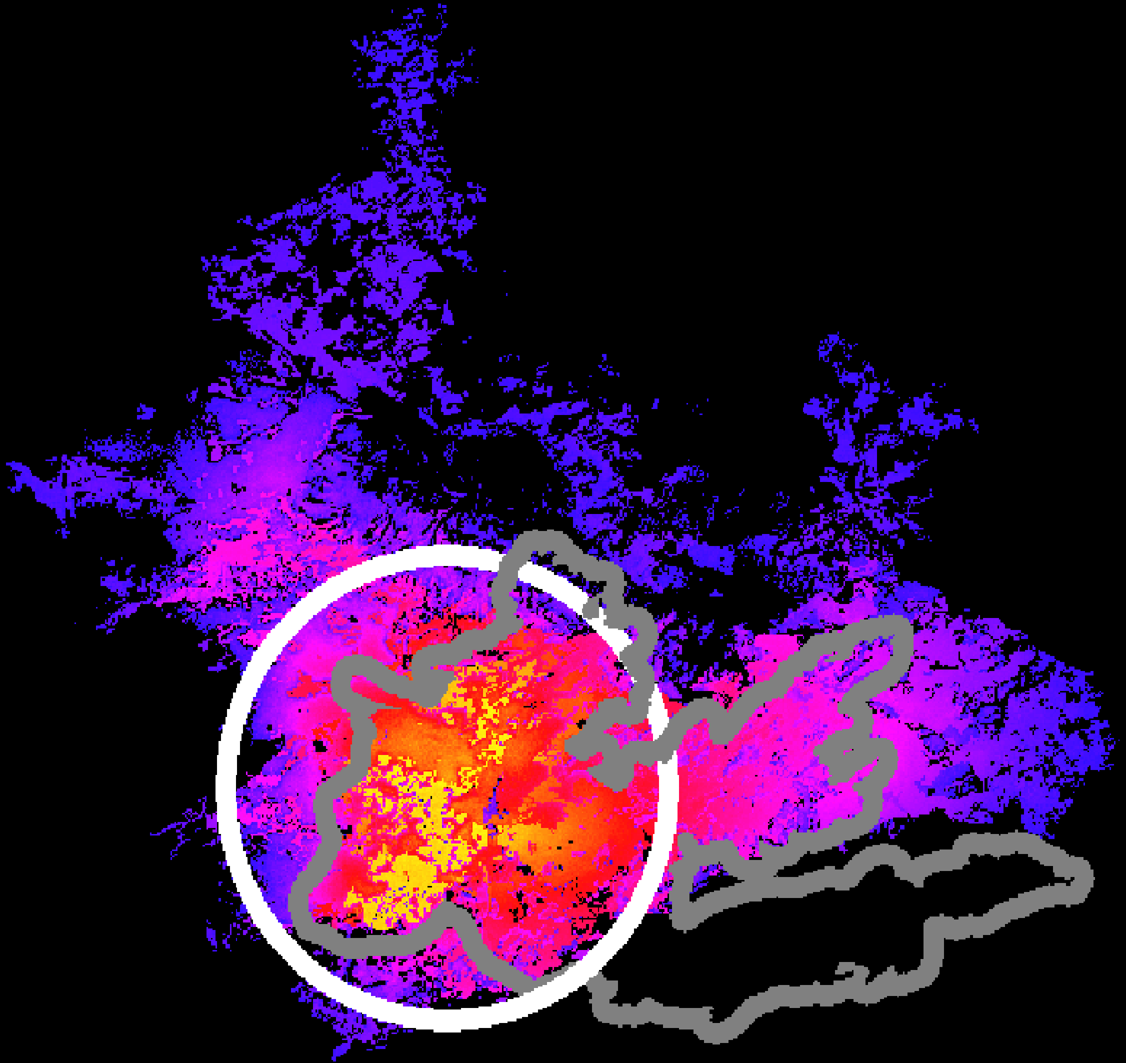




Validation: Test 2

Michel Creek Fire

- The values shown consist of 25% of the total times burned (25th percentile)



Validation: Test 2

Test:

- Compare agreement with actual fires (in cells with some fuel)
  - Random fires (null hypothesis; circle with same fire size): sum of % matches
  - Modelled fires: sum of % times burned within actual fire and 1-% times burned outside actual fire (up to 50% percentile of times burned)

2024 fire	% Agreement with random	% Agreement with modelled fires (50th percentile)
Wells Mountain	12.5%	48.0%
Sabina Lake	37.7%	46.1%
Michel Creek	38.9%	51.5%

Improvements Underway

- Spatial BUI and FFMC inputs (in addition to wind)
- Grass curing that varies over the season
- Fuel refinements (especially in recent fires and MPB-affected areas)

Bulkley Morice WILDFIRE RESILIENCE PROJECT

Project area hazard 1:00 – 2:15

1:00 – 1:20 Presentation

1:20 – 2:00 Small group discussion

2:00-2:15 Report out, full plenary

Bulkley Morice WILDFIRE RESILIENCE PROJECT

Time-based Empirical Fire (TEF) Model
Preliminary Application in the Bulkley-Morice Area

- TEF model design and inputs
- Set up and evaluation in the BuMo Study Area

- **Assessing likelihood and hazard**
- Comparison with other approaches

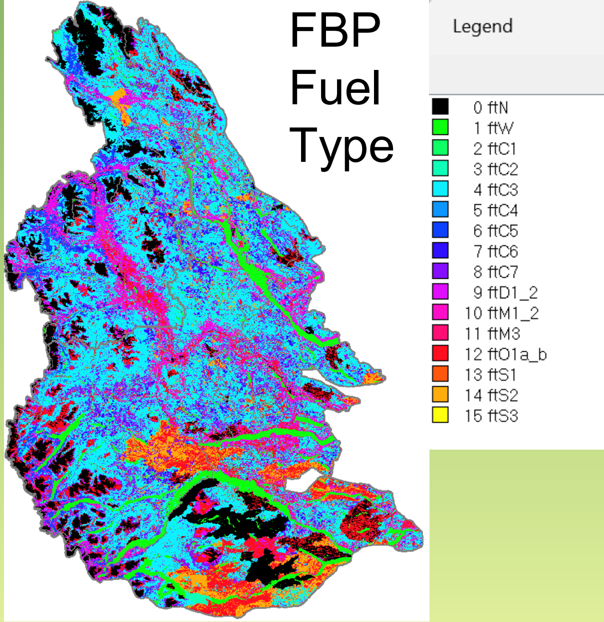
- Assessing potential effects of climate change

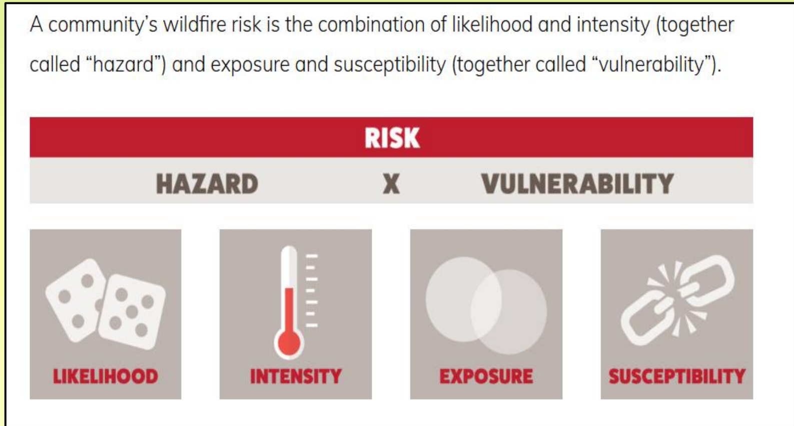
Landscape-scale Assessment

Run TEF to produce *many fires (10,000)*

- Fuel Type layer: Base run 2024 Fuel Type
- Ignition relative probability: lightning density (by HNFR x NDT)
- Weather: Random start day and year (2014-2024)
- Duration: based on distribution from 2018 fires
  - Average: 27 days (12 to 42 days long)
- Stochastic ROS calibration factor from fitted distribution
- Grass curing: 50%
- Run on buffered study area, but report only within study area

➢ **RESULTS ARE PRELIMINARY**



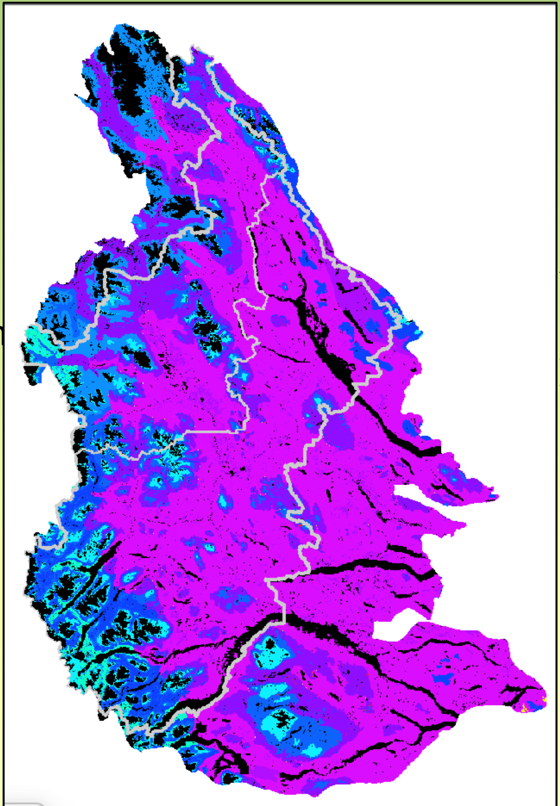


Relative Likelihood of Ignition (Fire Escapes)

Relative ignition likelihood

Range 42% to 200%

Light blue: ~50% random
Blue: below random
Purple: ~random
Pink: above random
Yellow: ~200% random



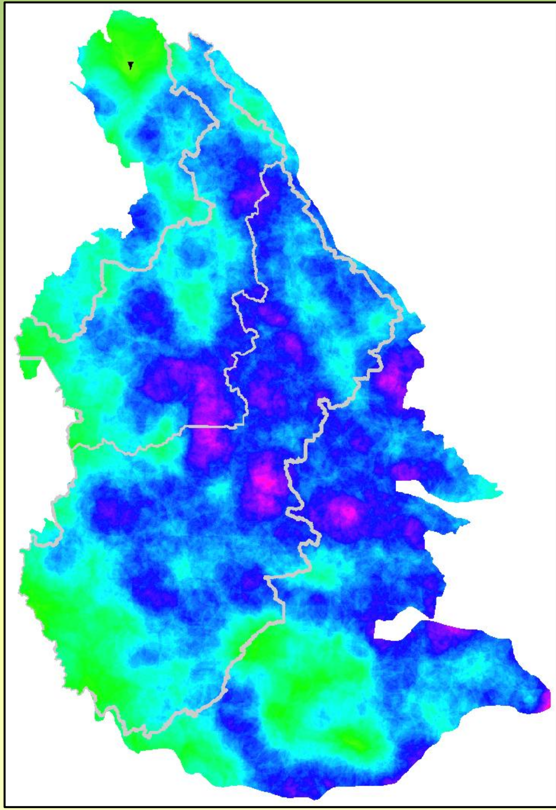
Times Ignited

Smoothed over 10km radius window (314 ha)

Result: n = 1 to 82

Colours:

- Green: low
- Blue: medium
- Red/yellow: high



Relative Likelihood of Burning

- Relative likelihood of burning: **# times burned** (may be normalized by dividing by number of fires)

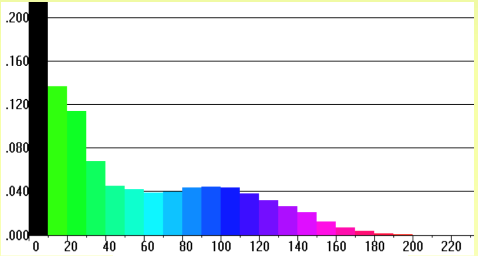
- Expected mean: ~53

$$\frac{\text{Total area burned over all fires}}{\text{Number of potentially flammable cells}}$$

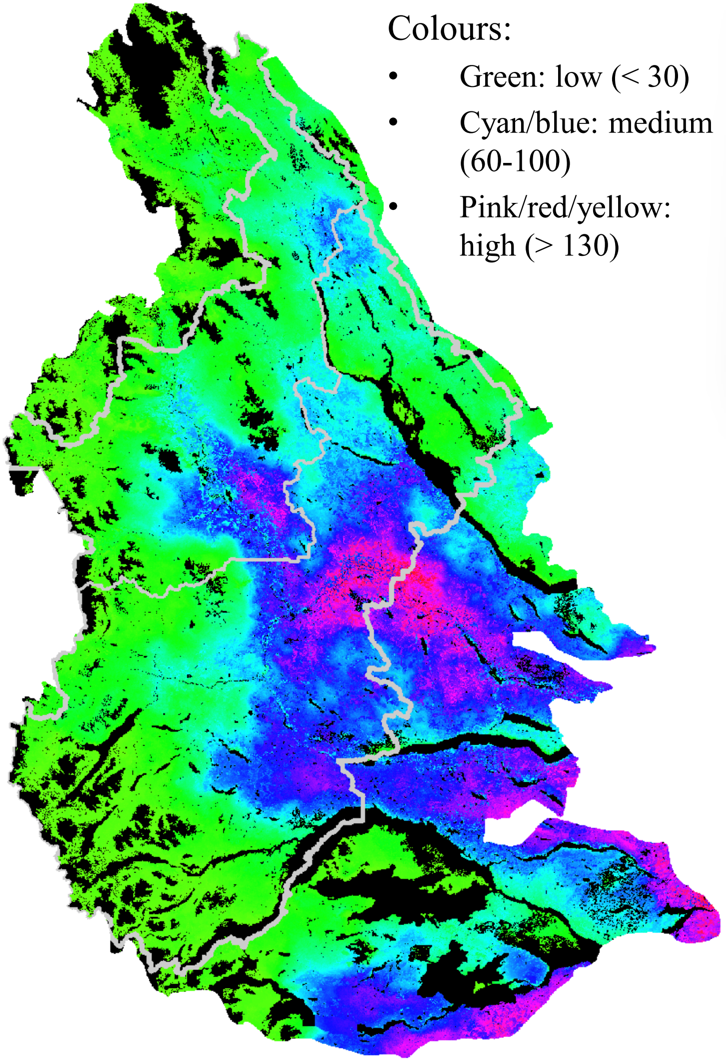
Mean fire size: ~37,700 ha

Median fire size: ~4,500 ha

Mean fire duration: 27 days



times burned



Colours:

- Green: low (< 30)
- Cyan/blue: medium (60-100)
- Pink/red/yellow: high (> 130)

