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Predicting fire behaviour in shrub vegetation assemblage

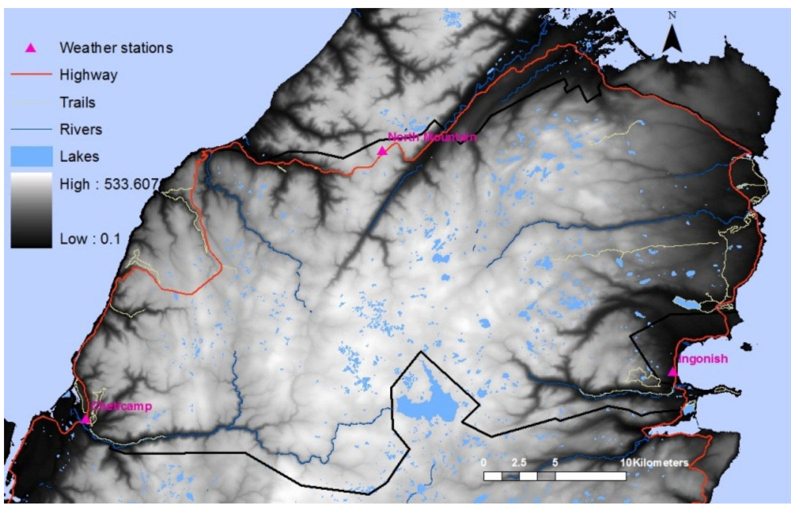
Anne-Claude Pépin,
Wildland Fire conference 2010

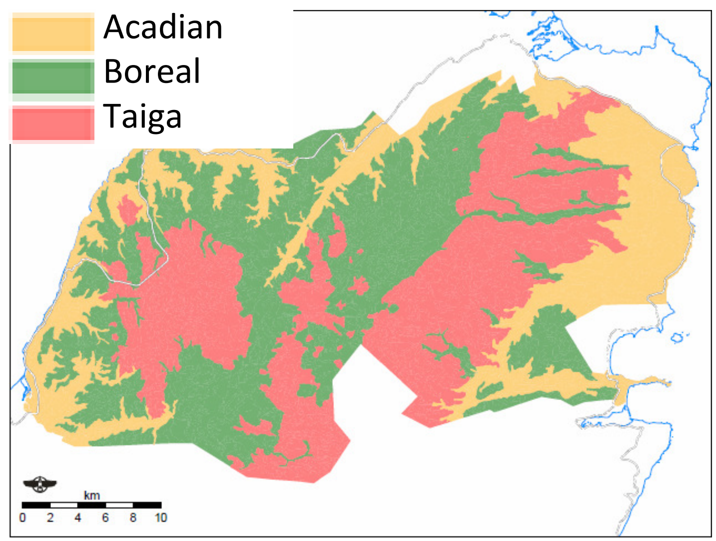
Parks Canada Parcs Canada

Canada

Cape Breton Highlands National Park (CBH)

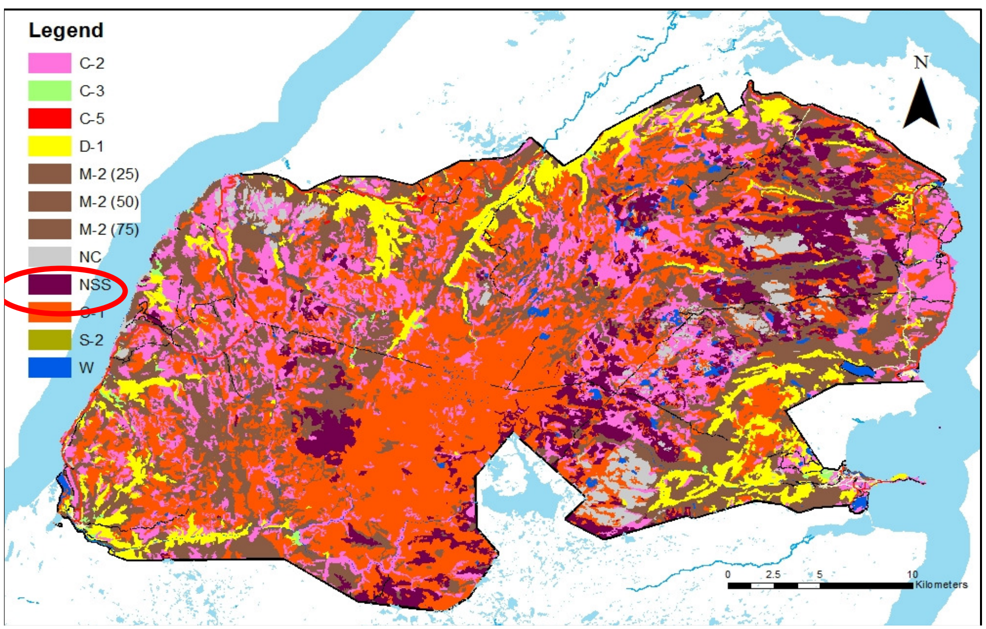
- 950 km² – 3 regions:
  - Acadian
  - Boreal
  - Taïga





Research problem

- 12% of CBHNP
- No standardized fuel type in CFFDRS
- 6% of Nova Scotia
- Extreme fire behaviour observed in spring



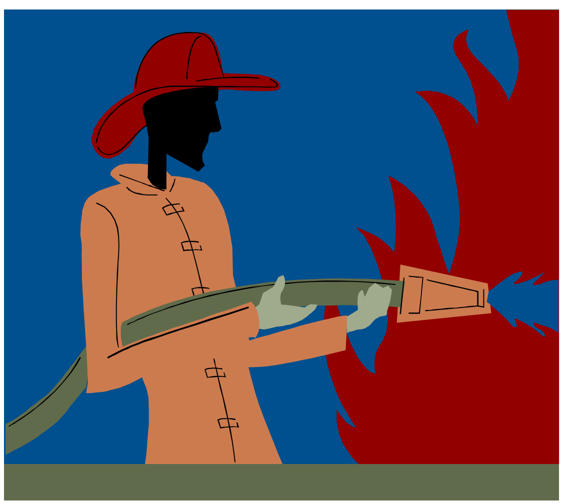
Nova Scotia Special (NS1)

Dominated by lambkill, rhodora, huckleberries, blueberries, sweet gale and reindeer lichens, mixed with sedges, bracken fern and stunted trees (spruce, fir, birch, larch) in various proportion

