Estimating Fire Severity

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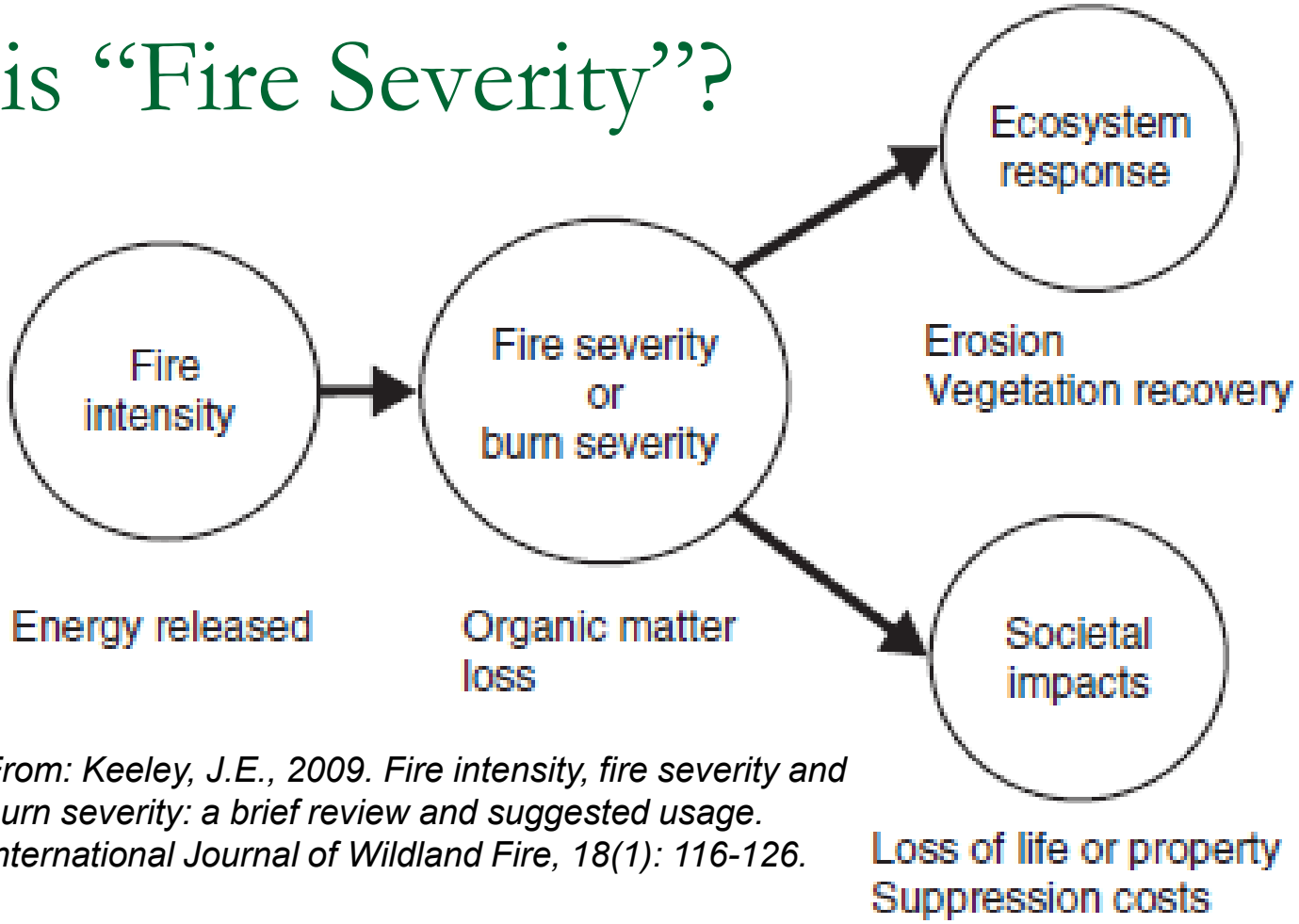
USDA Forest Service

What is "Fire Severity"?



From: Keeley, J.E., 2009. Fire intensity, fire severity and burn severity: a brief review and suggested usage. International Journal of Wildland Fire, 18(1): 116-126.