PRELIMINARY RESULTS

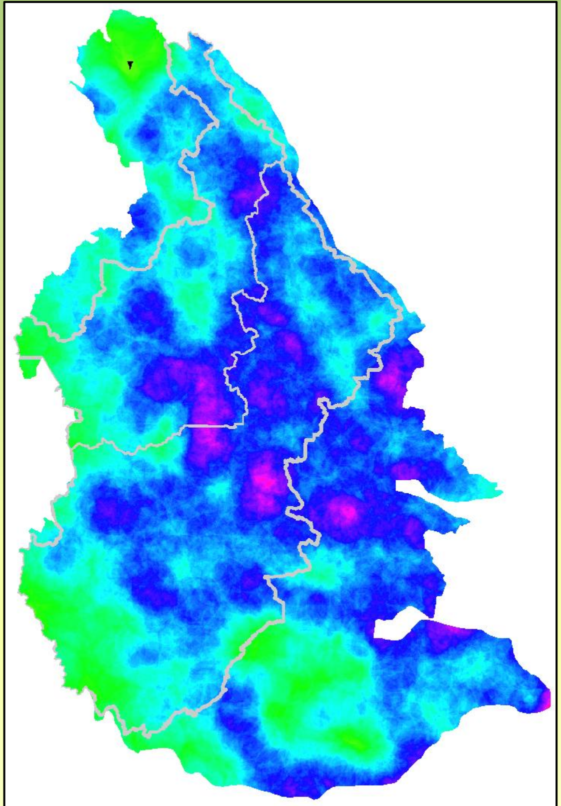
Ignition vs Burn Relative Likelihood

Times Ignited

Smoothed over 10km radius window

Colours:

- Green: low
- Blue: medium
- Red/yellow: high

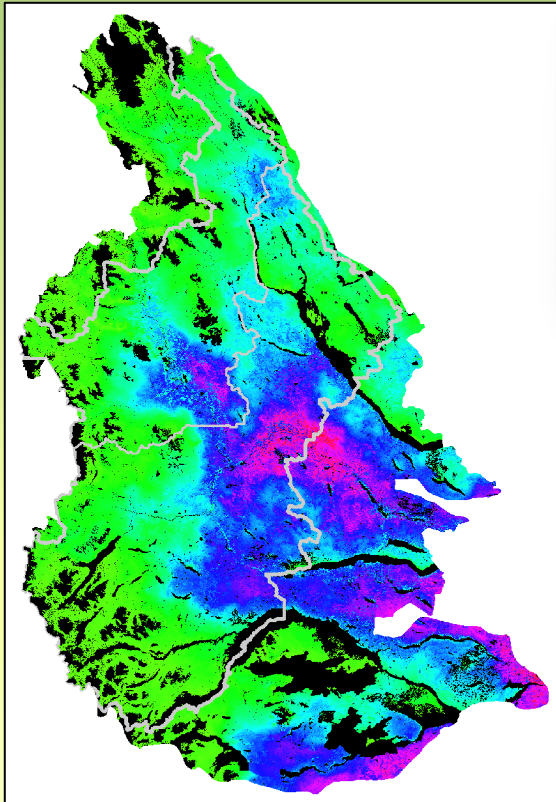


Times Burned

Effects of fuel, topography and wind patterns

Colours:

- Green: low
- Blue: medium
- Pink/red/yellow: high

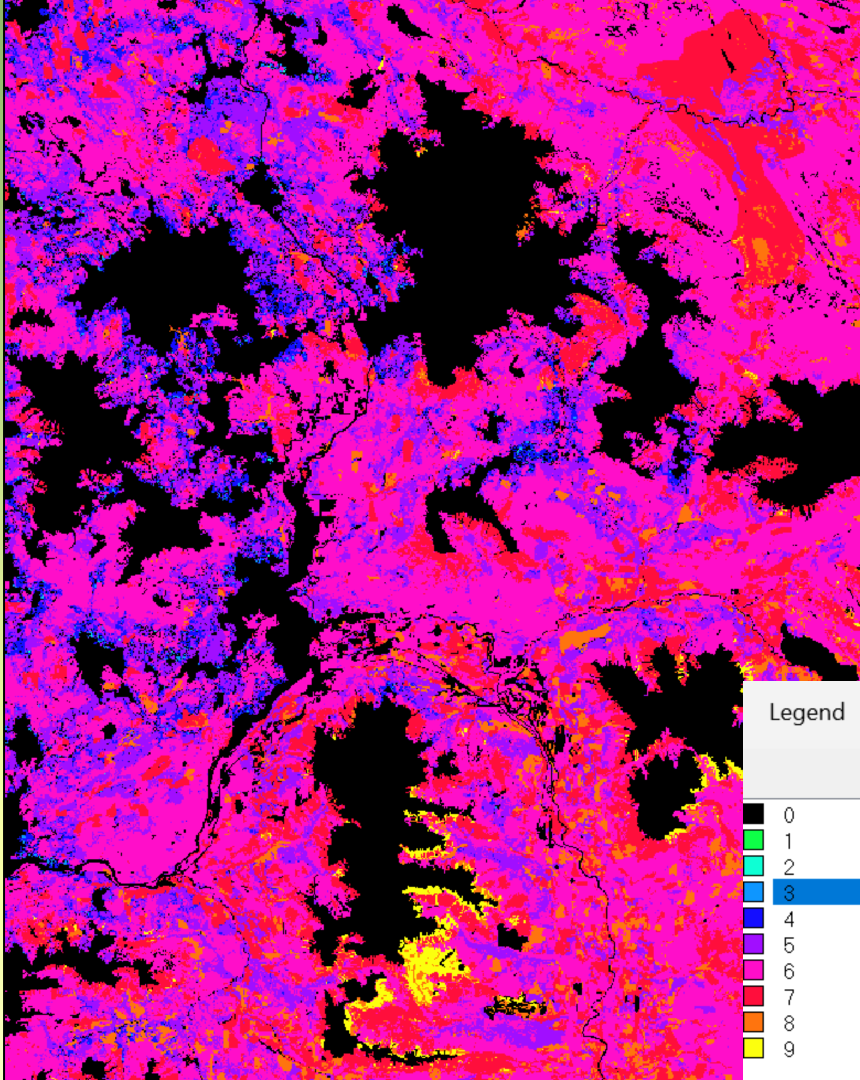


Mean Rate of Spread

Average rate of fire spread

LN(burn speed m/day)

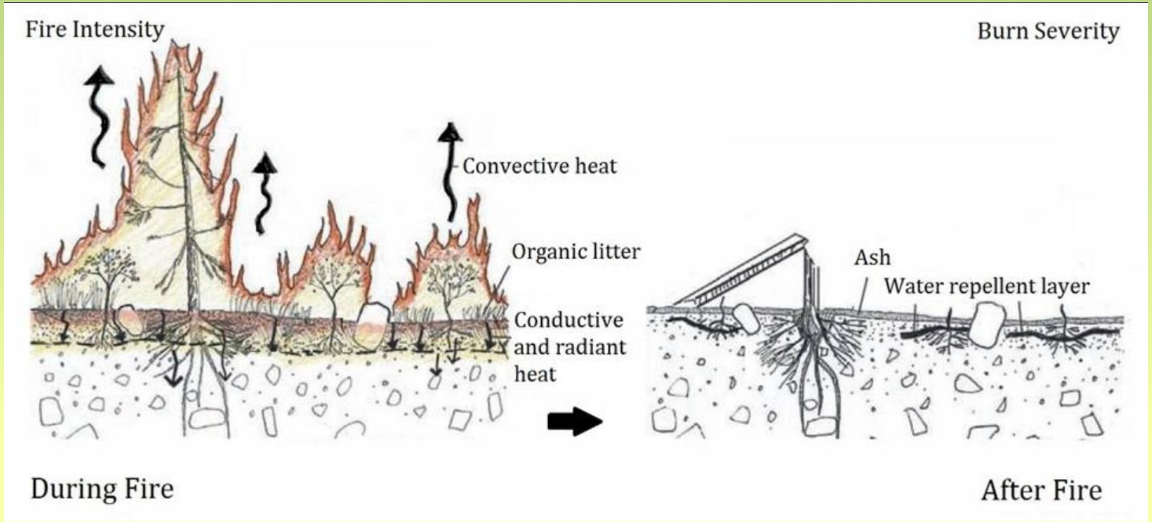
- Colours approximately represent:
  - Purple: ~90-240 m/day
  - Pink: ~250-650 m/day
  - Red: ~650-1,800 m/day
  - Orange: 1,800 – 4,900 m/day
  - Yellow: > 4,900 m/day



Fire Intensity based on the FBP System

Fire Intensity = Heat * fuel consumed * rate of spread
(kW/m) (kJ/kg) (kg/m) (m/s)

Fire Intensity (FI)



UN Office for Outer Space Affairs

Heat of combustion

Total Fuel Consumed

Rate of spread (ROS)

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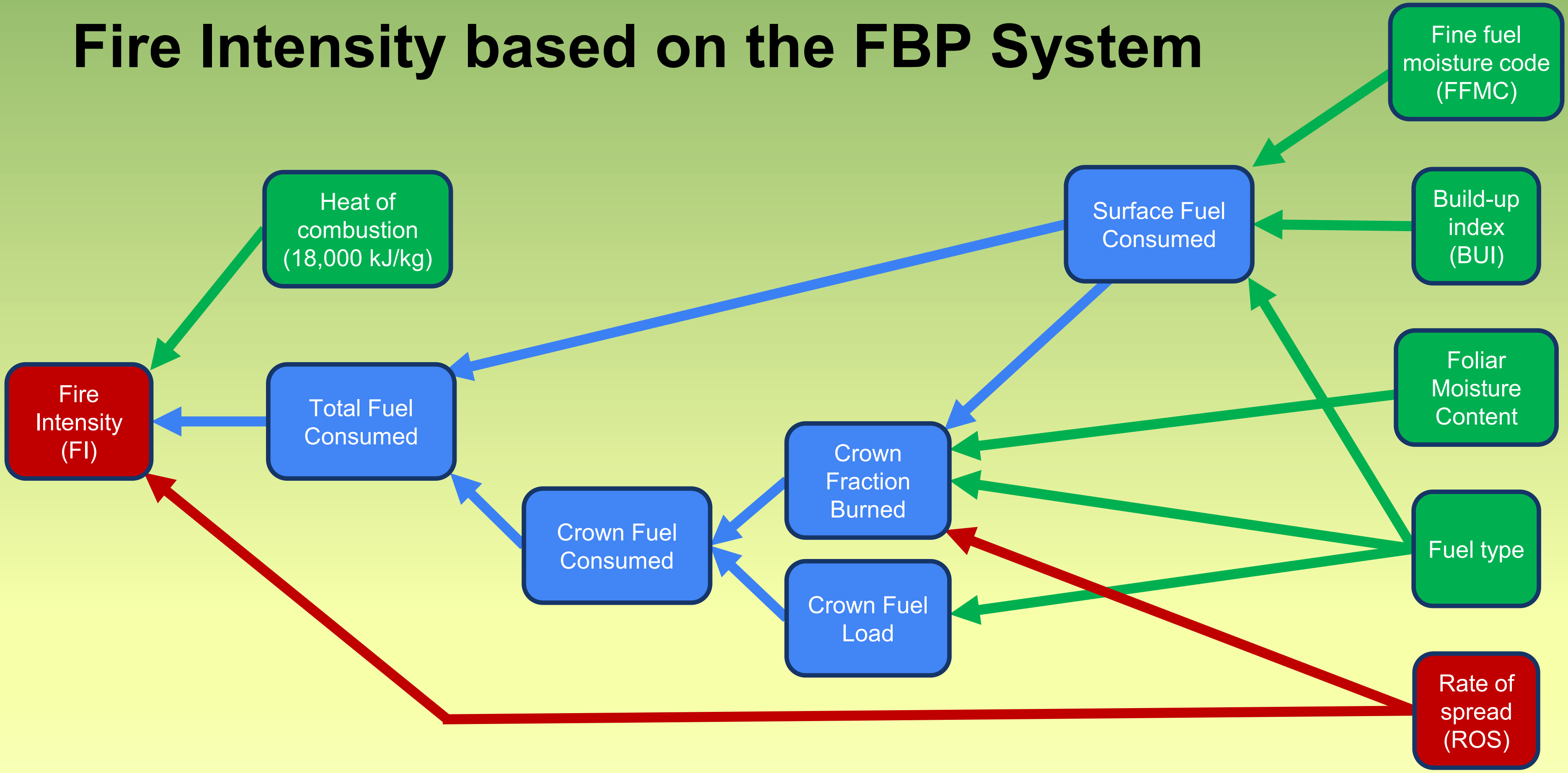
Fire Intensity based on the FBP System



Fire Intensity based on the FBP System

$$FI = 300 \times FC \times ROS$$

$$CFB = 1 - e^{-0.23 \times (ROS - RSO)}$$

$$RSO = \frac{CSI}{300 \times SFC}$$

$$ND = \left| D_j - D_0 \right|$$

$$FMC = 85 + 0.0189 \times ND^2 \quad ND < 30$$

$$FMC = 32.9 + 3.17 \times ND - 0.0288 \times ND^2 \quad 30 \le ND < 50$$

$$D_0 = 142.1 \times \left(\frac{LAT}{LATN} \right) + 0.0172 \times ELV$$

$$CSI = 0.001 \times CBH^{1.5} \times (460 + 25.9 \times FMC)^{1.5}$$

$$CFC = CFL \times CFB$$

$$TFC = SFC + CFC$$

C-3 or C-4

$$SFC = 5.0 \times \left[1 - e^{(-0.0164 \times BUI)} \right]^{2.24}$$

C-1

$$SFC = 1.5 \times \left[1 - e^{(-0.230 \times [FFMC - 81])} \right]$$

$$FFC = 4.0 \times \left[1 - e^{(-0.025 \times BUI)} \right]$$

$$WFC = 4.0 \times \left[1 - e^{(-0.034 \times BUI)} \right]$$

$$SFC = FFC + WFC$$

PRELIMINARY RESULTS

Crown Fraction Burned

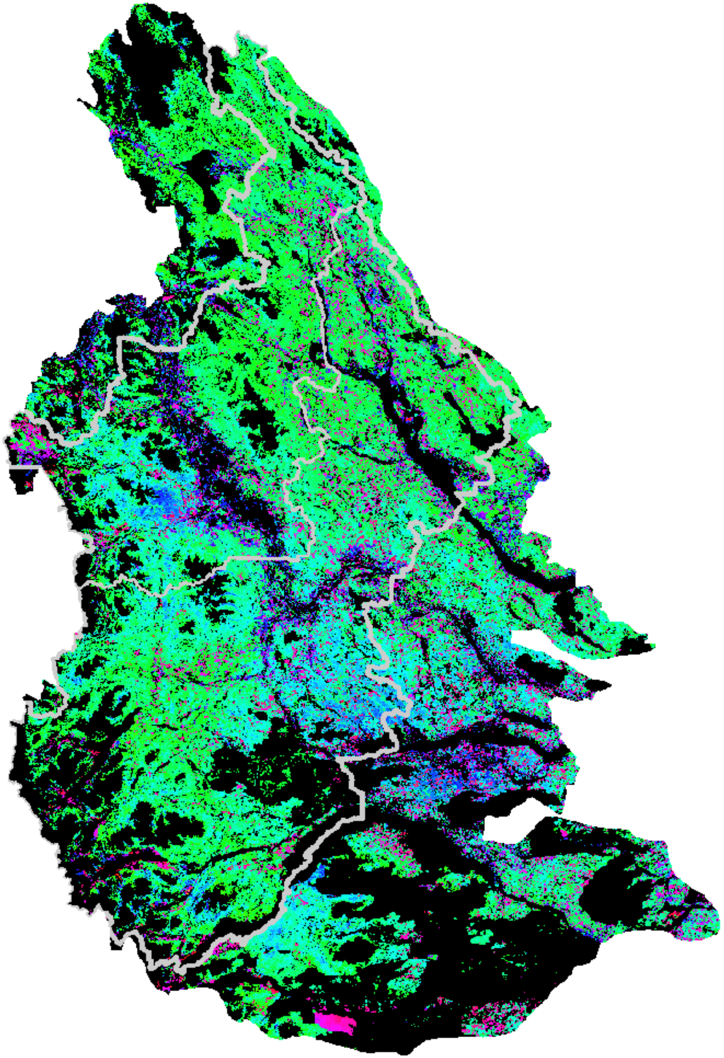
Average Crown Fraction Burned

- General indicator of magnitude of effect on the forest canopy

Note: CFB for a single fire can be significantly higher

Colours:

- Green/light blue: low (< 40%)
- Dark Blue/purple: moderate (40-60%)
- Pink/red/yellow: high (> 60%)



PRELIMINARY RESULTS

Fire Intensity

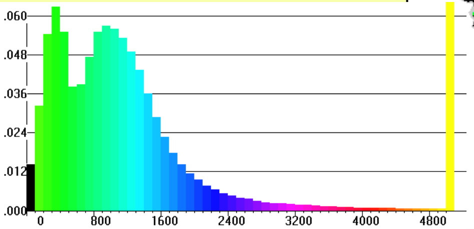
Average Estimated Fire Intensity (kW/m)

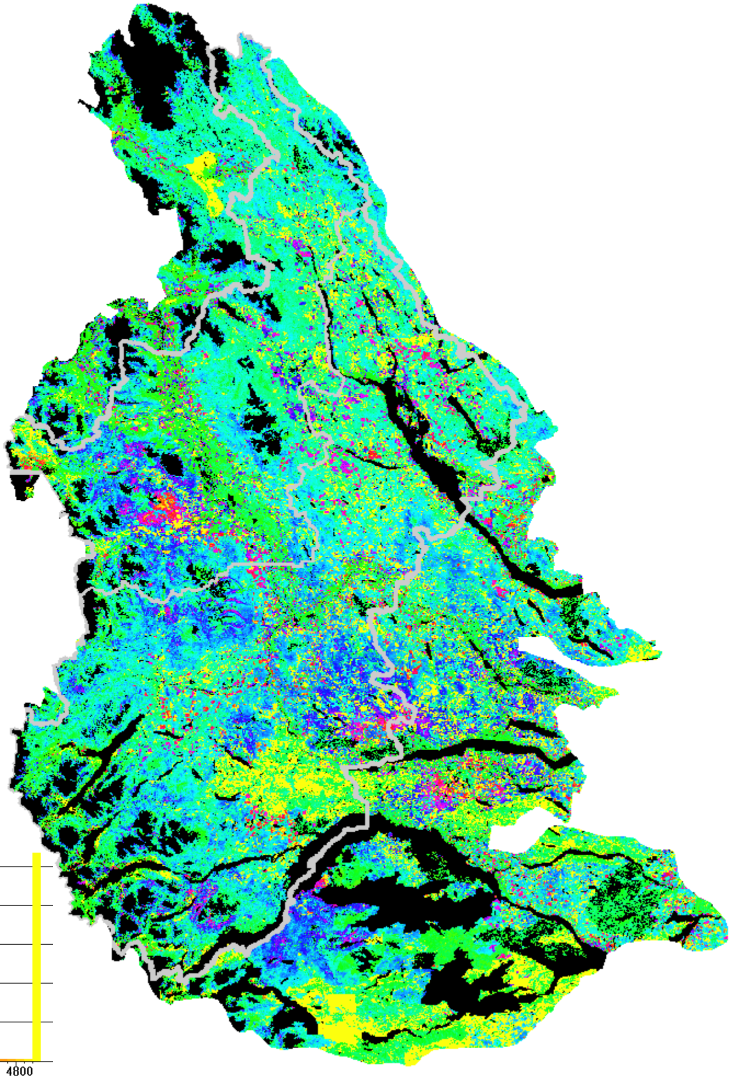
- Key component of fire hazard assessment
- Higher level of uncertainty compared to likelihoodof burning

Note: max. fire intensity can be significantly higher

Colours:

- Green: < 1,000 kW/m
- Light blue/dark blue/purple: 1,000-3,000 kW/m
- Pink/red: 3,000-5,000 kW/m
- Yellow: > 5,000 kW/m





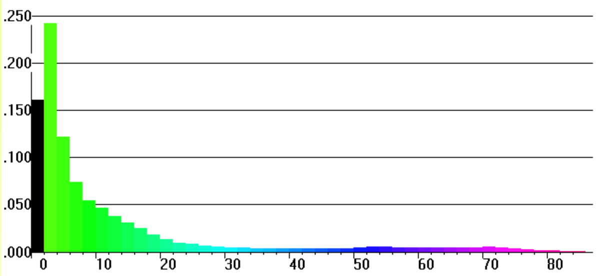
Estimated Fire Hazard

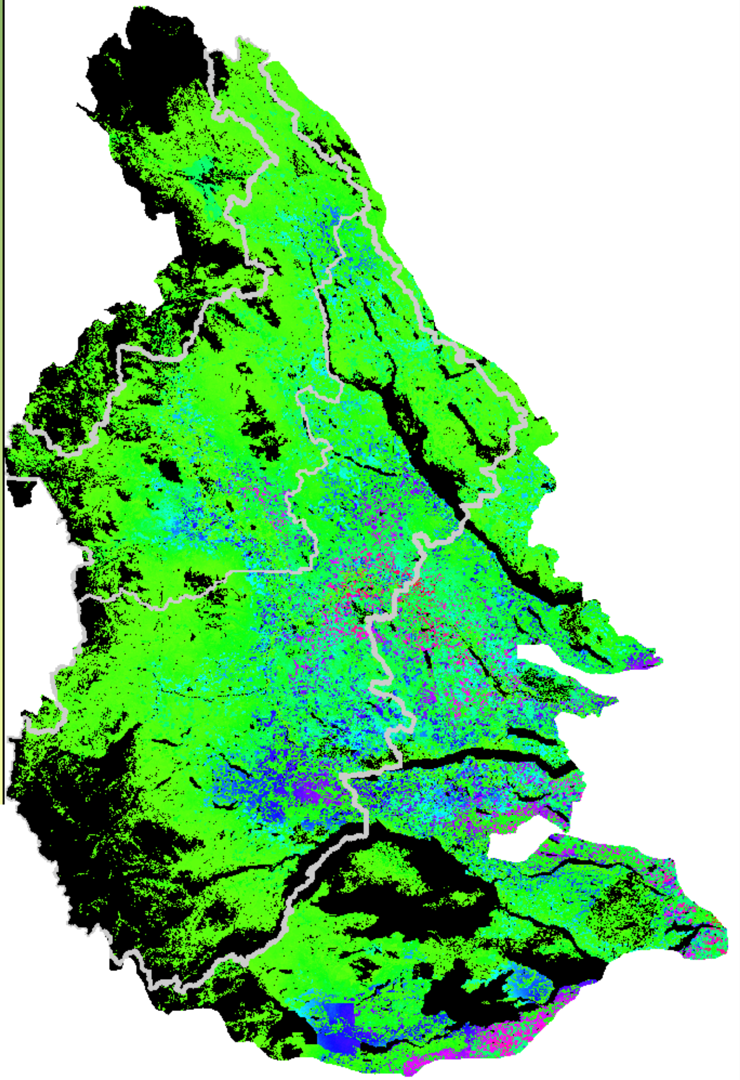
Burn Relative Likelihood * Fire Intensity

- Simple calculation of fire hazard
  - For display: fire intensity was capped at 5,000 kW/m
- Identifies areas with both relatively high likelihood and relatively high expected intensity

Colours:

- Green: relatively low
- Light blue/dark blue: relatively moderate
- Purple/pink/red: relatively high





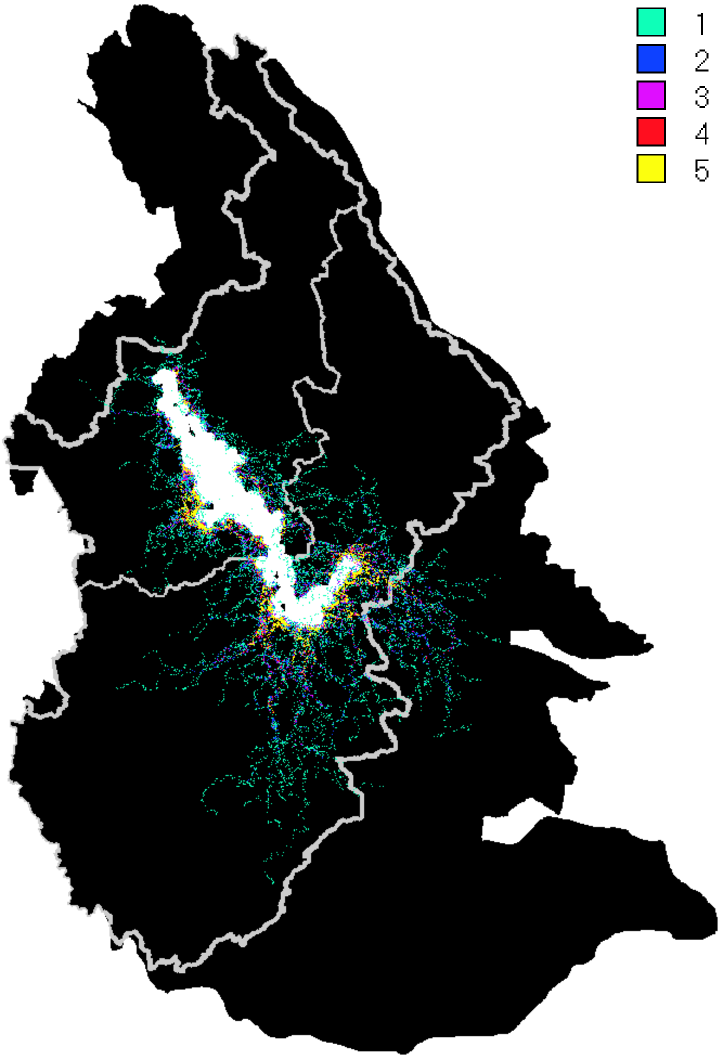
Fire Pathways

Wildfire hazard to identified areas (e.g. communities, rare ecosystems)

- Assessment of directions with relatively higher likelihood of hazard (community firesheds and fire pathways)

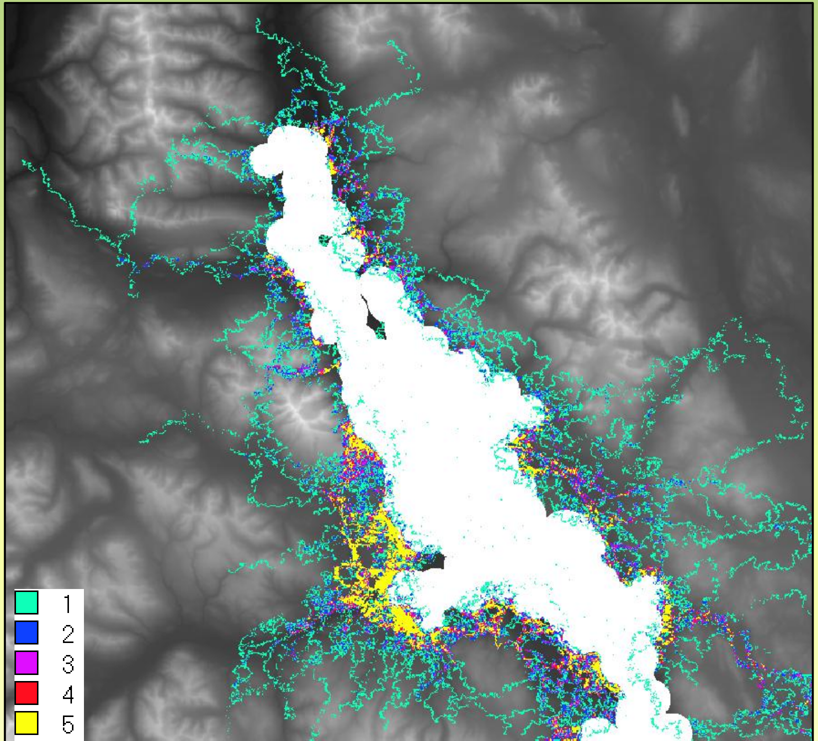
  Similar to Wang et al. 2024

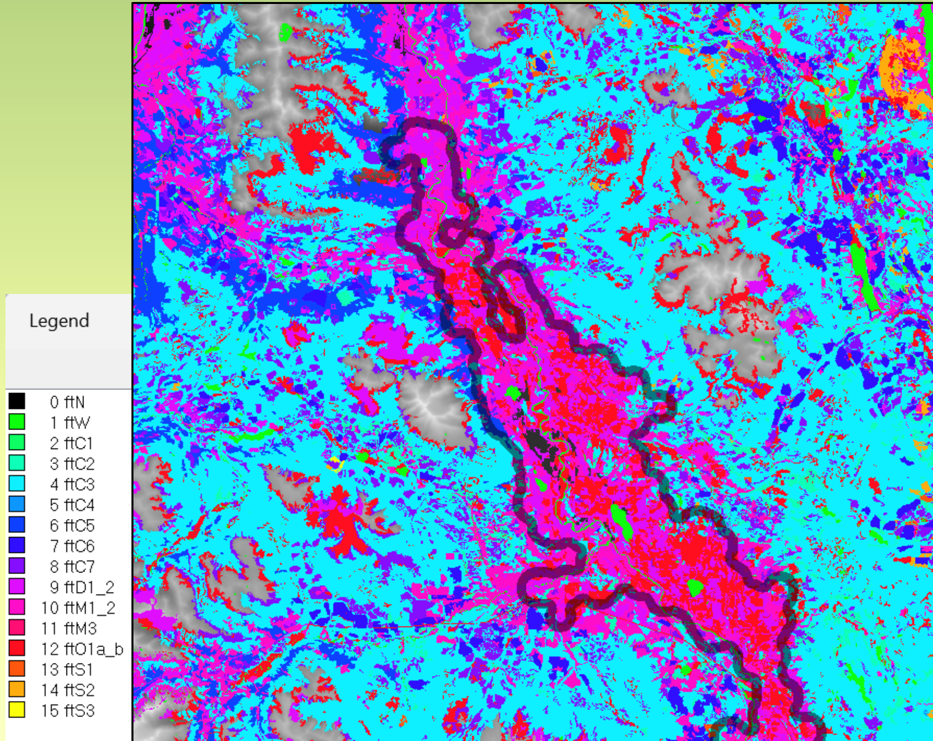
- Example: Bulkley Valley (Smithers/Telkwa and Houston)
  - Pathways of modelled fires that reach WUI boundary