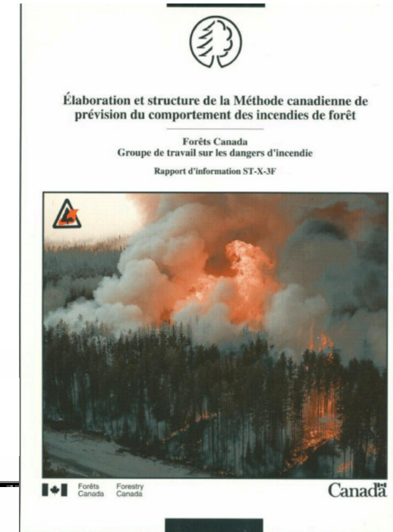


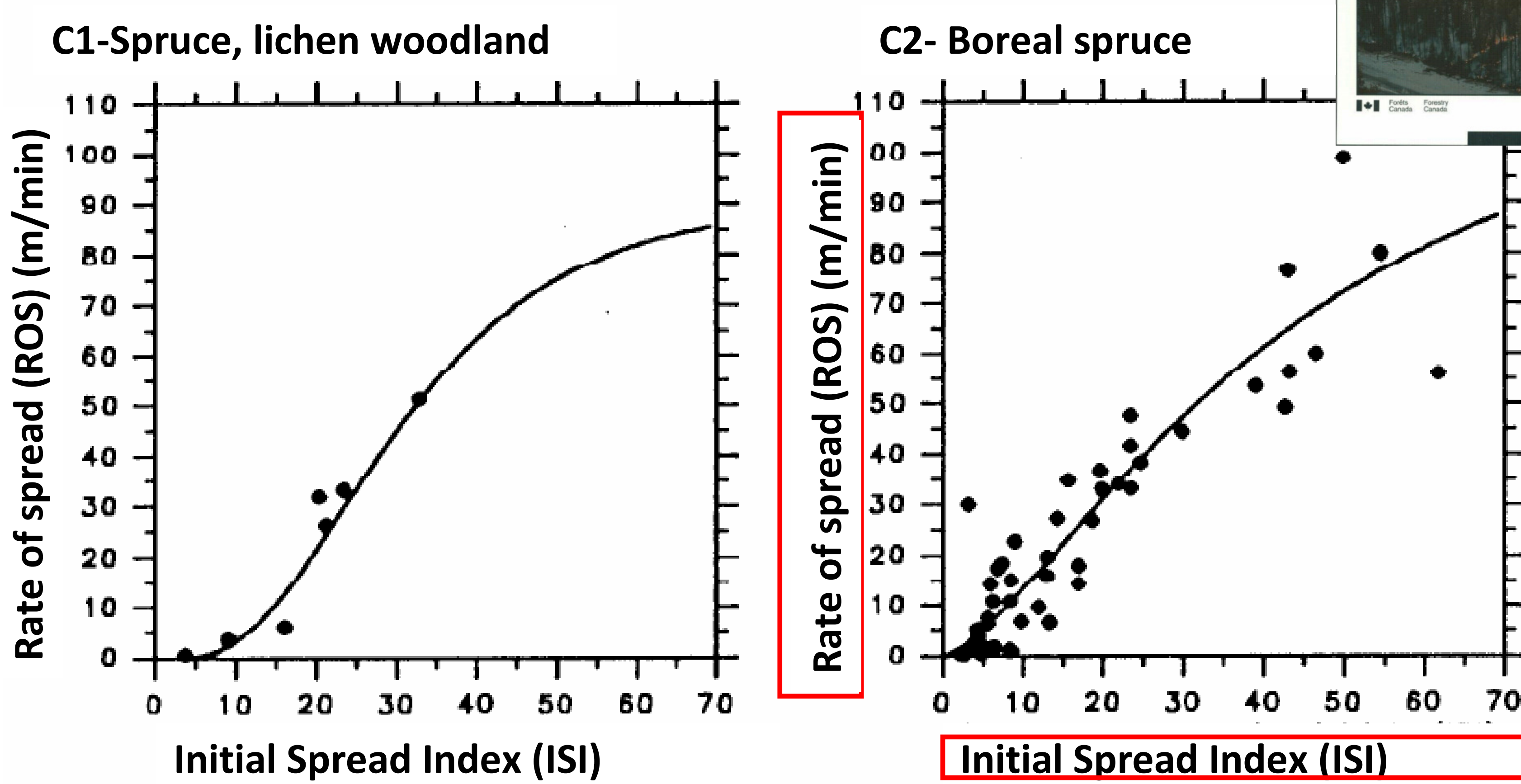

Objective

Develop fuel type parameters in order to predict fire behaviour in NS1



Modeling rate of spread



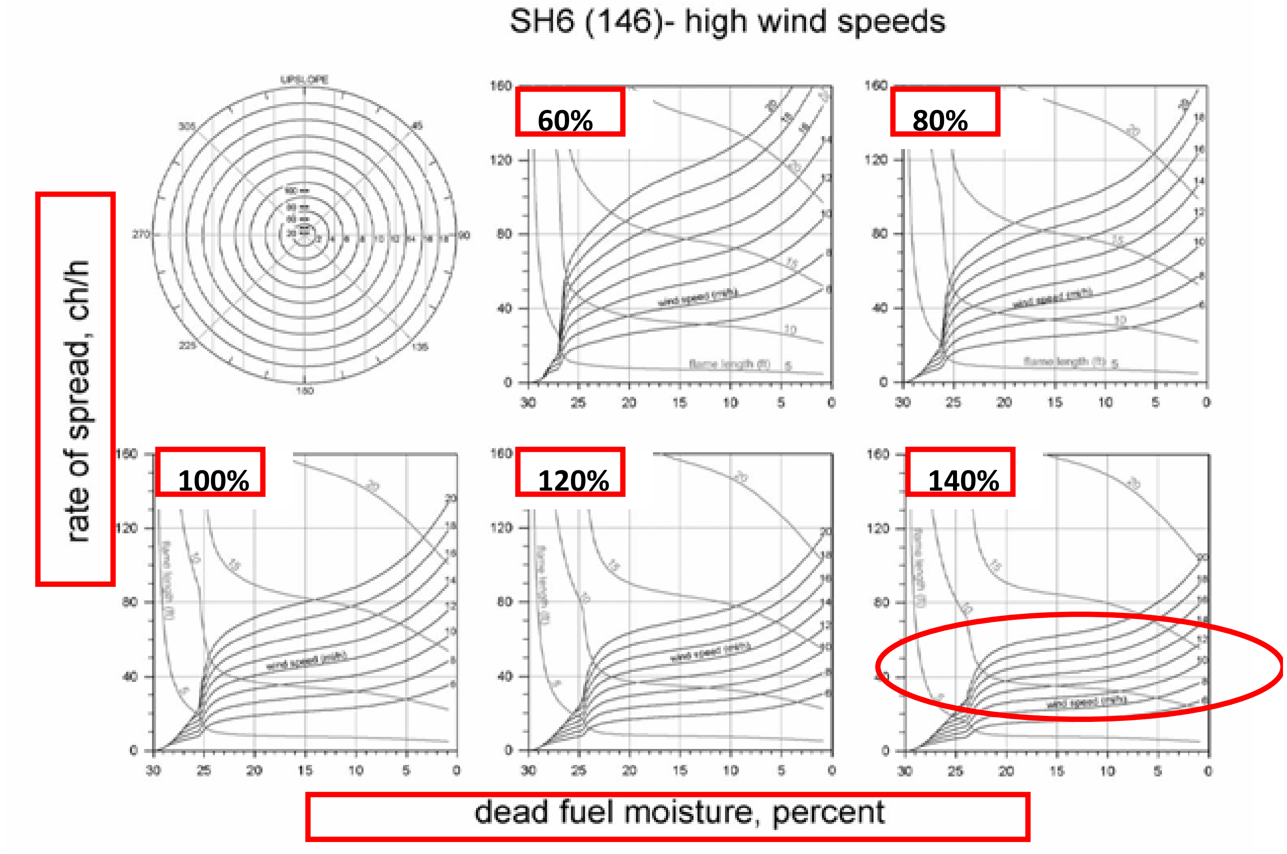


S-shape function: ROS (m/min) = a x [1 – e $^{(-b \times ISI)}$]^{c}

Forestry Canada 1992

Strategy: convert one of the 53 USA standardized fuel type

SH6: Low Load, Humid Climate Shrub *"The primary carrier of fire in SH6 is woody shrubs and shrub litter. Dense shrubs, little or no herbaceous fuel, fuelbed depth about 2 feet"* (Scott and Burgan 2005)