Fire Severity Indices are tools and metrics used to rapidly assess fire effects

- Visual Field Estimates (Percent cover of burned components)
- Remote Sensing

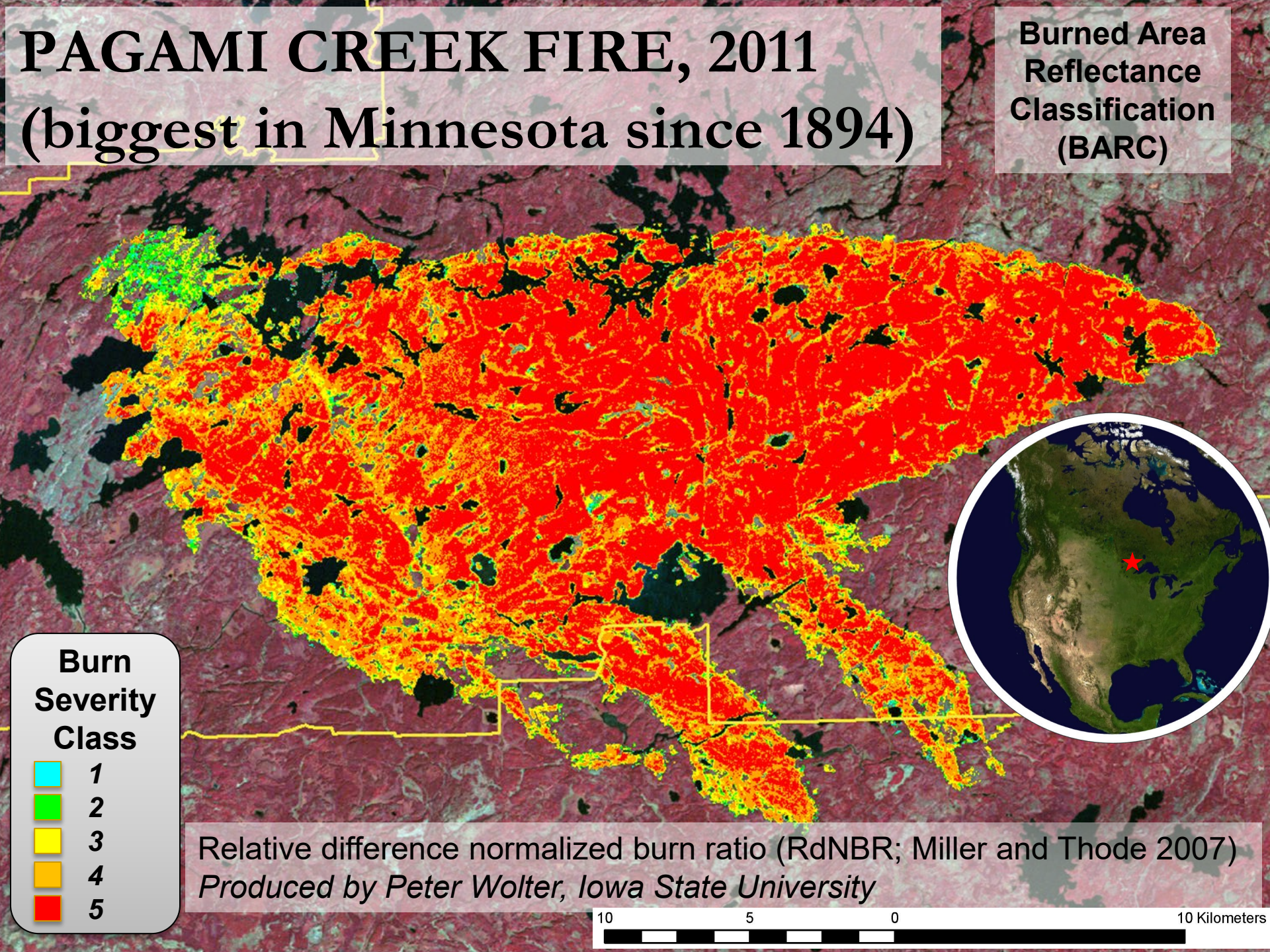
In each case - used to scale up actual effects that are time-consuming to measure

How does one measure fire severity? - *it depends…*

- Effect of fire on *what*…?
  - Vegetation
    - Which strata?
      - Canopy, subcanopy, shrub, grass/herbaceaous…
  - Fuel
    - Which component?
      - canopy, ladder, ground, woody, litter, humus…
  - Soil
    - What aspect?
      - Stability, organic matter, nutrients, water absorption

PAGAMI CREEK FIRE, 2011 (biggest in Minnesota since 1894)

Burned Area Reflectance Classification (BARC)



Burn Severity Class

- *1*
- *2*
- *3*
- *4*
- *5*

Relative difference normalized burn ratio (RdNBR; Miller and Thode 2007)

