Vulnerability of North American Boreal Peatlands to Interactions between Climate, Hydrology, and Wildland Fire

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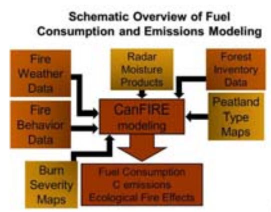
Presented at NASA CCE Meeting 20-22 April, 2015

OVERVIEW

The overall goal of this project was to improve our understanding of the vulnerability of boreal peatlands to wildfire by integrating field work, remote sensing, and modeling of the biophysical, hydrological, and climatic controls on wildfire.



Three remote sensing products were developed :

1) ***Peatland Type Maps*** (fen vs. bog including treed vs. open vs. shrubby) based on multi-date, multi-sensor fusion (Optical-IR, C-band and L-band SAR).
2) ***Burn Severity Maps (***1-percent unburned moss, and burn severity index (BSI) based on the ground consumption and Landsat pre- and post-burn imagery) specific to peatlands.
3) ***RADAR Soil Moisture Maps*** based on SAR backscatter and SAR polarimetry (polarimetric SAR algorithms R^2 ~0.77) were developed for mapping forests with biomass less than 3.0 kg/m².

Two field-based products were developed:

1) ***Estimates of fuel consumption to the ground layer*** in peatlands that can be related to the burn severity .
2) ***Biophysical data inputs for the various peatlands*** (aboveground biomass – tree and shrub, plant heights, density, etc.)

BURN SEVERITY MAPPING

Burn severity was measured in the field using the Burn Severity Index (BSI) (Dyrness and Norum 1983), a qualitative assessment of burn to the moss/organic soil layers that uses a 1-5 scale, with 1 being unburned and 5 being severely burned.

Low severity   Moderately Low severity   Moderate severity

The field data were correlated with Landsat data to develop multivariate models for calculating burn severity and 1-% unburned moss

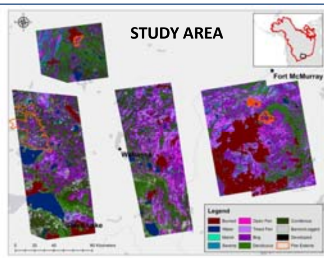
$$BSI = 72.6 + 504 * diff4{:}5$$

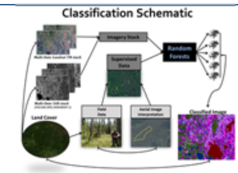
$$1 - \%\text{-unburned moss} = -7.4 + (73.6 * diff2{:}7) + (70.6 * diff4{:}5)$$

These models were used to generate the burn severity maps for four fires in northern Alberta, Canada seen in the orange maps to the right.

PEATLAND TYPE MAPPING

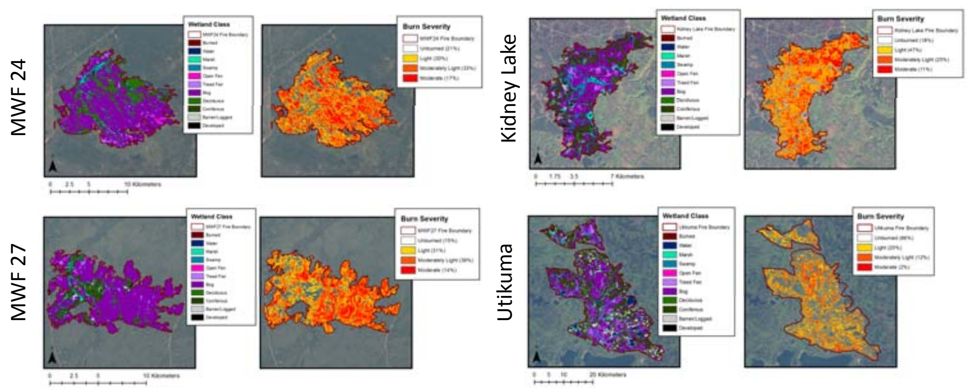
Over 350 field locations were sampled in central Alberta to train and validate the peatland type maps shown at right and below. Peatlands are shown in shades of purple. Overall map accuracy was 97% using a Random Forests classifier. Random Forests is a machine learning algorithm that uses a series of decision trees to classify individual pixels.