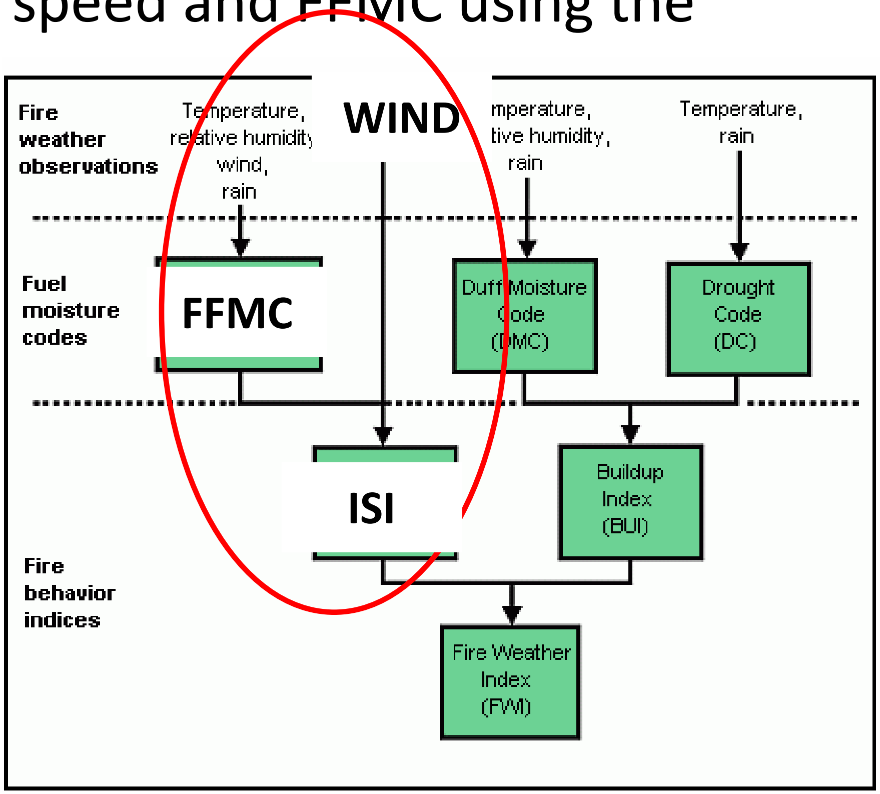


Conversion steps

#1: Convert dead moisture content into FFMC values using the Van Wagner equation FFMC ≈ 101 – dead moisture content (%)

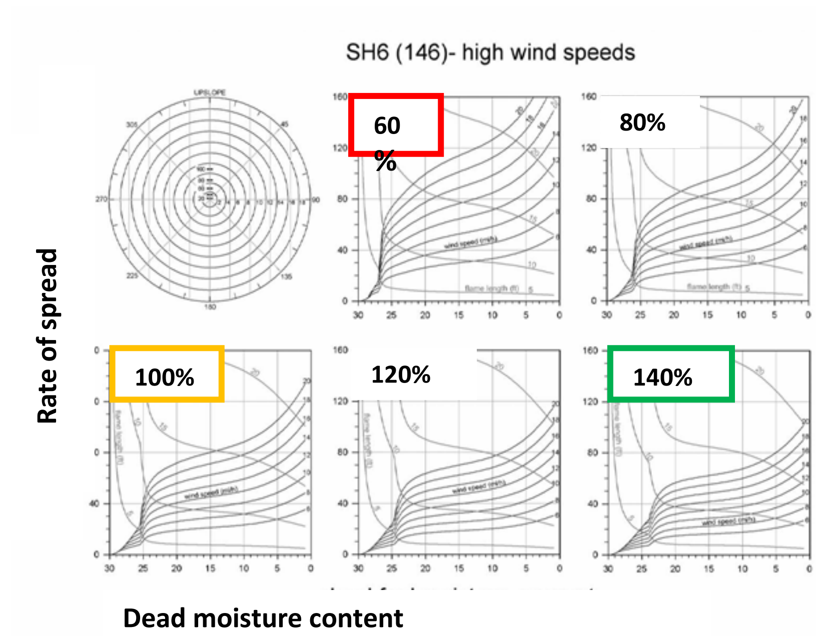
#2: Convert wind speed

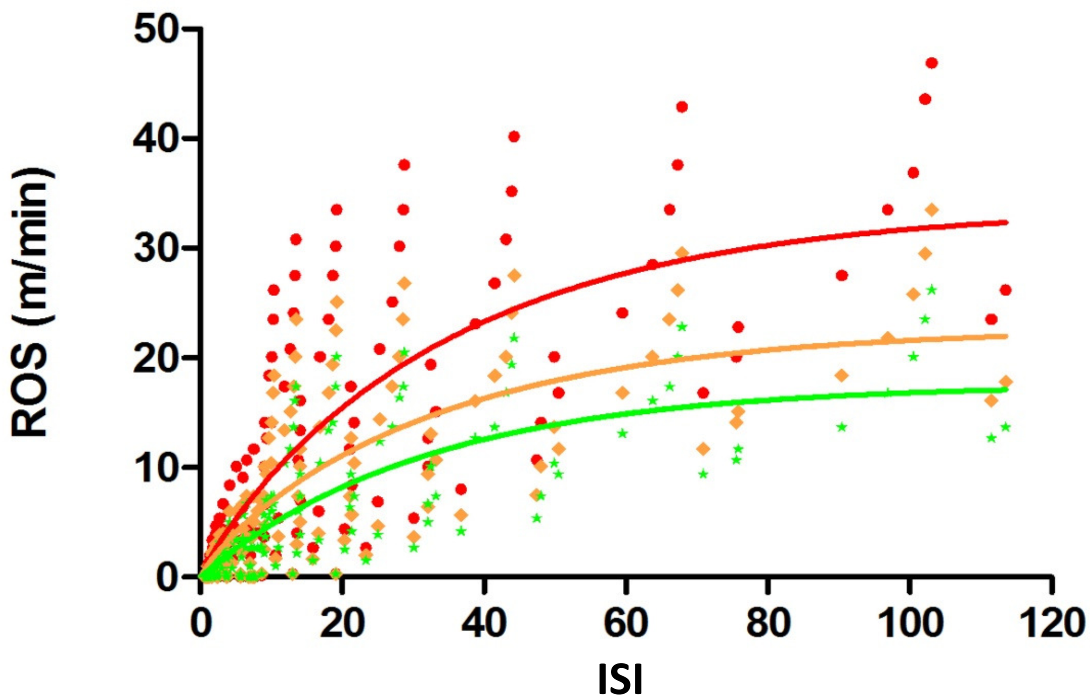
#3: Calculate l'ISI from converted wind speed and FFMC using the FWI system