Fire Pathways: Smithers/Telkwa

Focus on WUI around Smithers/Telkwa





Comparing Fire Pathways, Relative Burn Likelihood and Mean Burn Speed

Fire Pathways

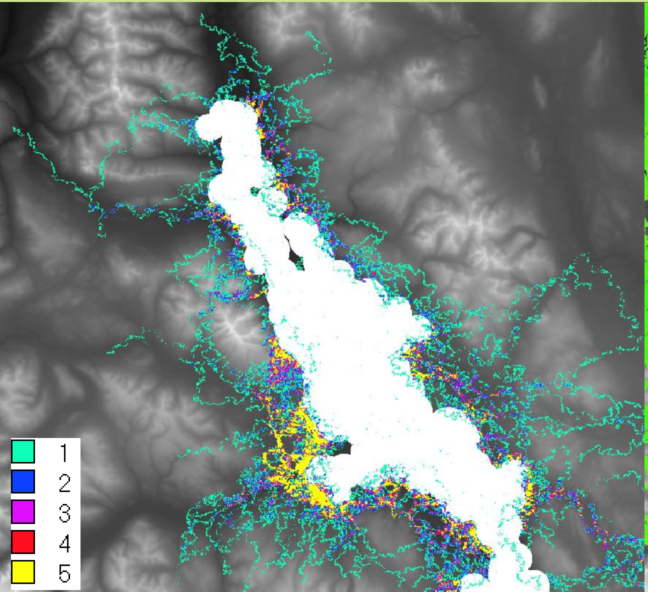
Colours: green: relatively low
blue: relatively moderate

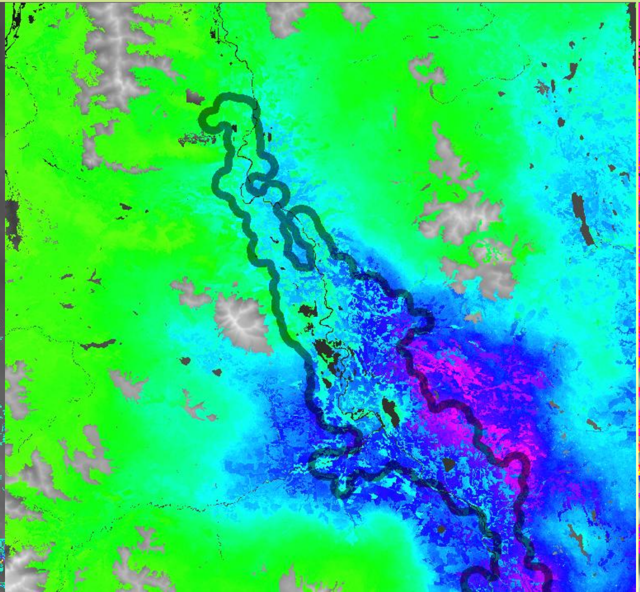
Times Burned

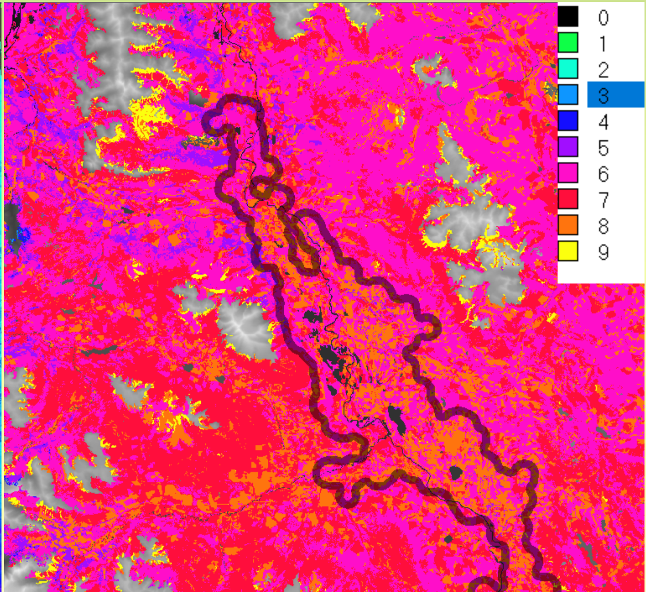
green: relatively low
blue: relatively moderate

Log of Burn Speed

blue/purple: moderate
pink/red/orange: relatively high







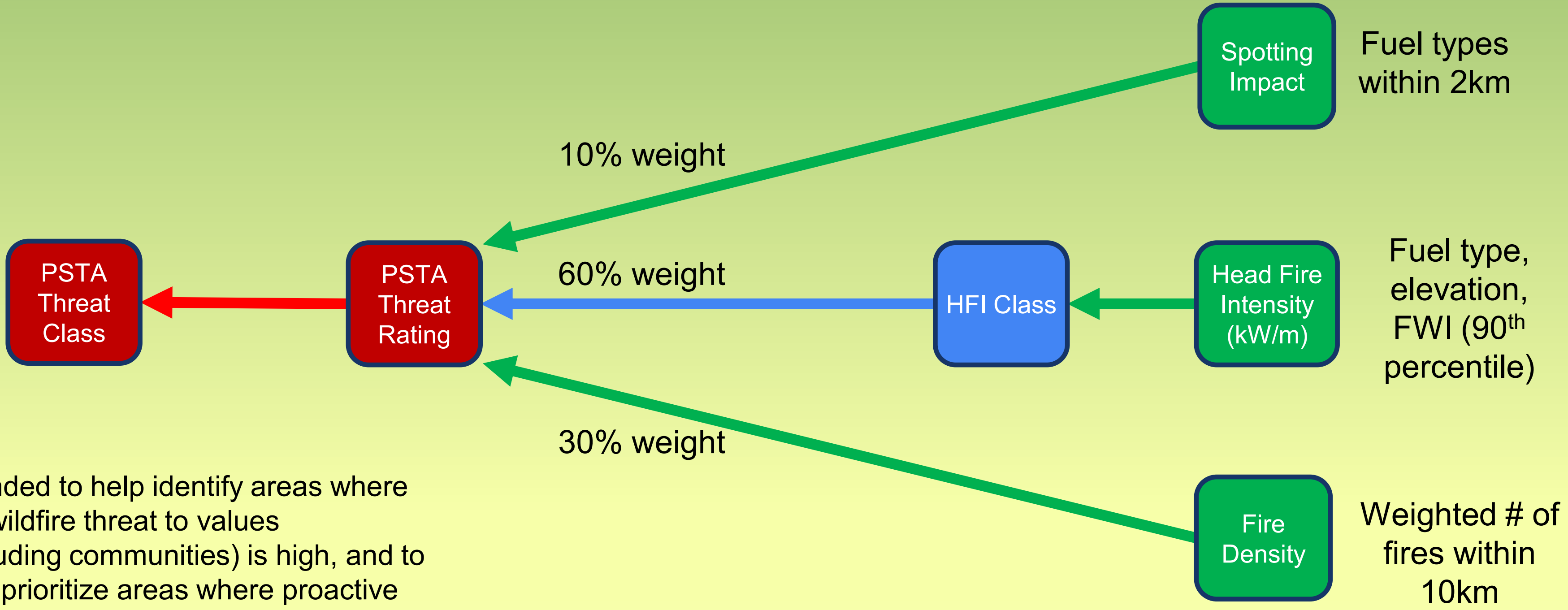
Time-based Empirical Fire (TEF) Model
Preliminary Application in the Bulkley-Morice Area

- TEF model design and inputs
- Set up and evaluation in the BuMo Study Area

- Assessing likelihood and hazard
- **Comparison with other approaches**

- Assessing potential effects of climate change

Provincial Strategic Threat Analysis (PSTA)

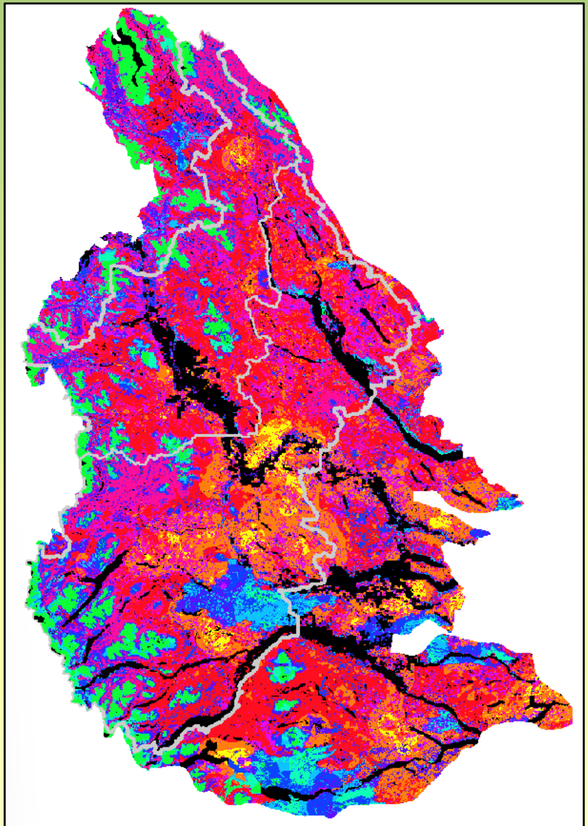


Intended to help identify areas where the wildfire threat to values (including communities) is high, and to help prioritize areas where proactive investment would help mitigate those potential impacts

PRELIMINARY RESULTS

PSTA Threat Rating vs Burn Relative Likelihood

2024 PSTA Threat Rating

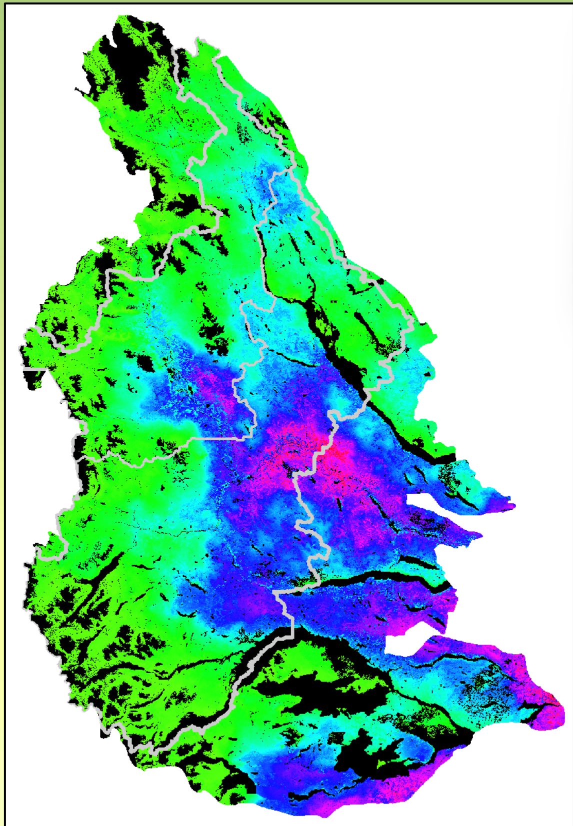


Times Burned

Effects of fuel, topography and wind patterns

Colours:

- Green: low
- Blue: medium
- Pink/red/yellow: high



Burn-P3

At a high level: similar design objectives to TEF

Some fine-scale differences:

- Burn-P3 invokes the fire growth model *Prometheus* for the modelled fire spread
  - Burn-P3 coordinates use of Prometheus to assess the relative likelihood of burn
- Prometheus:
  - Designed to predict growth of a specific fire under specific conditions (finer-scale than TEF)
  - deterministic (TEF is stochastic)
  - Based on the FBP system (as is TEF)
  - Fire perimeter expands as a connected boundary of points

Why use TEF instead of Burn-P3?

- Flexibility and potential to connect with other models
  (e.g. forest landscape models)

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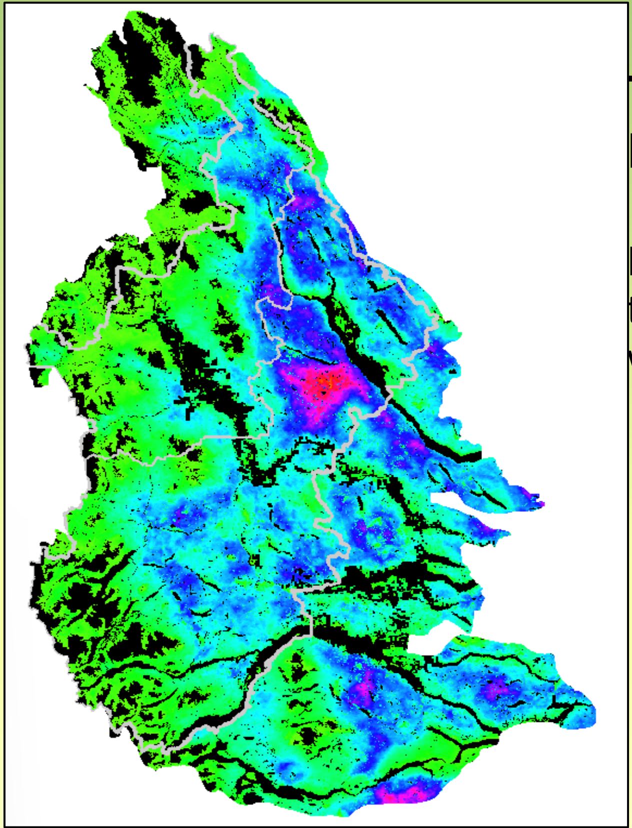
PRELIMINARY RESULTS

Burn Relative Likelihood: Burn-P3 vs TEF

Burn-P3

Output from 2020

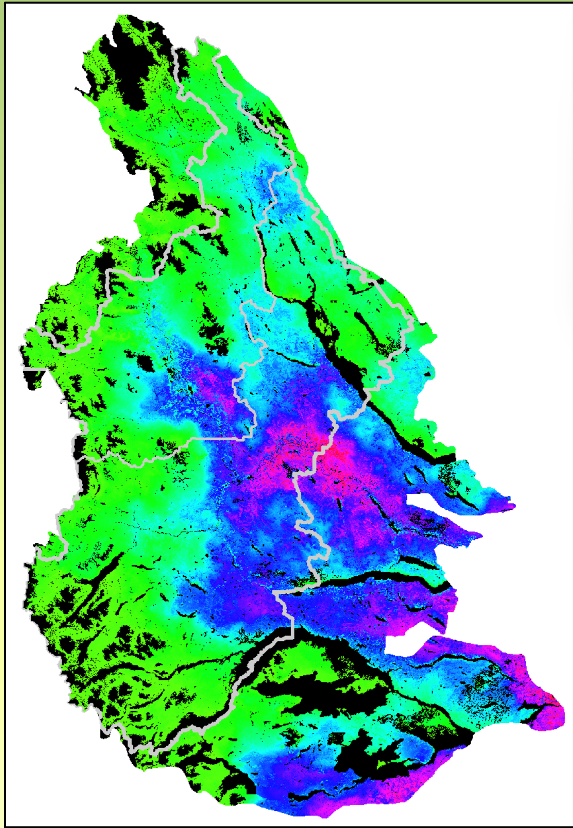
20-year burn probability



Times Burned

Effects of fuel, topography and wind patterns

Colours:
Green: low
Blue: medium
Pink/red/yellow: high



Small Group Discussion and Report Out

Details:

1:20 – 2:00 (40 minutes)
3 groups/hazard maps of sample areas where something interesting is going on, and structured questions.