Classification	Ground Truthed Values: Water	Marsh	Swamp	Open Fen	Treed Fen	Bog	Deciduous Upland	Coniferous Upland	Logged/ Barren	Developed	Sum	Comm-ission	User Acc.
Water	1004	0	0	0	0	0	0	0	0	0	1004	0%	100%
Marsh	0	932	10	3	9	0	0	0	1	41	996	6%	94%
Swamp	0	18	944	1	4	0	6	3	35	2	1013	7%	93%
Open Fen	0	2	3	1007	59	10	0	0	0	0	1081	7%	93%
Treed Fen	0	21	33	16	893	81	0	0	0	8	1052	15%	85%
Bog	0	0	17	0	64	943	2	19	0	3	1048	10%	90%
Deciduous Upland	0	0	0	0	0	0	992	44	1	0	1037	4%	96%
Coniferous Upland	0	1	0	0	0	2	9	949	18	6	985	4%	96%
Logged/Barren	0	24	0	0	0	0	1	0	958	292	1275	25%	75%
Developed	0	5	0	1	1	0	0	0	2	667	676	1%	99%
Sum	1004	1003	1007	1028	1030	1036	1010	1015	1015	1019			
Omission	0%	7%	6%	2%	13%	9%	2%	7%	6%	35%			
Prod. Acc.	100%	93%	94%	98%	87%	91%	98%	93%	94%	65%			97%

INTEGRATION OF PEATLAND TYPE MAPS with BURN SEVERITY MAPS



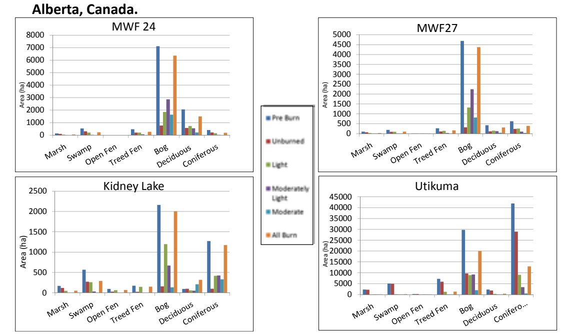
		Marsh	Swamp	Open Fen	Treed Fen	Bog	Deciduous	Coniferous	Sum
MWF 24	Pre Burn (hectares)	140.7	534.6	14.6	467.9	7114.7	2063.1	399.7	10735.3
	% area burned	29.4%	42.7%	40.8%	57.2%	89.3%	72.1%	46.1%	79.8%
	Light	26.6%	37.3%	25.2%	43.8%	26.0%	35.1%	38.6%	29.6%
	Moderately Light	2.6%	4.7%	15.6%	12.4%	40.3%	26.4%	6.6%	32.9%
	Moderate	0.3%	0.7%	0.0%	1.0%	23.0%	10.6%	0.9%	17.4%
Kidney Lake	Pre Burn (hectares)	169.6	566.8	95.4	172.6	2163.5	94.4	1273.8	4745.3
	% area burned	31.4%	51.7%	69.2%	86.4%	92.7%	68.9%	92.2%	83.3%
	Light	28.8%	45.8%	64.9%	83.8%	55.4%	32.1%	32.8%	47.0%
	Moderately Light	2.4%	5.3%	4.2%	2.5%	31.0%	19.4%	33.5%	25.3%
	Moderate	0.2%	0.6%	0.1%	0.1%	6.3%	17.4%	25.9%	11.0%
MWF27	Pre Burn (hectares)	95.0	185.1	3.7	265.4	4691.7	423.8	623.8	6288.5
	% area burned	30.1%	52.6%	28.9%	59.9%	93.2%	73.2%	62.5%	85.2%
	Light	29.2%	48.0%	24.7%	51.2%	28.1%	34.0%	40.9%	31.3%
	Moderately Light	0.9%	4.3%	3.7%	8.5%	47.8%	29.5%	15.9%	39.7%
	Moderate	0.0%	0.3%	0.4%	0.2%	17.3%	9.7%	5.7%	14.1%
Utikuma Burn	Pre Burn (hectares)	2262.7	5095.3	241.9	7206.7	29778.9	2240.6	41876.1	88702.2
	% area burned	1.4%	3.4%	0.5%	18.2%	67.3%	17.2%	30.9%	39.3%
	Light	1.2%	3.0%	0.5%	17.0%	29.9%	11.2%	21.6%	22.1%
	Moderately Light	0.2%	0.4%	0.0%	1.2%	30.8%	2.0%	8.0%	14.3%
	Moderate	0.0%	0.0%	0.0%	0.0%	6.6%	4.0%	1.2%	2.9%