#4: Build a scattered plot

#5: Determine best fit s-shape curve (software Graph Prism)

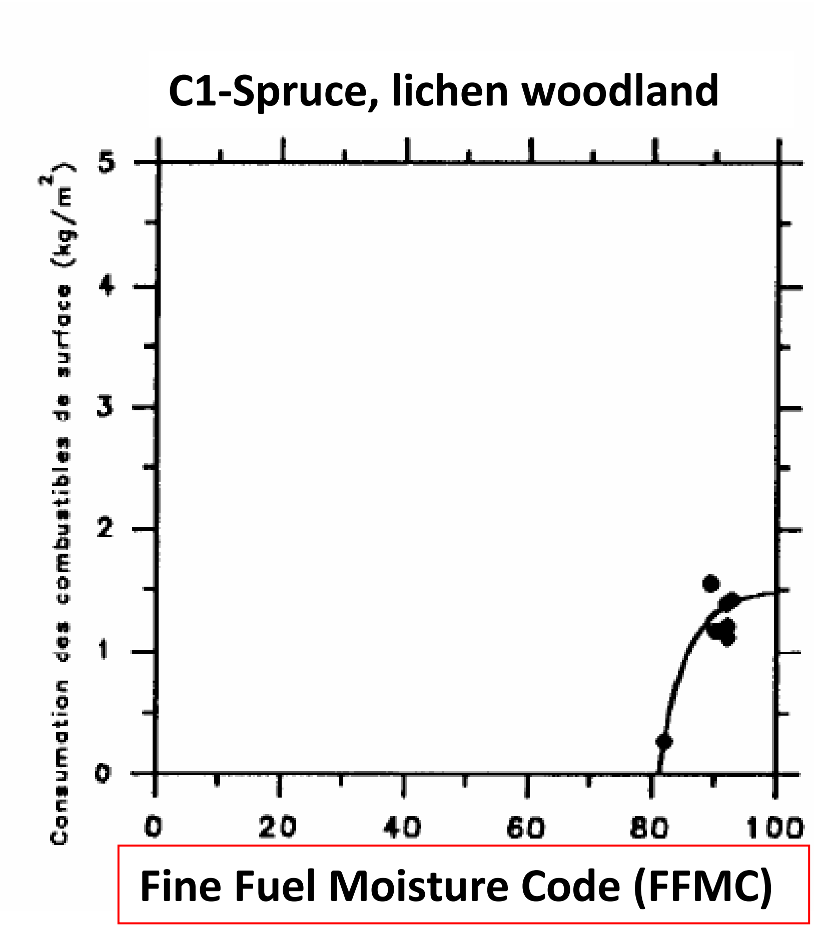


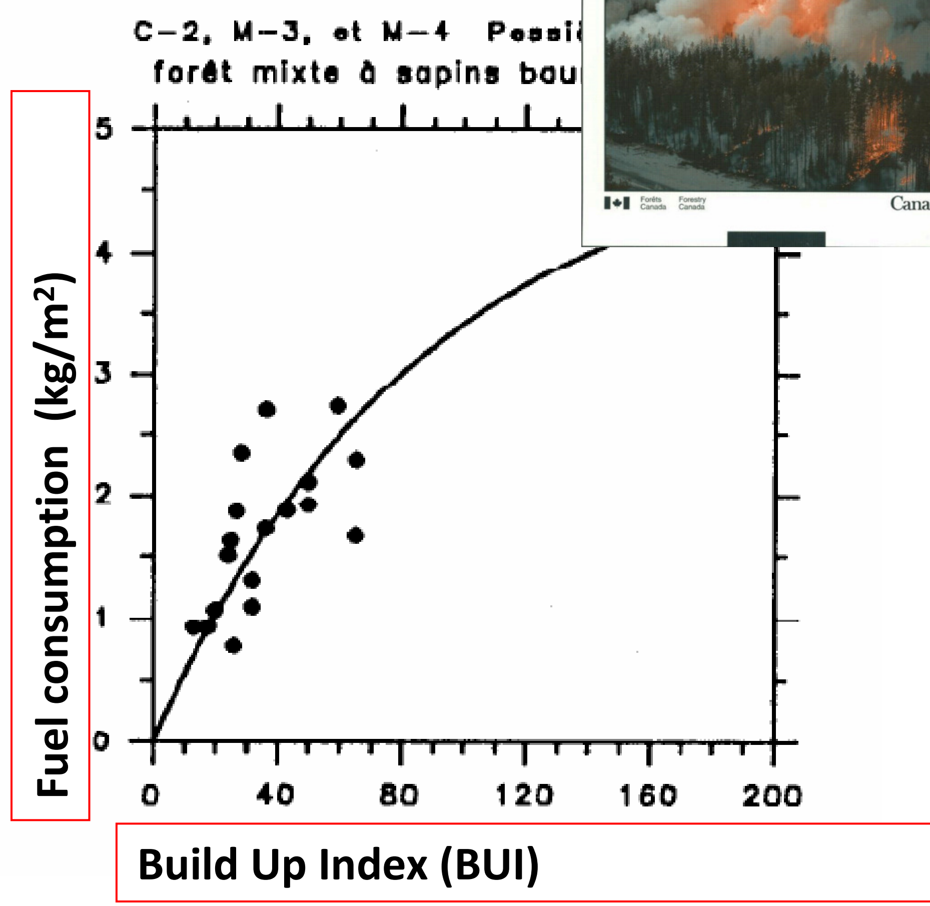


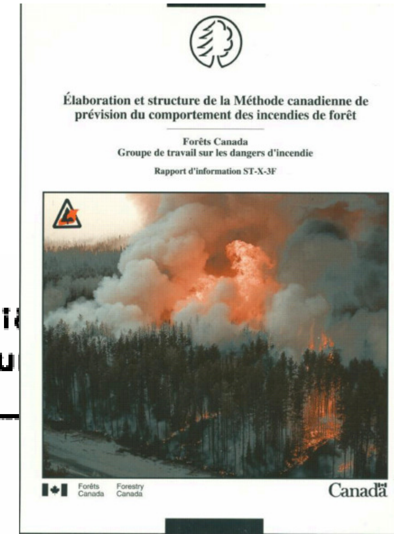
Live woody moisture content

60%: Before green-up
100%: Late summer
140%: During green-up

Modeling intensity







I (kw/m) =

ROS (m/min) * fuel low heat of combustion (300 kj/kg) * fuel consumption (kg/m^2)

Forestry Canada 1992

Verification :
Port Mouton fire, March 29th 2006

	OBSERVED	MODELED
RATE OF SPREAD		
12:00 - 16:00	4 - 8 m/min	7 - 9 m/min
17:00 - 21:00	9 - 11 m/min	8 - 10 m/min
INTENSITY		
12:00 - 16:00	3000 – 5000 kw/m	2858 à 3687 kw/m
17:00 - 21:00	3000 – 5000 kw/m	3318 à 4226 kw/m