Produced by Peter Wolter, Iowa State University

10 5 0 10 Kilometers

Tree Burn Severity

- No Recent Fire 0
- Evidence of recent fire
  - Presence of Green Trees
    - > 60% Green 1.1
    - 30-60% Green 1.2
    - 15-30% Green 1.3
    - <15% Green 1.4
  - Brown (>98%) 2
  - Mixture of Brown & Black
    - More Brown than Black 3.1
    - More Black than Brown 3.2
  - Black (>98%) 4

Jain, T.B. and Graham, R.T., 2007. The relation between tree burn severity and forest structure in the Rocky Mountains. Pages 213-250 in R. F. Powers, technical editor. Restoring fire-adapted ecosystems: proceedings of the 2005 National Silviculture Workshop, USDA Forest Service, Albany, California, USA.


1.1


1.3


1.4


2


3.1

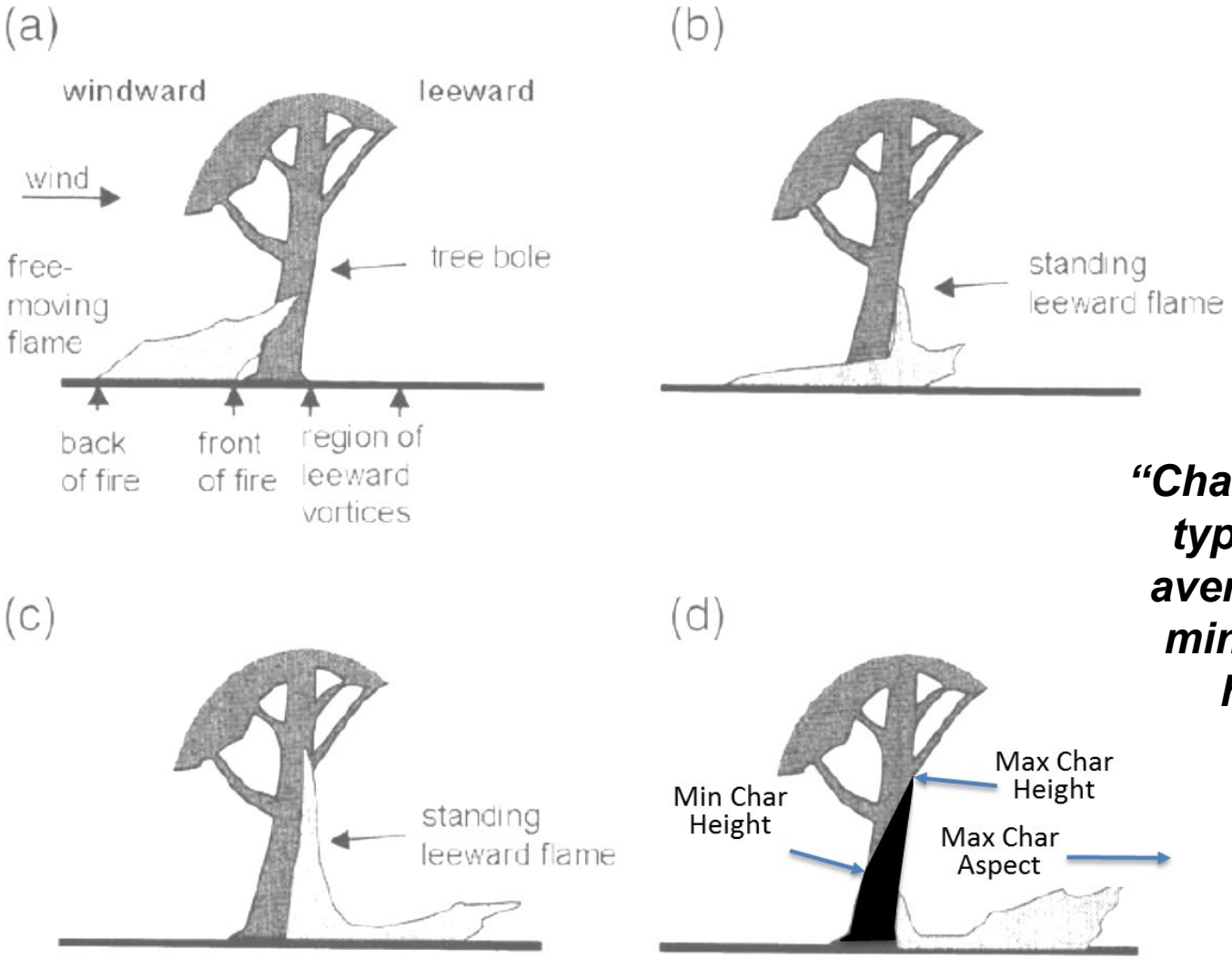

3.2


3.2


4

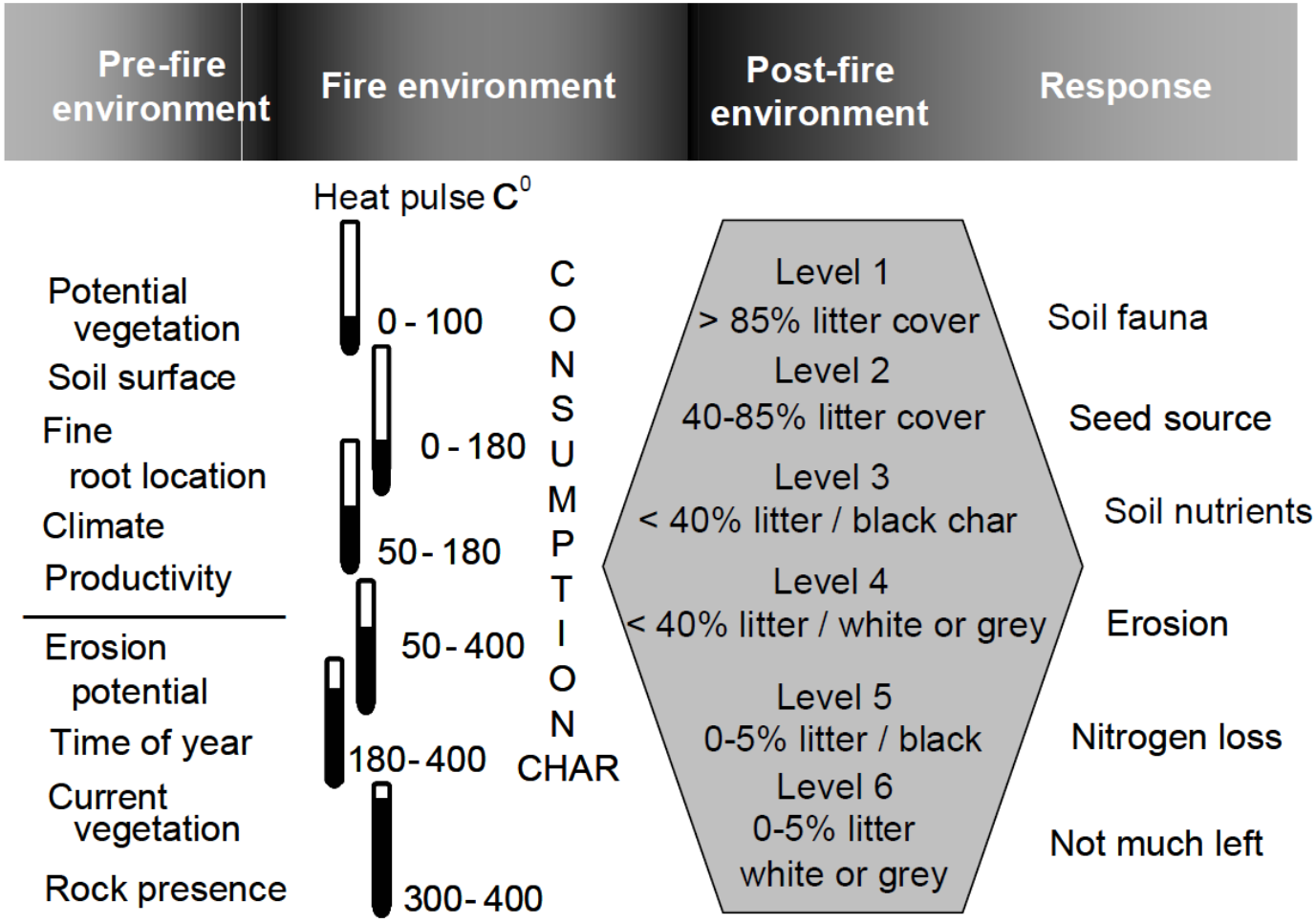

4

Char Height – *an indicator of flame length*



"Char Height" is typically the average of the min and max heights

Soil Burn Severity



Jain, T.B. and Graham, R.T., 2007. The relation between tree burn severity and forest structure in the Rocky Mountains. Pages 213-250 in R. F. Powers, technical editor. Restoring fire-adapted ecosystems: proceedings of the 2005 National Silviculture Workshop, USDA Forest Service, Albany, California, USA.