Facilitated conversation about trends/patterns

1. Upland forest south of the Babine Mountains,
2. WUI near Granisle
3. Recent historic burns, 2018 Nadina fire

2:00-2:15 (15 minutes)
5-minute report out by each small group facilitator in full plenary.

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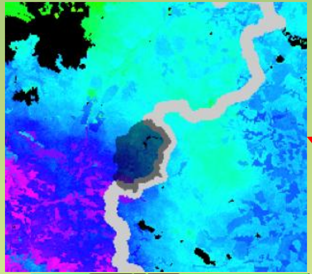
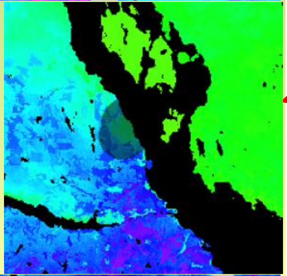
Relative Likelihood of Burning

➢ Three areas for discussion focus

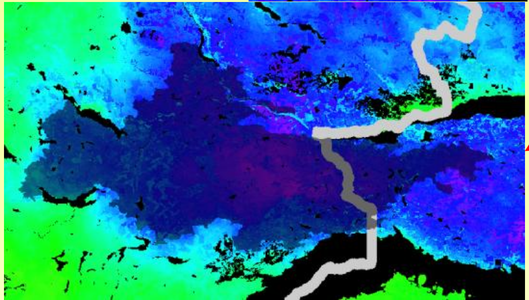
1. Forest values
   - South of Babine Mountains

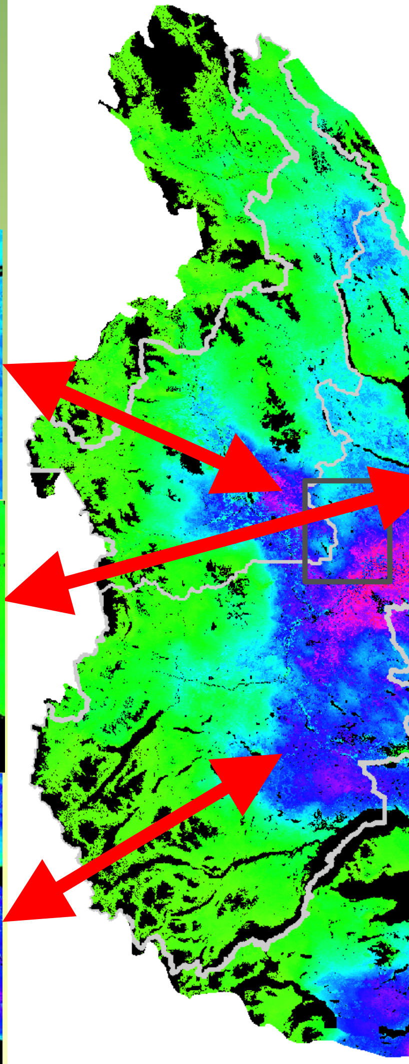


2. Communities
   - WUI around Granisle: “firesheds”
   - Lake effect regarding prevailing wind direction (“fetch”)



3. Recent burned areas: Nadina Fire
   - Changes in fuel over time following fire





Colours:

- Green: low (< 30)
- Cyan/blue: medium (60-100)
- Pink/red/yellow: high (> 130)

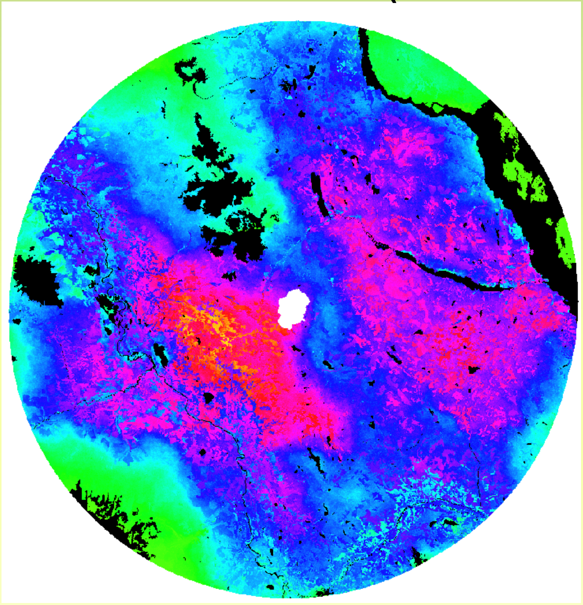
Break out Group Discussion

Relative Likelihood of Burning

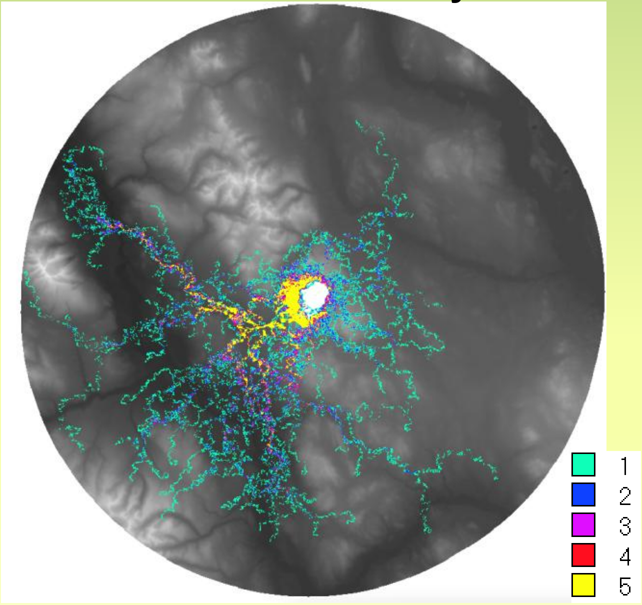
1. Forest values: Core Ecosystem south of Babine Mountains

- ➢ What are the primary drivers related to relative burn likelihood?
- ➢ What are key uncertainties, and ways to improve?
- ➢ What are some strategic/tactical decisions that might use this type of info?

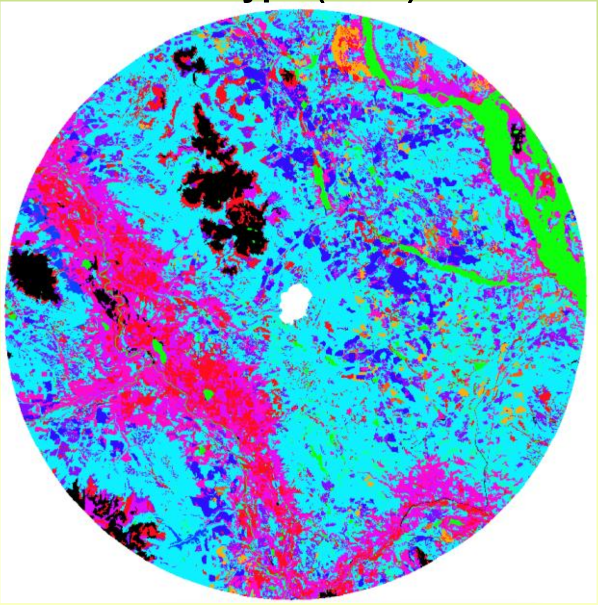
Times Burned (within 40km)



Fire Pathways



Fuel Type (2024)



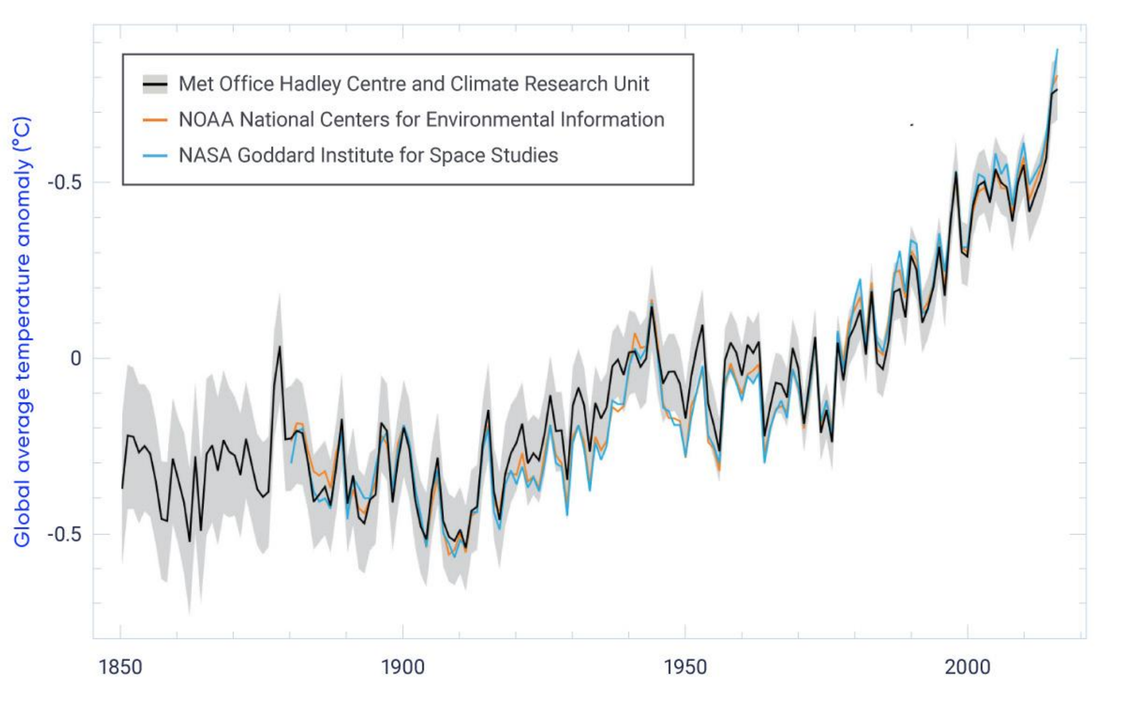
Climate change and future fire

Outline

- Climate change averages
- Climate Extremes
- Projected fire

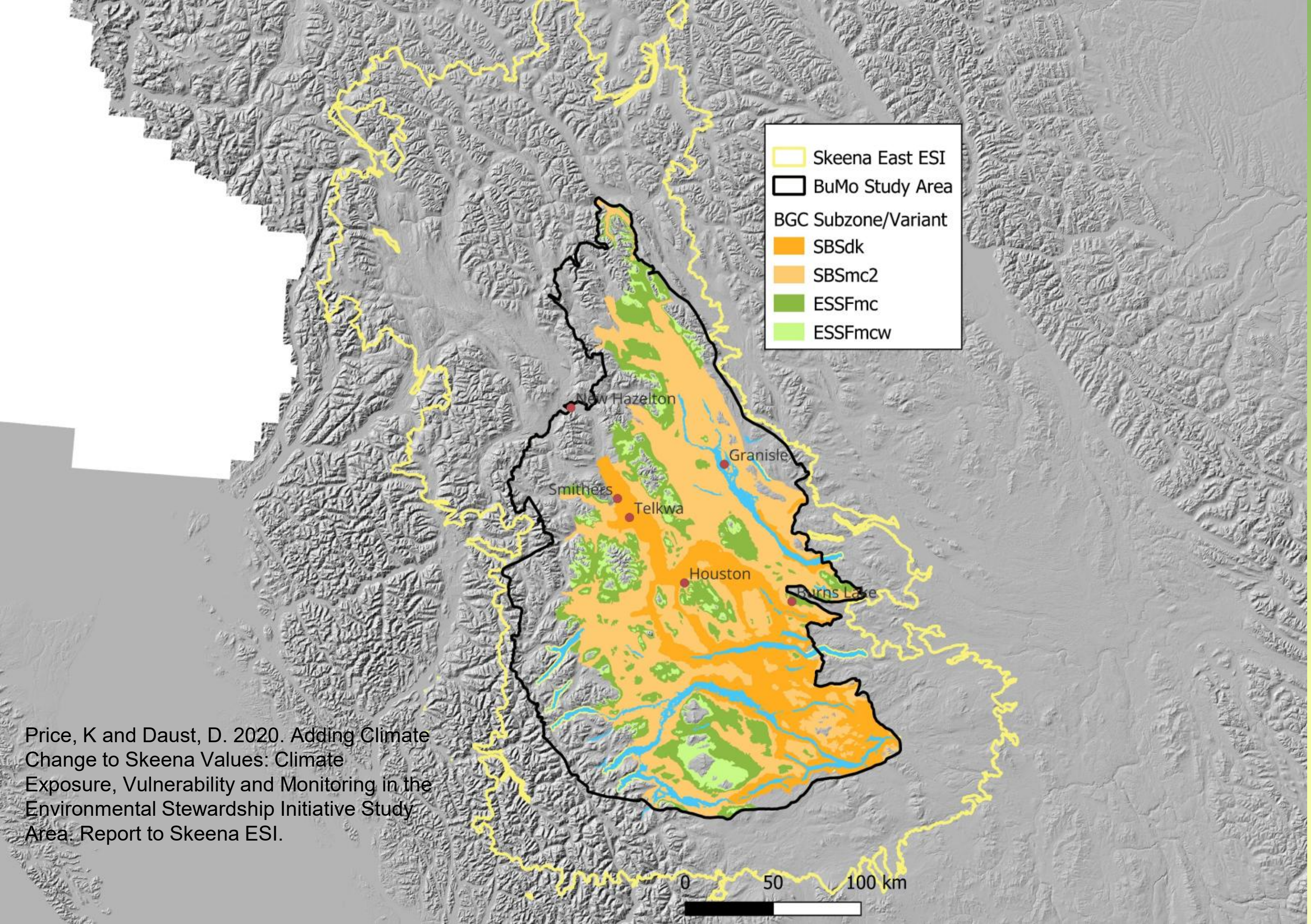
Bulkley Morice
WILDFIRE
RESILIENCE
PROJECT

Global temperature increasing



Canada is warming at 2X the global rate

United in Science 2019 UN World Meteorological Organization



Price, K and Daust, D. 2020. Adding Climate Change to Skeena Values: Climate Exposure, Vulnerability and Monitoring in the Environmental Stewardship Initiative Study Area. Report to Skeena ESI.