CAUTION

not based on observed fire behaviour

Tool for validation

Equilibrium rate of spread (m/min) and fire intensity class

NSS-140 **Nova Scotia Special, 140% live woody moisture content**

Intensity class	
1	< 10 kW/m
2	10-500
3	500-2 000
4	2 000-4 000
5	4 000-10 000
6	> 10 000

140% LWMC (June-July)

ISI 10: ROS = 4 m/min

	BUI							
ISI	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
2	1	1	1	1	1	1	1	1
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	4	4	4	4	4	4	4	4
11	5	5	5	5	5	5	5	5
12	5	5	5	5	5	5	5	5
13	5	5	5	5	5	5	5	5
14	6	6	6	6	6	6	6	6
15	6	6	6	6	6	6	6	6
16	6	6	6	6	6	6	6	6
17	7	7	7	7	7	7	7	7
18	7	7	7	7	7	7	7	7
19	7	7	7	7	7	7	7	7
20	8	8	8	8	8	8	8	8
21-25	9	9	9	9	9	9	9	9
26-30	10	10	10	10	10	10	10	10
31-35	10	10	10	10	10	10	10	10
36-40	12	12	12	12	12	12	12	12
41-45	13	13	13	13	13	13	13	13
46-50	14	14	14	14	14	14	14	14
51-55	14	14	14	14	14	14	14	14
56-60	15	15	15	15	15	15	15	15
61-65	15	15	15	15	15	15	15	15
66-70	15	15	15	15	15	15	15	15

CAUTION

not based on observed fire behaviour

Tool for validation

Equilibrium rate of spread (m/min)
and fire intensity class

NSS-60 **Nova Scotia Special, 60% live woody moisture content**

(before bud break or late fall)

Intensity class	
1	< 10 kW/m
2	10-500
3	500-2 000
4	2 000-4 000
5	4 000-10 000
6	> 10 000

	BUI							
ISI	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
2	3	3	3	3	3	3	3	3
3								
4								
5								
6								
7								
8								
9								
10	8	8	8	8	8	8	8	8
11	9	9	9	9	9	9	9	9
12	9	9	9	9	9	9	9	9
13	10	10	10	10	10	10	10	10
14	11	11	11	11	11	11	11	11
15	11	11	11	11	11	11	11	11
16	12	12	12	12	12	12	12	12
17	12	12	12	12	12	12	12	12
18	13	13	13	13	13	13	13	13
19	13	13	13	13	13	13	13	13
20	14	14	14	14	14	14	14	14
21-25	16	16	16	16	16	16	16	16
26-30	18	18	18	18	18	18	18	18
31-35	19	19	19	19	19	19	19	19
36-40	21	21	22	22	22	22	22	22
41-45	23	23	23	23	23	23	23	23
46-50	25	25	25	25	25	25	25	25
51-55	26	26	26	26	26	26	26	26
56-60	27	27	27	27	27	27	27	27
61-65	27	27	27	27	27	27	27	27
66-70	28	28	28	28	28	28	28	28

60% LWMC (June-July)
ISI 10: ROS = 8 m/min

CAUTION

not based on observed fire behaviour

Tool for validation

Equilibrium rate of spread (m/min)
and fire intensity class

NSS-100 **Nova Scotia Special, 100% live woody moisture content**

Intensity class	
1	< 10 kW/m
2	10-500
3	500-2 000
4	2 000-4 000
5	4 000-10 000
6	> 10 000

100% LWMC (June-July)

ISI 10: ROS = 6 m/min

	BUI							
ISI	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4								
5								
6								
7								
8								
9								
10	6	6	6	6	6	6	6	6
11	7	7	7	7	7	7	7	7
12	7	7	7	7	7	7	7	7
13	8	8	8	8	8	8	8	8
14	8	8	8	8	8	8	8	8
15	8	8	8	8	8	8	8	8
16	9	9	9	9	9	9	9	9
17	9	9	9	9	9	9	9	9
18	10	10	10	10	10	10	10	10
19	10	10	10	10	10	10	10	10
20	11	11	11	11	11	11	11	11
21-25	12	12	12	12	12	12	12	12
26-30	13	13	13	13	13	13	13	13
31-35	14	14	14	14	14	14	14	14
36-40	16	16	16	16	16	16	16	16
41-45	17	17	17	17	17	17	17	17
46-50	18	18	18	18	18	18	18	18
51-55	18	18	18	18	18	18	18	18
56-60	19	19	19	19	19	19	19	19
61-65	19	19	19	19	19	19	19	19
66-70	19	19	19	19	19	19	19	19

Limitations

- US model not based on experimental observations
- Research work in progress:
  - Assumption that the Van Wagner relation between FFMC and dead moisture content works for NS1
  - Assumption regarding live woody moisture content

Aknowledgements

- Victor Kafka, Parks Canada
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- Martin Lavoie, Université Laval
- Geordon Harvey, Parks Canada
- John Ross, Nova Scotia Department of Natural Resources
- Dustin Oikle, Nova Scotia Department of Natural Resources

References and relevant documentation

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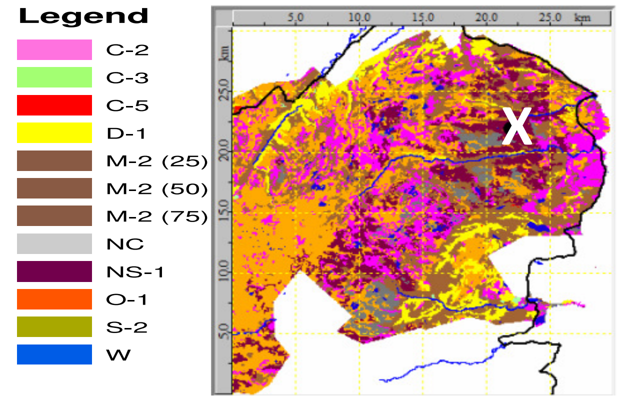
- Van Nest, T.A and Alexander, M.E. 1999. Systems for Rating Fire Danger and Predicting Fire Behaviour Used in Canada. Paper presented at the National Interagency Fire Behaviour Workshop, March 1-5, 1999, Phoenix, Arizona. A large part of this paper was adapted from Alexander et al. (1996).
- Van Wagner, C.E. 1987. Development and structure of the Canadian Forest Fire Weather Index System. Canadian Forest Service. Ottawa, ON. Forestry Technical Report 35. 37 p.
- Van Wagner, C.E. 1975. A comparison of the Canadian and American forest fire danger rating systems. Can. For. Serv. Inf. Rep. PS-X-59. (Now virtually obsolete due to significant changes to both the Canadian and U.S. fire danger rating/fire behaviour prediction systems since the mid 70s).