Substrate (Soil) Severity

Proportions of:

- Litter
  - Fresh
  - Old unburned
  - Burned
- Duff
  - Burned
  - Unburned
- Moss, Shrubs, etc.
- Mineral Soil
  - Unburned
  - Black
  - Gray
  - Orange
- Woody Debris
  - Unburned
  - Surface Char
  - Moderate char
  - Deep Char
- Exposed Rock

	Soil characteristics	Soil PFI category
1a	No evidence of a recent fire	0.0
1b	Evidence of recent fire	
2a	Surface organic cover ≥85%	1.0
2b	Surface organic cover <85%	
3a	Forest floor surface organic cover ≥40% and mineral soil appearance has a plurality of:	2.0
4a	unburned mineral soil	2.1
4b	black charred mineral soil	2.2
4c	gray/white charred mineral soil	2.3
4d	orange charred mineral soil	2.4
3b	Surface organic cover <40% and mineral soil appearance has a plurality of:	3.0
5a	unburned mineral soil	3.1
5b	black charred mineral soil	3.2
5c	gray/white charred mineral soil	3.3
5d	orange charred mineral soil	3.4
3c	(Forest floor absent) No surface organic matter left and mineral soil appearance has a plurality of:	4.0
6a	unburned mineral soil	4.1
6b	black charred mineral soil	4.2
6c	gray/white charred mineral soil	4.3
6d	orange charred mineral soil	4.4

Jain, T.B., Pilliod, D.S., Graham, R.T., Lentile, L.B. and Sandquist, J.E., 2012. Index for Characterizing Post-Fire Soil Environments in Temperate Coniferous Forests. Forests, 3: 445-466.