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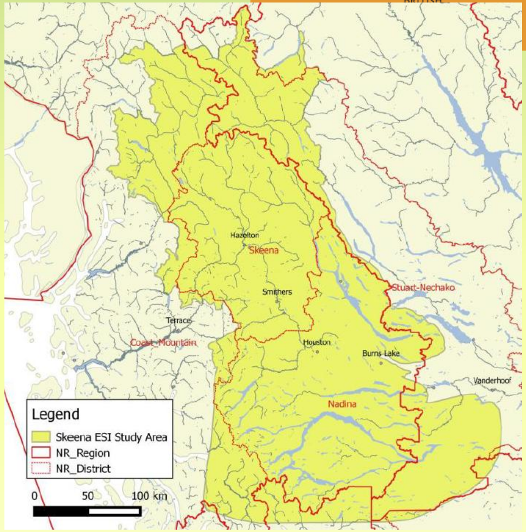
Skeena District Climate Projections 2055

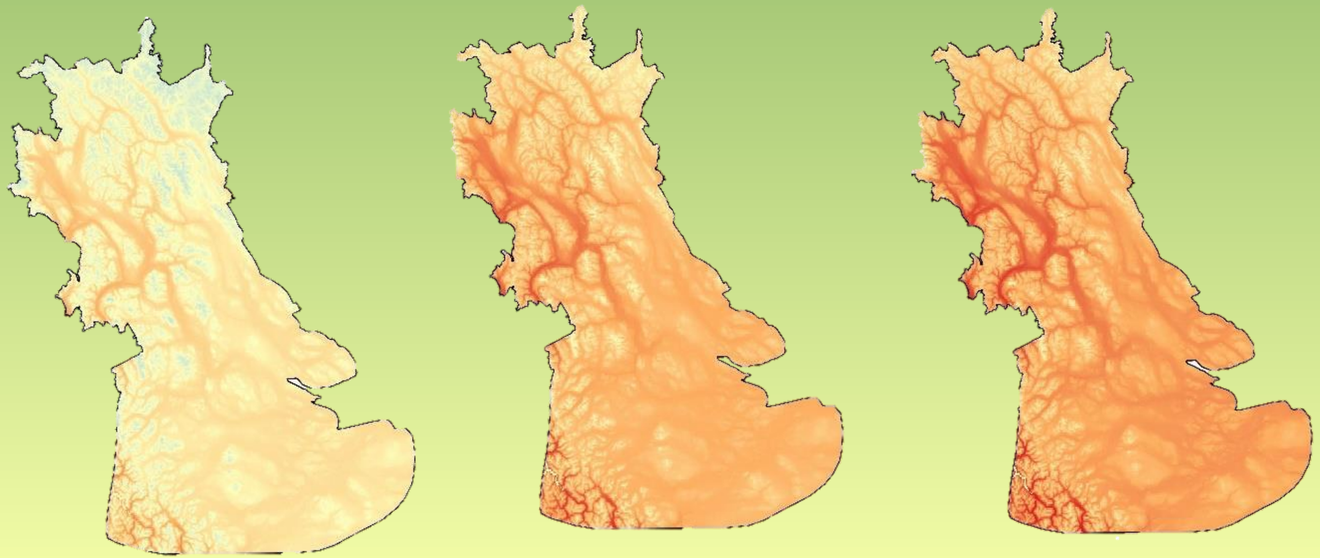
Variable	Winter	Summer
Mean temp (C)	+ 3.1	+ 3.6
Changed ppt (%)	+ 4.9	- 0.3
Moisture deficit (mm)	0	42
Changed ppt as snow (%)	- 30	

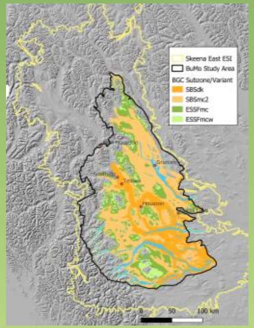
- All seasons warmer; summers warm most
- More rain, less snow
- Drier in summer—drought stress

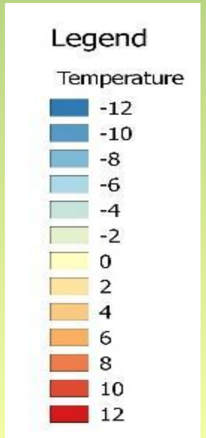
Foord V. 2016 TR097



Projected temperature 2055





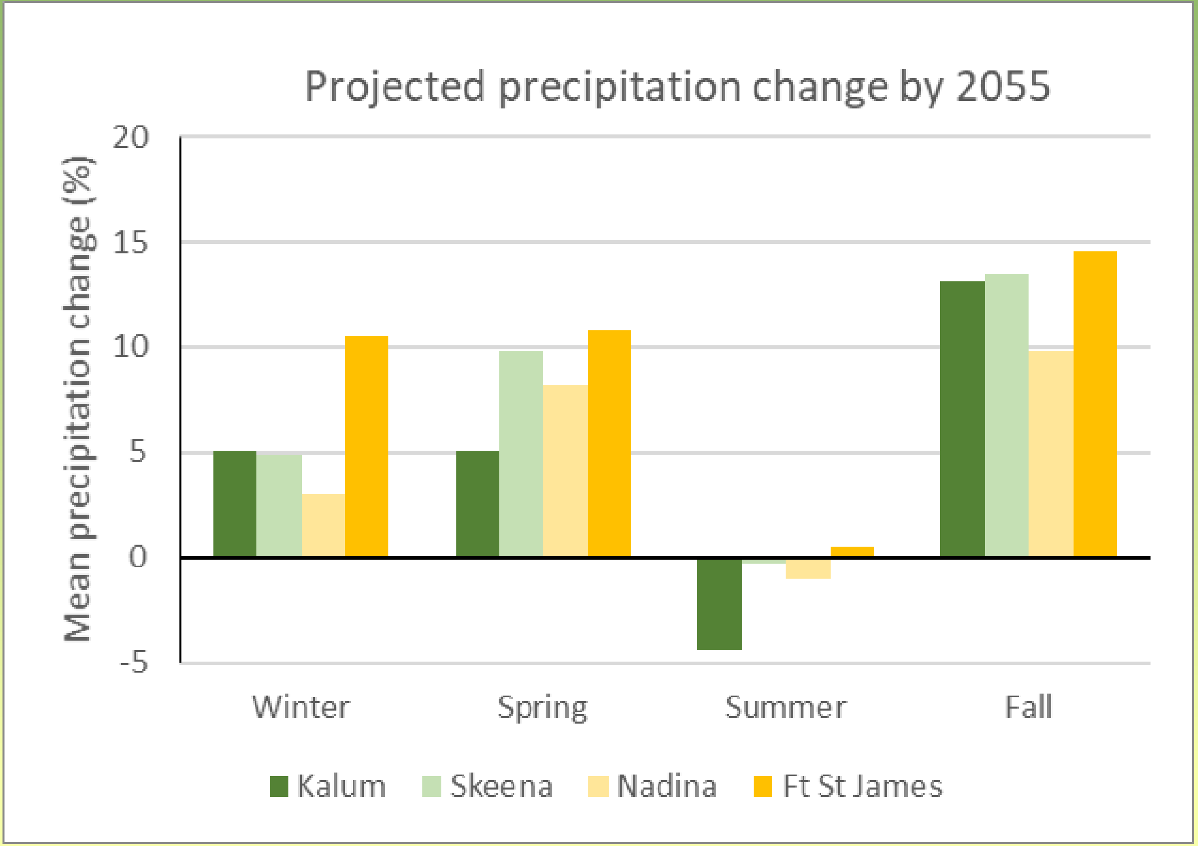


1960-90

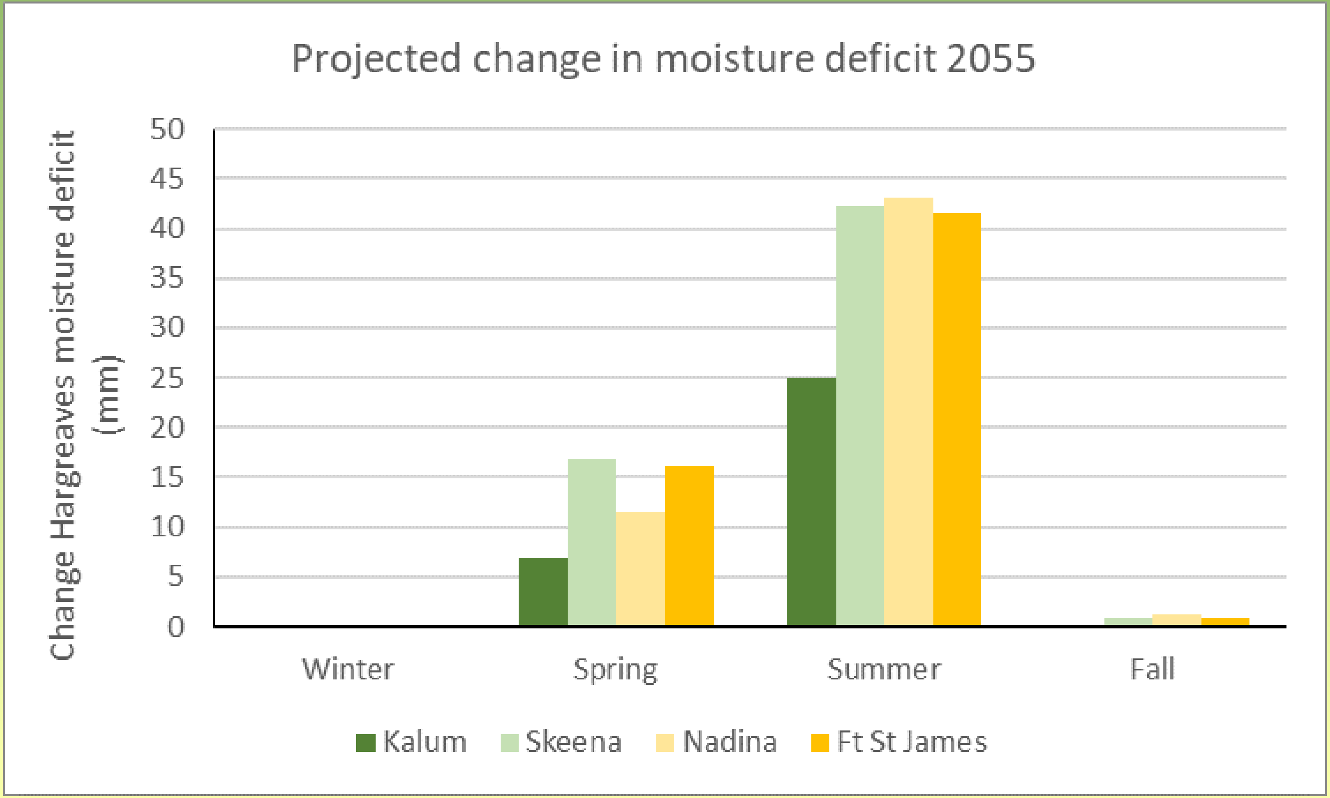
2040-70
CCSM4

2040-70
Can ESM2

- Average increase more than 3 – 4C (Smithers to Merritt)
- Most in summer

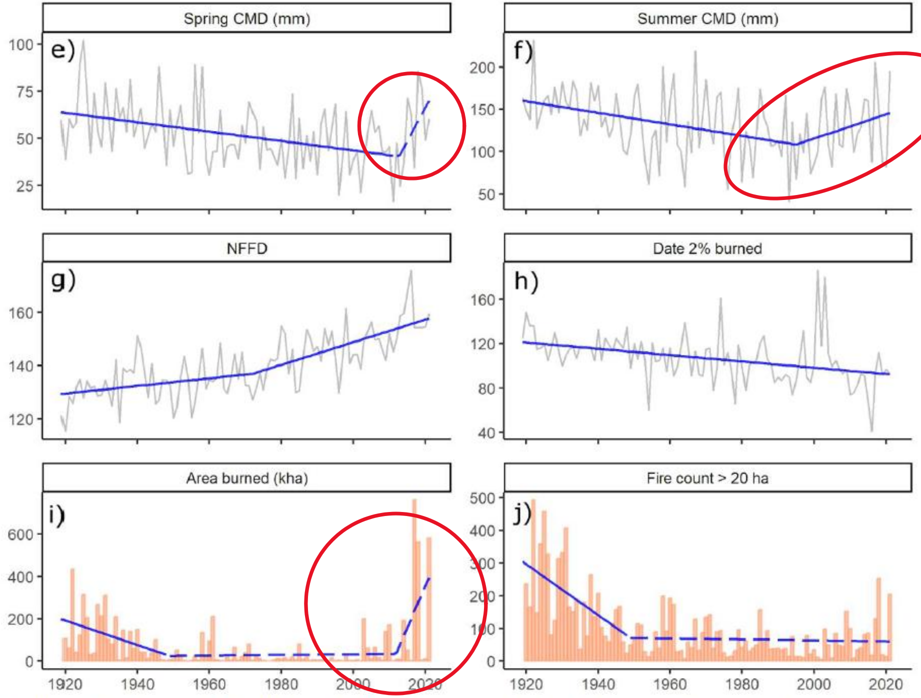


Average increase by 5 – 10% except summer



Increase substantially

Wildfire



Supplementary Figure 2. Central zone trends in temperature (a, b), total precipitation (c, d), climatic moisture deficit (CMD) (e, f), number of frost-free days (NFFD) (g), date at which 2% of cumulative annual area burned is reached (h), annual area burned (i), and annual number of fires larger than 20 ha (j). Gray lines indicate annual means and, blue lines represent segmented regression trendlines. Solid lines indicate a significant trend (one-sided Mann-Kendall test, $p < 0.10$).

Parisien, M. A., Barber, Q. E., Bourbonnais, M. L., Daniels, L. D., Flannigan, M. D., Gray, R. W., ... & Whitman, E. (2023). Abrupt, climate-induced increase in wildfires in British Columbia since the mid-2000s. Communications Earth & Environment, 4(1), 309.