Questions

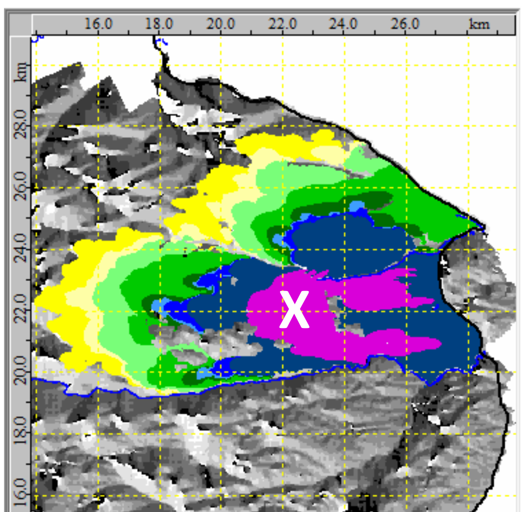
EXTRA

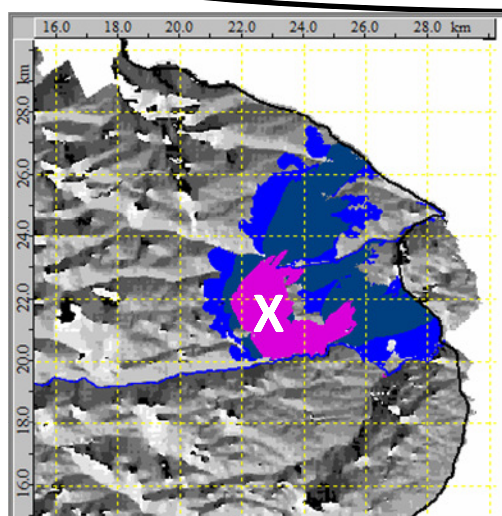
Prometheus simulations:

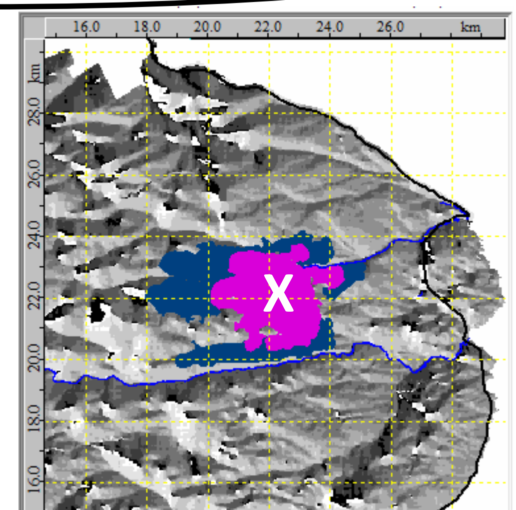
High fire danger, fictiv ignitions in NS1



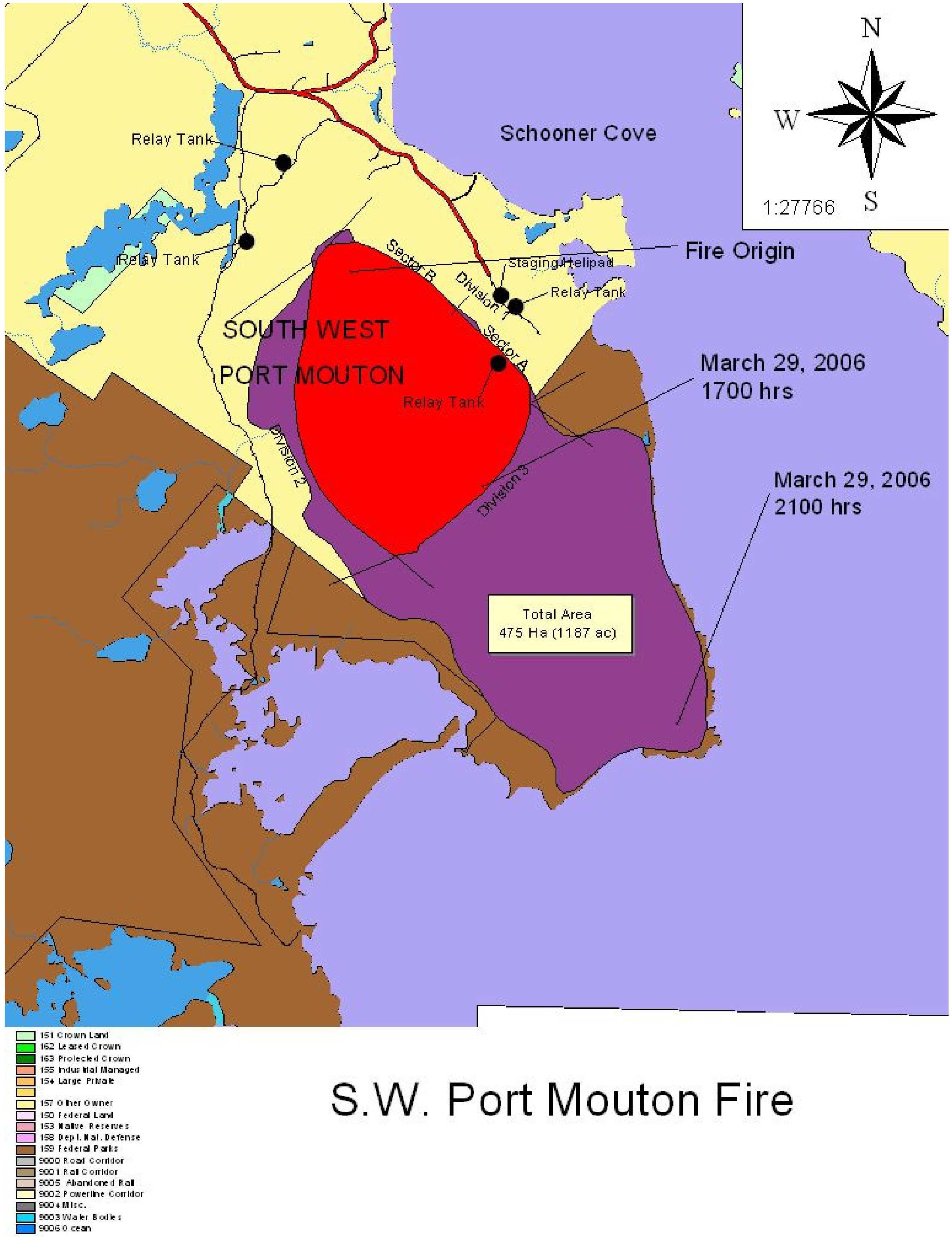
July, NSS-100	June, during budbreak NSS-140	May, before débourrement NSS-60
ISI = 33; FFMC = 89	ISI = 36; FFMC = 90	ISI = 10; FFMC = 90







10 days, 7596 ha, 26476 kw/m, 28 m/min	4 days, 3743 ha, 51162 kw/m, 56 m/min	2 days, 1889 ha, 4880 kw/m, 16 m/min



S.W. Port Mouton Fire

Heure	Temp	HR	Dir vent	Vit vent	Precip	ICL	IPI	FWI	Vit obs	Int obs	Vit prédite	Int. prédite
12:00	14	21	320	19	0	89	9	10	4-8	3000-5000	0	6
13:00	8.4	65	180	17	0	89	8	9	4-8	3000-5000	9	3687
14:00	8.3	67	180	19	0	88	9	10	4-8	3000-5000	8	3413
15:00	8.6	63	190	17	0	88	7	8	4-8	3000-5000	8	3207
16:00	15.3	18	300	17	0	89	8	9	4-8	3000-5000	7	2858
17:00	14.3	18	280	19	0	90	10	11	9-11	3000-5000	8	3411
18:00	12.4	20	290	15	0	90	9	10	9-11	3000-5000	10	4226
19:00	9.5	27	290	13	0	90	8	9	9-11	3000-5000	9	3609
20:00	8.1	29	280	15	0	90	9	10	9-11	3000-5000	8	3318
21:00	6.6	35	290	19	0	90	11	12	9-11	3000-5000	9	3588