DO PEATLANDS BURN AS SEVERELY AS UPLAND FORESTS?

To answer this question the land cover classification maps were integrated with the burn severity maps.

- In all cases treed sites experienced burning of a greater percentage of the total class area than non-treed covertypes.
- In all cases bog and upland forest experienced the greatest percentage of area burned within their covertypes.
- The Utikuma Fire of 2011 was a large early season fire. It had about 44,000 ha of upland forest and 30,000 ha of bog within its border. While 67% of the bog burned only 30% of the upland forest was burned.
- The percent of upland burned for the other 3 wildfires was much greater, 67 to 88%, but in all cases the bog class experienced the greatest percent area burned.
- With the exception of the Kidney Lake fire, bog experienced more severe burning than upland or other classes.

The assumptions that peatlands do not burn as frequently as upland, or that they burn less severely, are shown to be false for these four wildfires of northern Alberta, Canada.



CONSUMPTION AND EMISSIONS MODELLING

A fuel consumption and carbon emissions model (CanFIRE) was used to model emissions from the four study fires. The results show a large discrepancy in estimated emissions when using the standard Leonie Nadeau fuel type map for uplands (top) versus the output based on integration of the peatland specific field and remote sensing data products (bottom). Further quantification of peatland surface fuel loadings and consumption are needed to decrease the uncertainty in the emissions estimates. These fires represent spring fires when consumption is lowest to the surface, research on later season fires are needed to better understand the range of emissions expected from peatlands.

TOTAL EMISSIONS

Standard Model Runs

(using Leonie Nadeau fuel type map for fuels and burn)

Fire Name	Area Burned (ha): Fuel	Area Burned (ha): Non-Fuel	Total Perimeter Area (ha)	Fire behaviour: Forest floor fuel consumption (kg m²)	Fire behaviour: Dead woody debris fuel consumption (kg m²)	Fire behaviour: Crown fuel consumption (kg m²)	Carbon emissions rate (t ha⁻¹)	Total carbon emissions (t)
MWF024	10,847.26	0.00	10,847.26	6.64	0.75	3.35	53.72	582,671
MWF027	6,378.18	0.00	6,378.18	6.64	0.75	3.68	55.36	353,103
Utikuma	81,352.712	625.31	81,978.02	4.57	0.55	4.70	49.10	3,994,690
Kidney Lake	4,915.05	0.00	4,915.05	3.88	0.42	3.43	38.68	190,096

Peat Fuel Consumption Runs

(using Project field and remote sensing products)

Fire Name	Area Burned (ha): Fuel	Area Burned (ha): Non-Fuel	Total Perimeter Area (ha)	Fire behaviour: Forest floor fuel consumption (kg m²)	Fire behaviour: Dead woody debris fuel consumption (kg m²)	Fire behaviour: Crown fuel consumption (kg m²)	Carbon emissions rate (t ha⁻¹)	Total carbon emissions (t)
MWF024	10,617.23	230.03	10,847.26	2.04	0.20	0.53	13.82	146,699
MWF027	6,191.32	186.86	6,378.18	1.26	0.03	0.65	9.70	60,030
Utikuma	76,243.19	5,734.86	81,978.05	2.37	0.22	2.88	27.34	2,084,709
Kidney Lake	4,658.70	256.34	4,915.04	1.97	0.15	1.28	17.03	79,351