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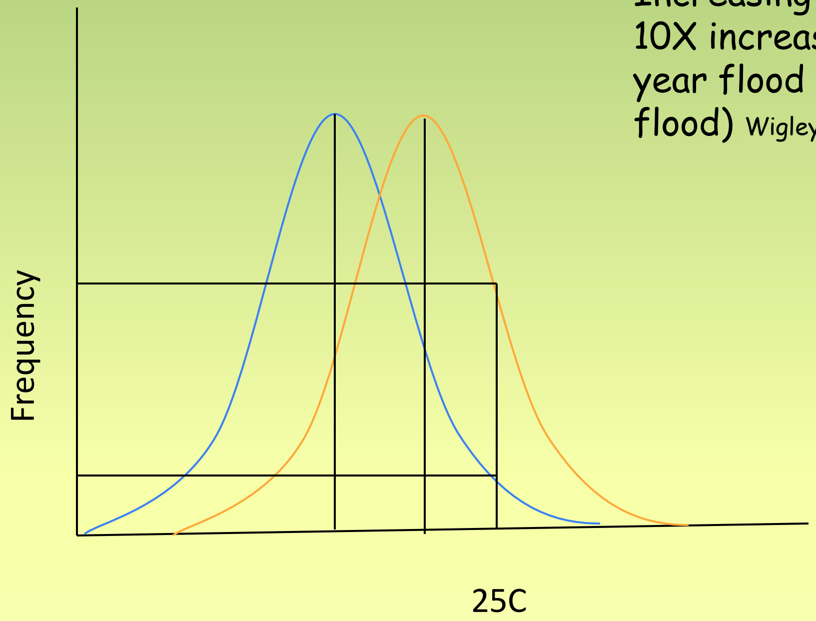
Extremes



- Small change in mean leads to big increase in frequency of extremes
- Increasing mean by 1 SD can lead to 10X increase in extremes (e.g., 100-year flood can become a 10-year flood) Wigley 2009

Increasing Variability

- Short intense rainstorms—atmospheric rivers
- Non-linear effects of jet-stream—more variable cold fronts
- Increased freeze/thaw cycles

Heatwaves 2-10 x more likely

- In 2025, 9 climate-change related heatwaves in Canada
- Northern British Columbia
  - August 23 to September 9
  - Peak daily high temperature during the heat wave: 23.5 ˚C
  - Degrees above normal daily high temperature: 9.6 ˚C

https://www.canada.ca/en/environment-climate-change/news/2025/09/recent-canadian-heat-waves-made-much-more-likely-by-human-caused-climate-change.html

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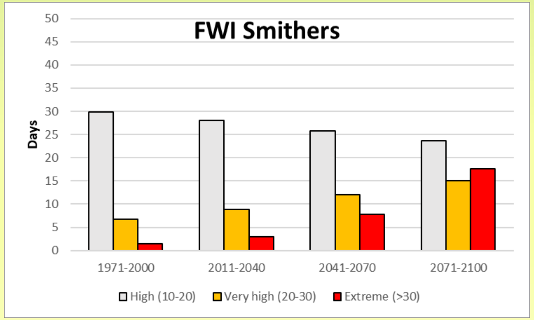
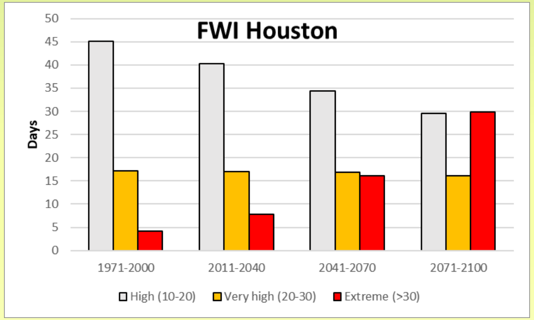
Fire Trends and Projections

Projected fire weather

- 2 x CO2 → 46% increase in seasonal severity rating
  - (Flannigan and Van Wagner 1991)
- 3 × CO_2 scenario → 74 to 118% increase in AAB
  - (Flannigan et al 2005)
- SRES A2 → 3.7 x AAB (Canada)
  - (Boulanger et al. 2014)





(https://climatedata.ca/app/fire-weather-projections/)

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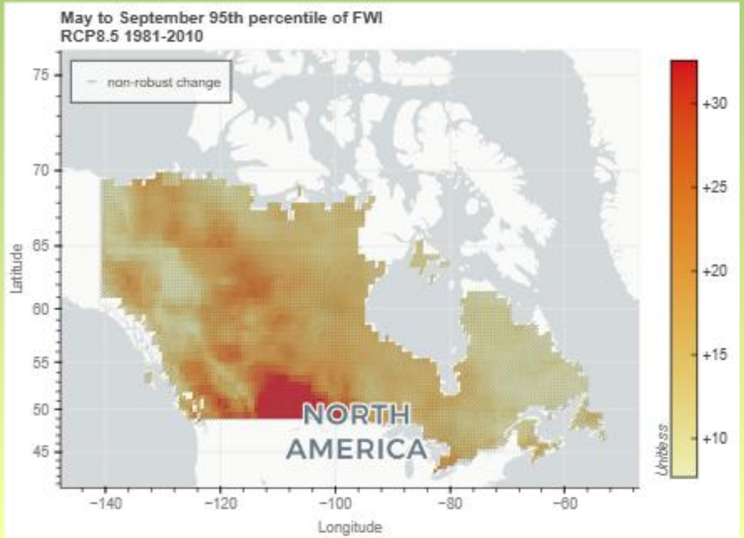
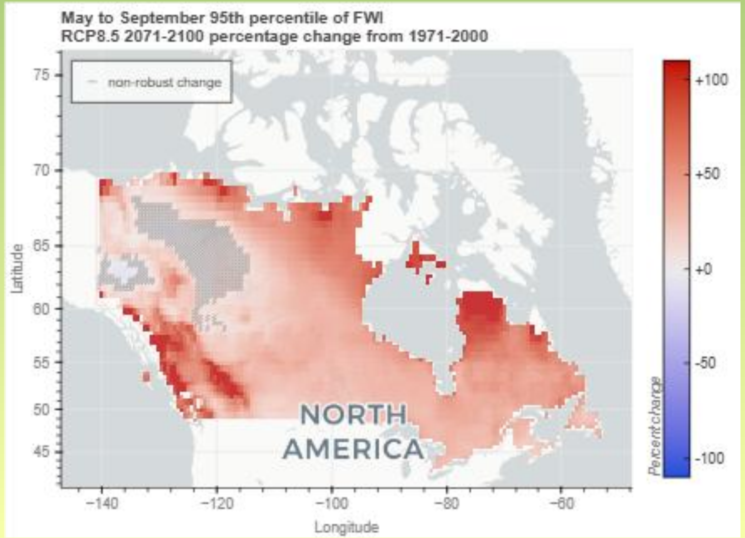
Peak FWI values could double





https://climatedata.ca/app/fire-weather-projections/

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How to fight fire—step one

- "Global climate change below 2 ˚C avoids large end-of-century increases in burned area in Canada"

Curasi, S. R., Melton, J. R., Arora, V. K., Humphreys, E. R., & Whaley, C. H. (2024). Global climate change below 2° C avoids large end century increases in burned area in Canada. npj Climate and Atmospheric Science, 7(1), 228.

Time-based Empirical Fire (TEF) Model Preliminary Application in the Bulkley-Morice Area

- TEF model design and inputs
- Set up and evaluation in the BuMo Study Area

- Assessing likelihood and hazard
- Comparison with other approaches

- **Assessing potential effects of climate change**

Some Potential Effects of Climate Change on Wildfire

Ignitions per year: increase (or decrease)

- TEF: focus on a single ignition

Spread: Fires may spread faster or slower due to

- Changes in fuel
- Changes in weather (wind, drought, build-up)

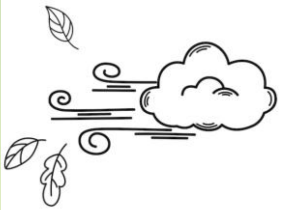
Extinguishment: fires may spread longer (or shorter)

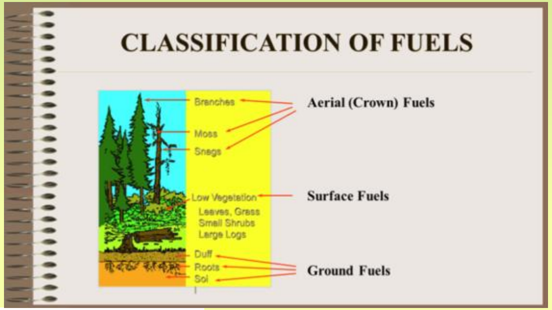
Effects: fire intensity may increase (or decrease)

➢ **Changes in multiple factors will likely have non-linear effects**

Rate of spread based on FBP Fuel Types

Rate of spread (ROS)





Wind speed & direction

Fine fuel moisture

Prior weather build-up

Fuel type

Slope & aspect

FASTER

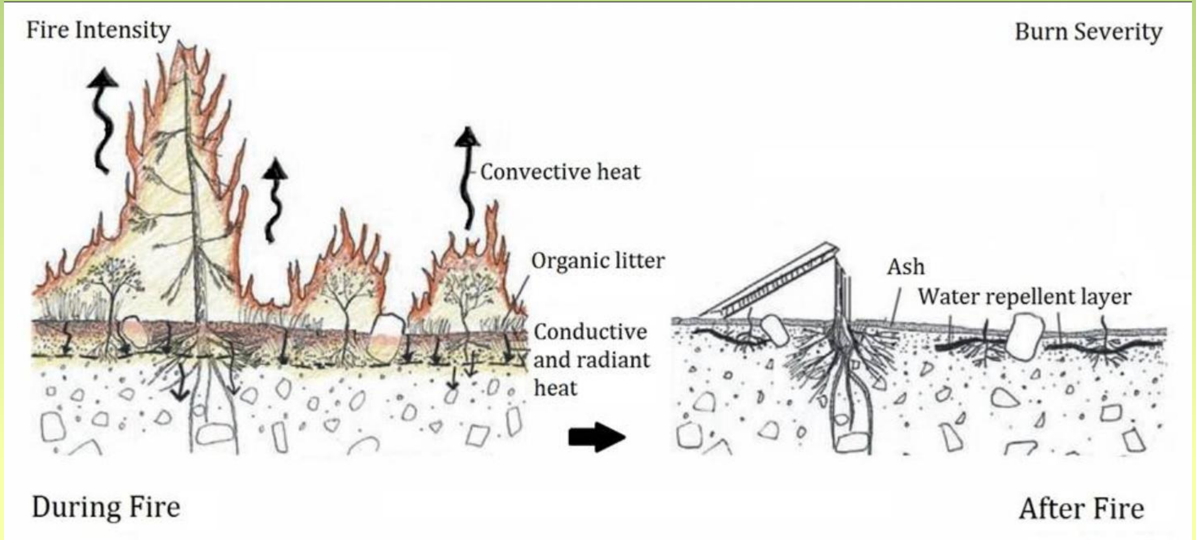
Temporal change

SLOWER

Fire Intensity based on the FBP System

Fire Intensity
(FI)

Fire Intensity = Heat * fuel consumed * rate of spread



UN Office for Outer Space Affairs

Heat of combustion

Total Fuel Consumed

Rate of spread (ROS)

Simple Exploratory Scenarios

Scenario 1: increased rate of spread

- Same as base scenario *except* increase the average rate of spread by 20%

Scenario 2: increased fire duration

- Same as base scenario except increase the average fire duration by 20%

Scenario 3: both 1&2

These scenarios do not make assumptions about the cause of the increases, just the net outcome

Overall Outcome: average area burned per fire

Rate of Spread / Duration	Base scenario	20% faster rate of spread
Base scenario	-	+41%
20% longer durations	+40%	+117%

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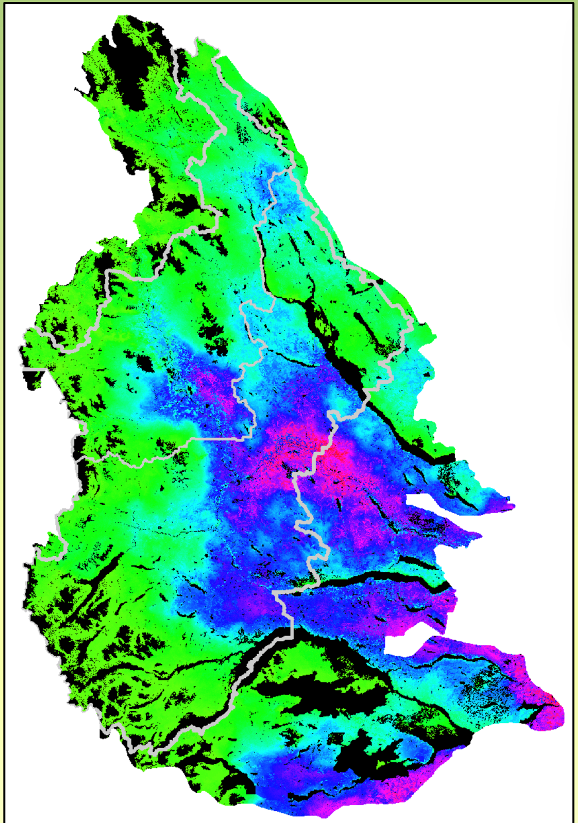
PRELIMINARY RESULTS

Burn Relative Likelihood (Times Burned):

Base Scenario



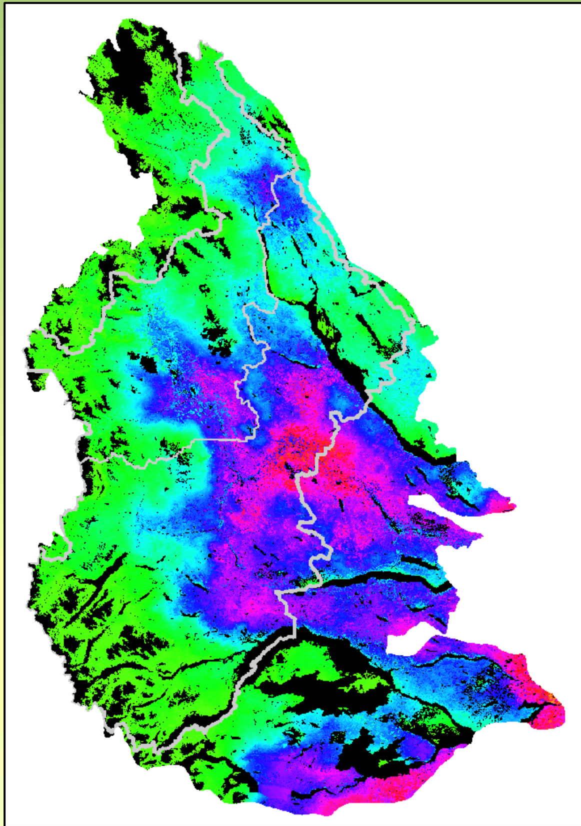
Colours:

Green: low

Blue: medium

Pink/red/yellow: high

Increased Fire Duration (20%)



PRELIMINARY RESULTS

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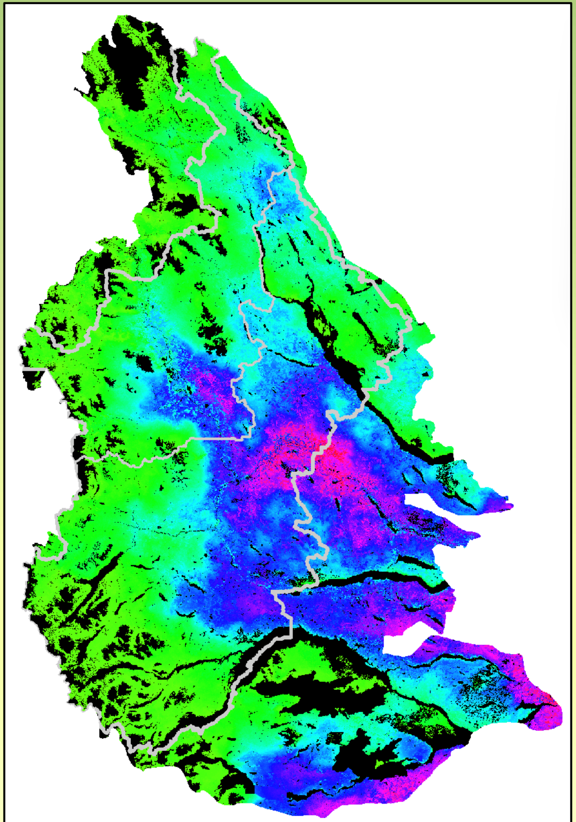
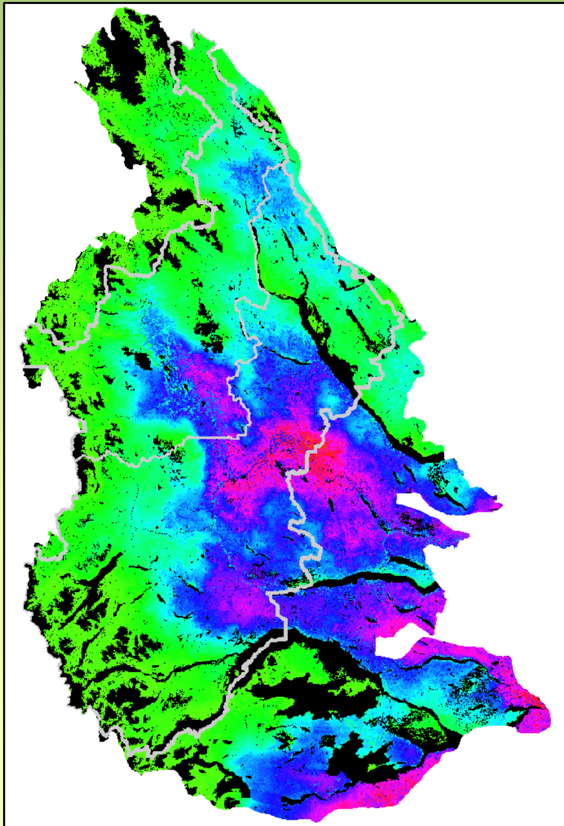