Les étapes de conversion

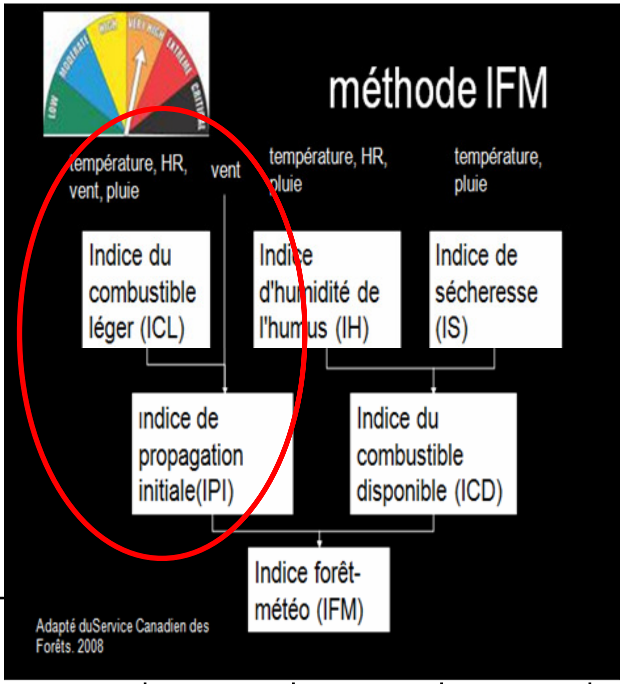
#1: Convertir l'humidité du combustible en indice ICL

$$ICL = \frac{59.5(250-m)}{(147.2+m)} \approx 101 - m$$

Dead fuel moisture (%)	0	3	6	9	12	15	18	21	24	27	30
ICL	101	98	95	92	89	86	83	80	77	74	71

#2: Convertir les vitesses de vent

Vents au sol (m/h)	Vents 20' (m/h)	Vents 20' (km/h)	Vents 10 m (km/h)
A	A/0.42	(A/0.42)*1.6	1.15*[(A/0.42)*1.6]
0	0	0	0
2.5	6	10	11
5	12	19	22
7.5	18	29	33
10	24	38	44
12.5	30	48	55
15	36	57	66
17.5	42	67	77
20	48	76	88



#3: Calculer l'IPI en fonction des vitesses de vent et ICL

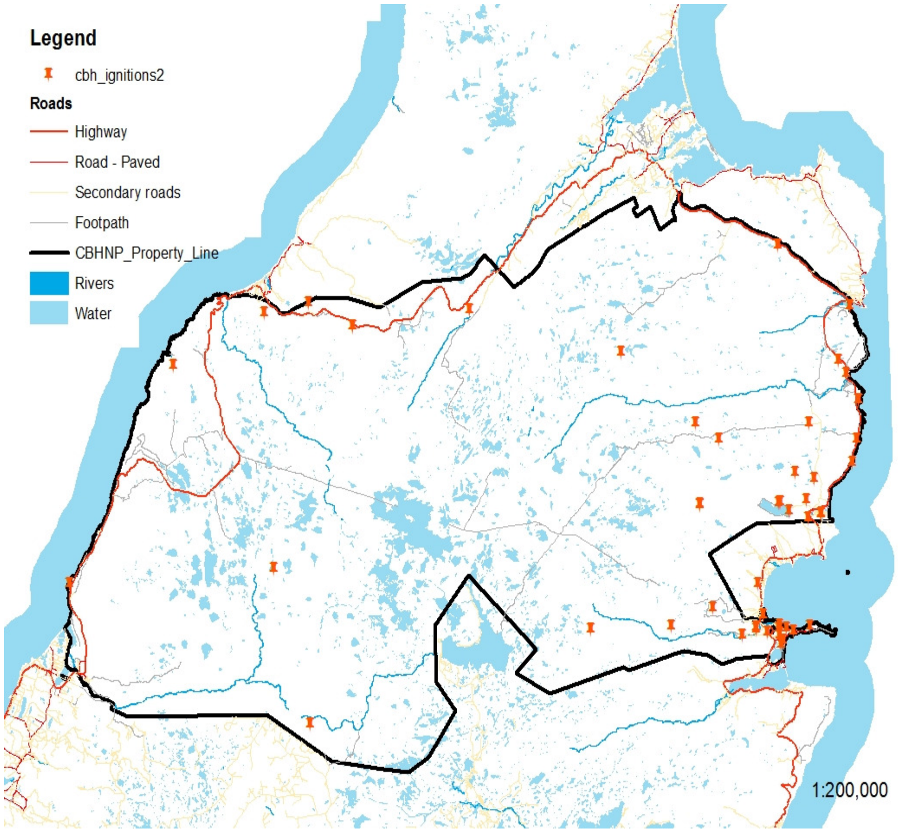
Vent - 10m (km/h)/ICL	101	98	95	92	89	86	83	80	77	74	71
0	19.1	13.0	8.7	5.7	3.7	2.4	1.6	1.1	1.0	0.7	0.7
4	23.4	15.9	10.6	7.0	4.5	3.0	2.0	1.4	1.1	0.9	0.8
9	30.1	20.4	13.6	9.0	5.8	3.8	2.5	1.8	1.4	1.1	1.0
13	36.8	25.0	16.7	11.0	7.2	4.7	3.1	2.2	1.7	1.4	1.2
18	47.4	32.1	21.4	14.1	9.2	6.0	4.0	2.8	2.2	1.8	1.6
26	70.9	48.0	32.1	21.1	13.8	9.0	6.0	4.2	3.2	2.7	2.4
35	111.5	75.6	50.5	33.2	21.7	14.1	9.4	6.6	5.1	4.2	3.8
44	167.4	113.5	75.8	49.9	32.5	21.2	14.1	10.0	7.6	6.4	5.7
53	199.7	135.4	90.4	59.5	38.8	25.3	16.9	11.9	9.1	7.6	6.8
61	214.0	145.0	96.9	63.8	41.5	27.1	18.1	12.7	9.7	8.1	7.2
70	222.0	150.5	100.5	66.2	43.1	28.1	18.7	13.2	10.1	8.5	7.5
79	225.8	153.1	102.2	67.3	43.9	28.6	19.1	13.4	10.3	8.6	7.6
88	227.7	154.3	103.1	67.9	44.2	28.8	19.2	13.5	10.4	8.7	7.7

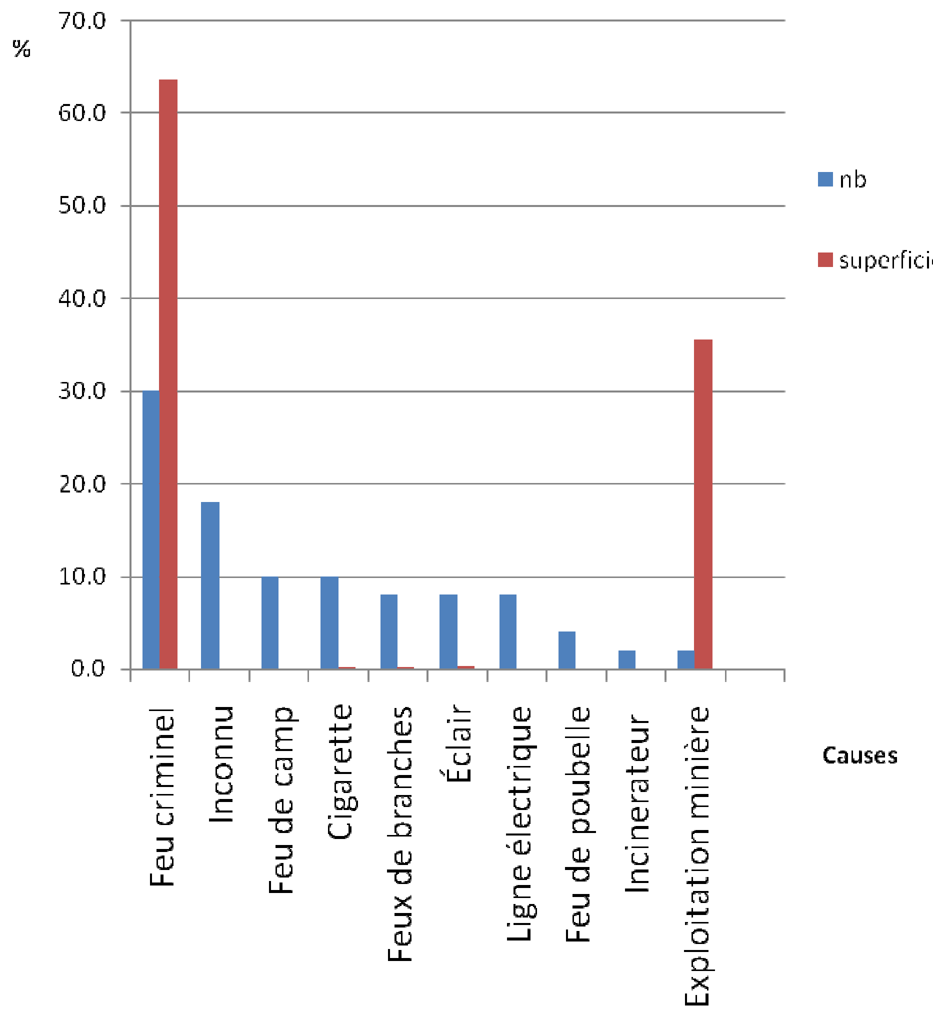
Paramètres de l'équation de la vitesse de propagation

$$\text{Vit (m/min)} = \mathbf{a} \times [1 - e^{(-\mathbf{b} \times \text{IPI})}]^{\mathbf{c}}$$

	60% LWMC	100% LWMC	140% LWMC
scurvefire			
Best-fit values			
a	**33.74**	**22.78**	**17.61**
b	**0.02712**	**0.02808**	**0.03096**
c	**0.8978**	**0.8509**	**0.9856**
Std. Error			
a	4.594	3.044	2.116
b	0.01312	0.01397	0.01353
c	0.2111	0.2043	0.2376
95% Confidence Intervals			
a	24.74 to 42.75	16.81 to 28.75	13.46 to 21.76
b	0.001412 to 0.05284	0.0006886 to 0.05546	0.004446 to 0.05748
c	0.4840 to 1.312	0.4505 to 1.251	0.5199 to 1.451
Goodness of Fit			
Degrees of Freedom	129	129	129
R square	0.6012	0.5808	0.609
Absolute Sum of Squares	7826	3948	2227
Sy.x	7.789	5.532	4.155
Number of points			

Compilation des feux PNHTCB



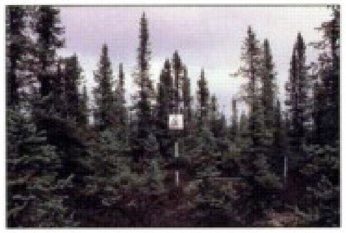


Extinction lorsque IH <20

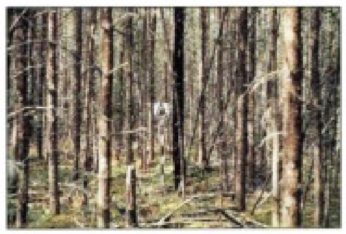
Paramètres	Avant débourremnet (1er avril – 31 mai)	Durant débourrment (1er juin- 30 juin)	Été (1er juillet—15 septembre)	Automne (15 septembre- 31 octobre)
O1	O1A-80%	O1B-15%	O1B- 40 to 60%	O1B-80%
NSS	NSS-60	NSS-140	NSS-100	NSS-60
Green-up	OFF	ON	ON	ON

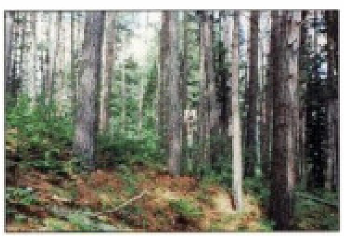
16 types de combustible standardisés


C-1

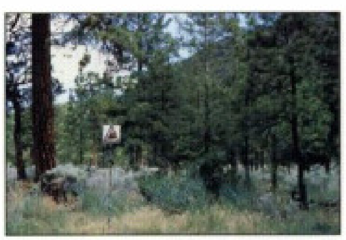

C-2


C-3


C-4


C-5


C-6


C-7


D-1

Groupe et code	Nom descriptif
Conifères	
C-1	Pessière à lichens
C-2	Pessière boréale
C-3	Pins gris ou pins tordus à maturité
C-4	Jeunes pins gris ou pins tordus
C-5	Pins rouges et pins blancs
C-6	Plantation de conifères
C-7	Pins ponderosas et douglas taxifoliés
Feuillus	
D-1	Peupliers faux-trembles sans feuilles
Forêts mixtes	
M-1	Forêt boréale mixte sans feuilles
M-2	Forêt boréale mixte avec feuilles
M-3	Forêt mixte à sapins baumiers morts, sans feuilles
M-4	Forêt mixte à sapins baumiers morts, avec feuilles
Rémanents	
S-1	Rémanents de pins gris ou de pins tordus
S-2	Rémanents d'épinettes blanches et de sapins baumiers
S-3	Rémanents de thuyas, de pruches et de douglas côtiers
Secteurs ouverts	
O-1	Herbes

Standard photographs of CFFDRS FBP System fuel types – page 2

M-1

M-2

M-3

M-4

S-1

S-2

S-3

O-1

Simulations dans Prometheus

1. Préparation des données
2. Création d'un projet et importation des données
3. Définir les paramètres de base
4. Créer/importer des stations météos et des fichiers météo
5. Créer/Importer des allumages
6. Construire des scénarios
7. Simuler