Increased Rate of Spread (20%)



PRELIMINARY RESULTS

Fire Intensity

Base Scenario

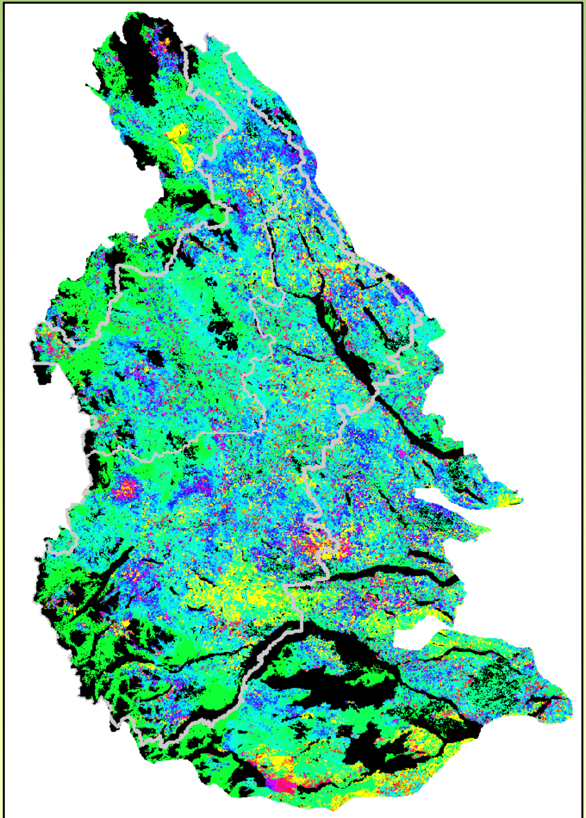
Colours:

Green/cyan/light blue:
< 400 kW/m

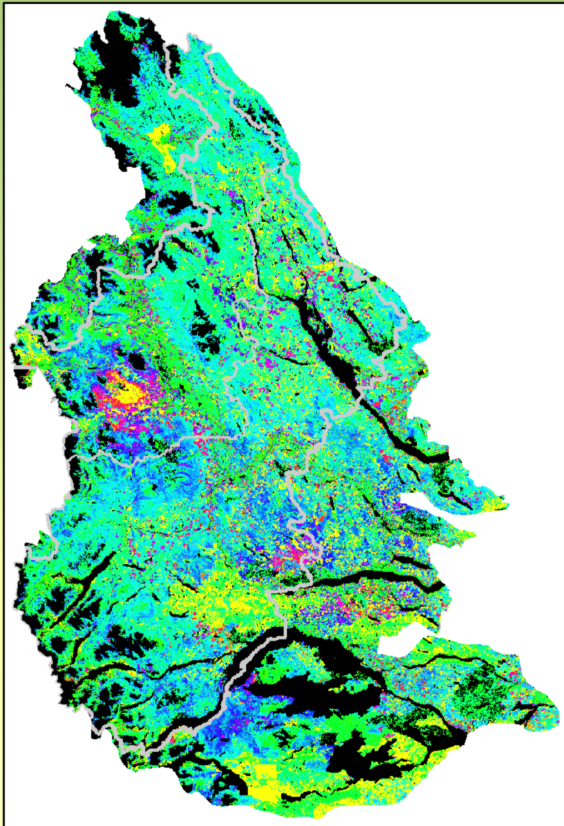
Dark Blue/purple:
400-600 kW/m

Pink/red:
600-1,000 kW/m

Yellow:
> 1,000 kW/m

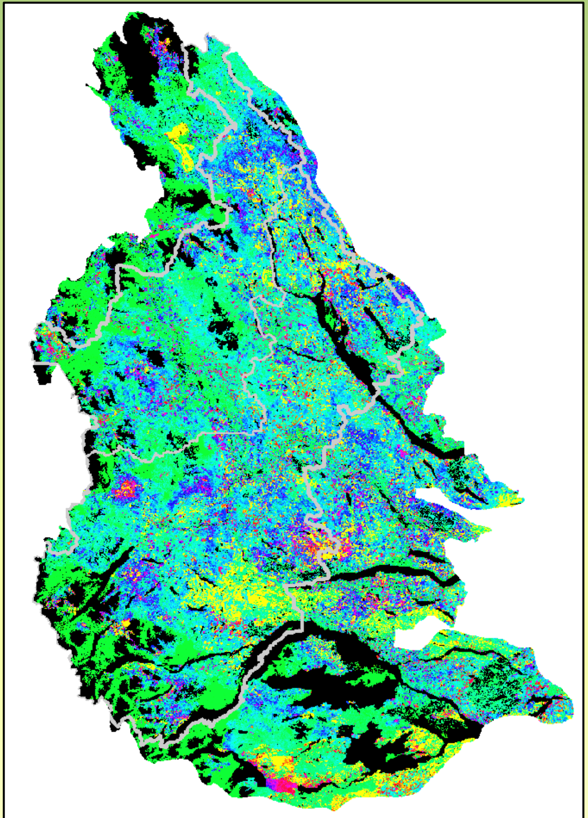


Increased Fire Duration (20%)



Fire Intensity

Base Scenario



Colours:

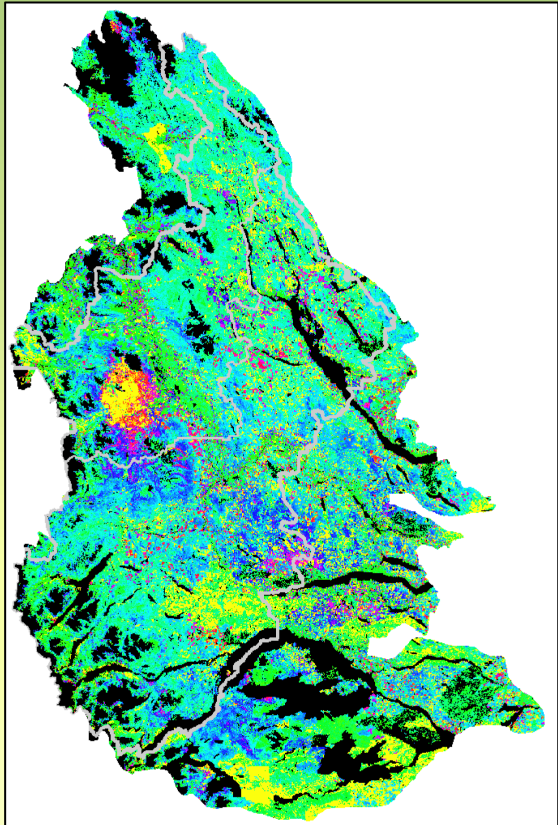
Green/cyan/light blue:
< 400 kW/m

Dark Blue/purple:
400-600 kW/m

Pink/red:
600-1,000 kW/m

Yellow:
> 1,000 kW/m

Increased Rate of Spread (20%)



What does this show?

The effects of climate change on wildfire are complex

Linear effects on different factors are not equal

- Linear (power 1): changes in number of fires
  - e.g. 20% more fires => 20% more expected area burned
- Geometric (power 2): changes in rate of spread or fire duration
  - e.g. 20% longer duration or faster fires => ~40% more area burned ($120\%^2 = 1.44\%$)

Some effects combine by multiplication

- e.g. increasing both rate of spread *and* duration by 20% => 113% more expected area burned

Effects may be similar for area burned, not for fire intensity

- e.g. fire intensity is more sensitive to rate of spread than fire duration

Questions

What is known about likely/potential effects of climate change on the elements related to wildfire initiation, spread and extinguishment?

Learning vs. Management scenarios

Learning Scenarios

- Educational or exploratory exercises designed to build knowledge and awareness about systems. ***They are not about making binding decisions but about understanding complexities.***
- **Purpose:** To help researchers, practitioners and managers explore ecological, social, and management dynamics.

The BuMo project will undertake learning scenarios

Management scenarios

- In contrast, management scenarios are decision-oriented frameworks used by land managers, policymakers, or communities to guide actual resource and land use.
- They involve real choices, often trade-offs with consequences.
- **Purpose:** To evaluate options and select strategies for forest and wildfire management.

Management scenarios are the work of the project clients such as the FLP table. TEF can run assessments of management scenarios against BuMo wildfire indicators.

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Learning vs. Management scenarios

Aspect	Learning Scenarios	Management Scenarios
Goal	Build knowledge, test ideas	Decisions, strategies and policy direction
Context	Research, educational	Operational, policy, governance
Risk level	Low – hypothetical & exploratory	High – real world consequences
Stakeholders	Researchers, knowledge holders, land managers	Decision makers, planning tables, policy makers
Output	Knowledge, insights	Plans, regulations, actions

Learning Examples:

- Simulating how much treatment is required to make a significant difference in wildfire hazard
- Simulating the landscape effect of treatment arrangements on wildfire hazard
- Simulating how different harvesting techniques affect surface fire spread.
- Modelling climate change impacts on wildfire behaviour.

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Scenario direction

In June, the Steering Committee provided direction to:

Evaluate how much treatment is needed, bounded and unbounded by social choice or capacity

1. Hazard reduction - constrained:
   - assume the policy/social constraints are binding
   - assume capacity is limited
2. Hazard reduction – unconstrained:
   - assume human resource capacity is not limiting
   - assume the policy/social constraints are flexible

Evaluate treatment scenarios for resilience indicators

3. Beneficial wildfire/ecosystem landscape (resilience indicators).
   - values for fire size, fire severity, fire frequency, stand composition, and landscape pattern

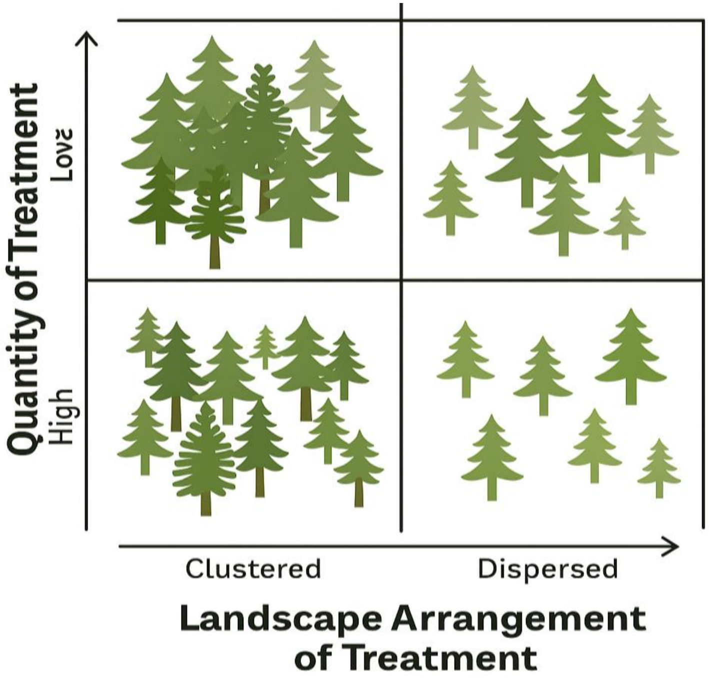
Example: Amount and Arrangement of Treatments

Scenario: Hazard reduction unconstrained by cost and social interests.

Questions:
Simulating how much treatment (quantity) may be required to make a difference?

How does the spatial arrangement of treatments on the landscape affect the hazard level?

Output:
Hectares by hazard category
- *Surface and crown fire spread*
- *Size*
- *Intensity*

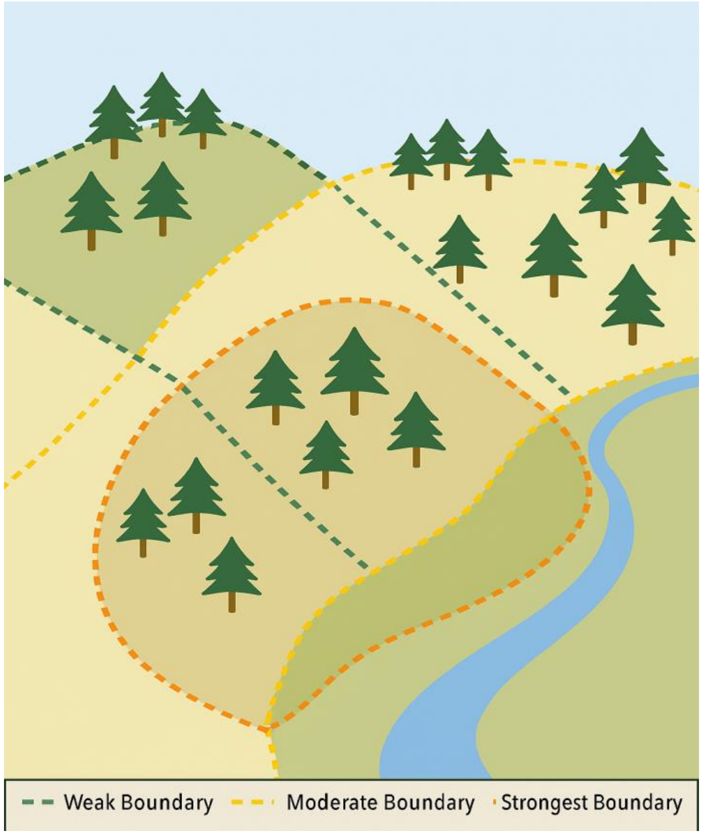


Example: PODs and potential control features

Scenario: Hazard reduction is guided by POD objectives and landscape attributes.

Treatment placement is determined by the strength of potential control features and the overall objective for the POD.

Question: *What is the effect of landscape POD planning on hazard reduction?*



Wildfire resilience indicators

Question: *How do treatment placement and suppression objectives encourage resistance in some areas, while allowing more fire in others?*

Outputs: Resilience indicators, may include - fire size, severity, frequency, landscape pattern

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Steering Committee Direction

What are your key learnings from today?
What areas of uncertainty do you see?
What are your hopes for what this project can deliver?

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