1.0

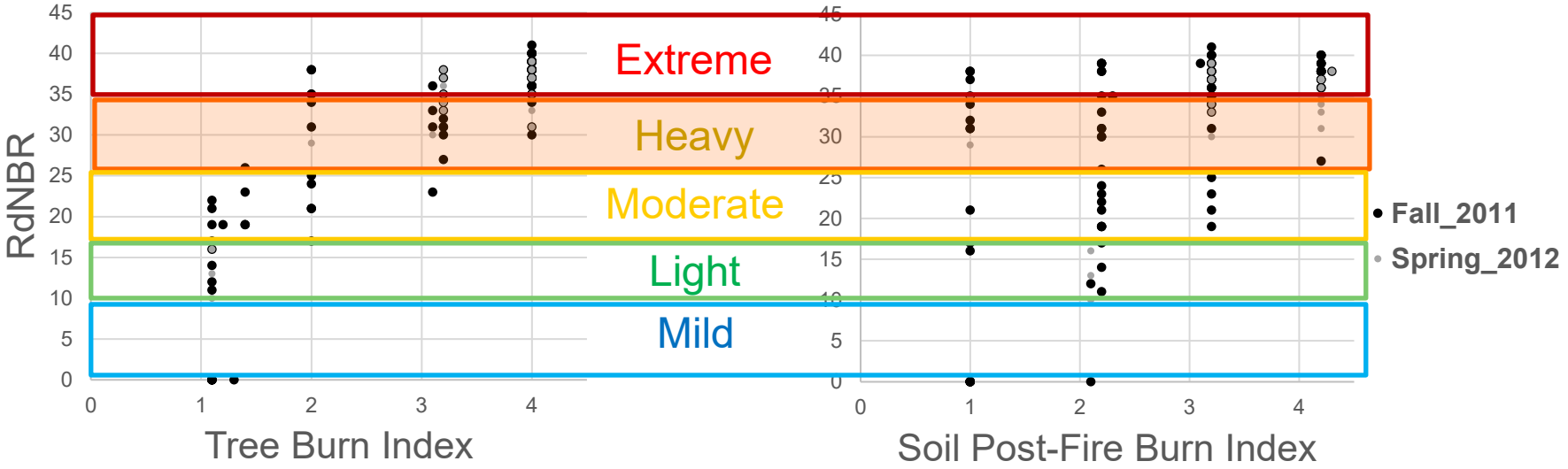

3.2

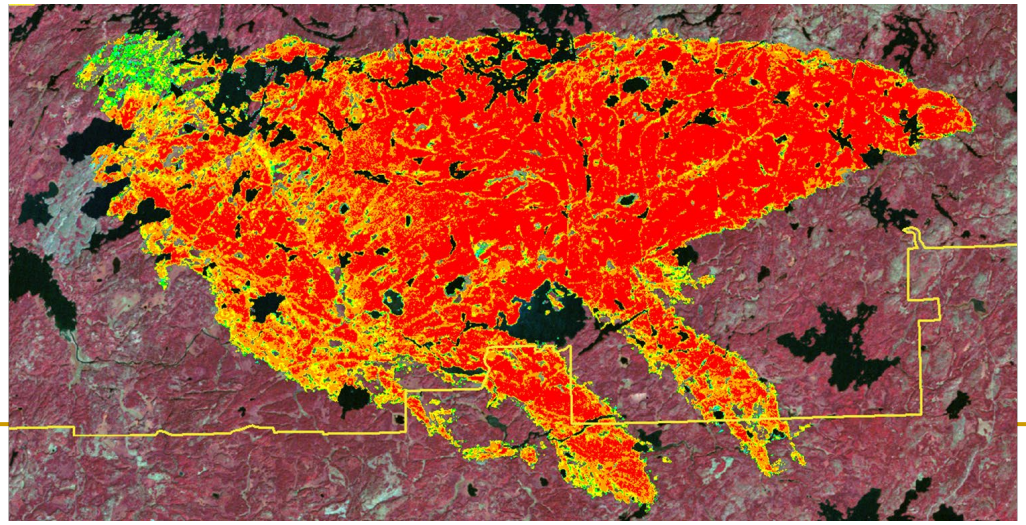

4.2


4.4

Relative difference normalized burn ratio

Relationship with field estimates of severity










Interpretations of severity and response are often sensitive to the system, timing of burn, and time since burn


Late October 2011


Oct 28, 2011

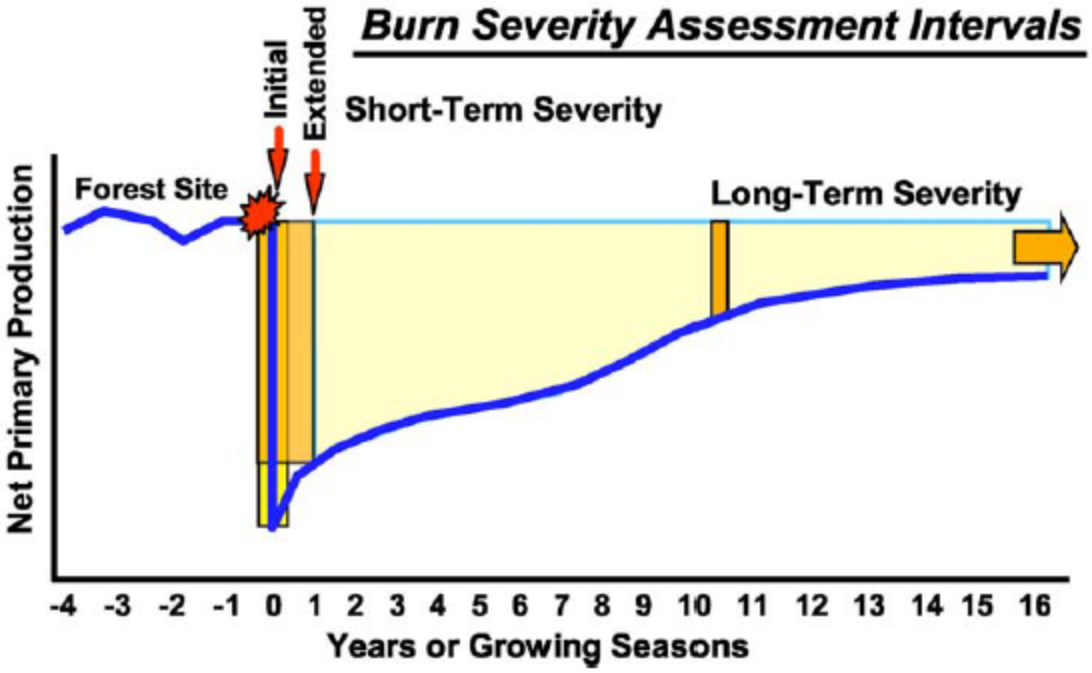

Late April 2012


Aug 10, 2012

How does one measure fire severity?

- *it depends…*

- Effect of fire on *what*…?
- At what spatial scale?
- At which stage post-burn?
- Quantitative or qualitative?



Manipulating soil heating patterns to optimize barrens restoration

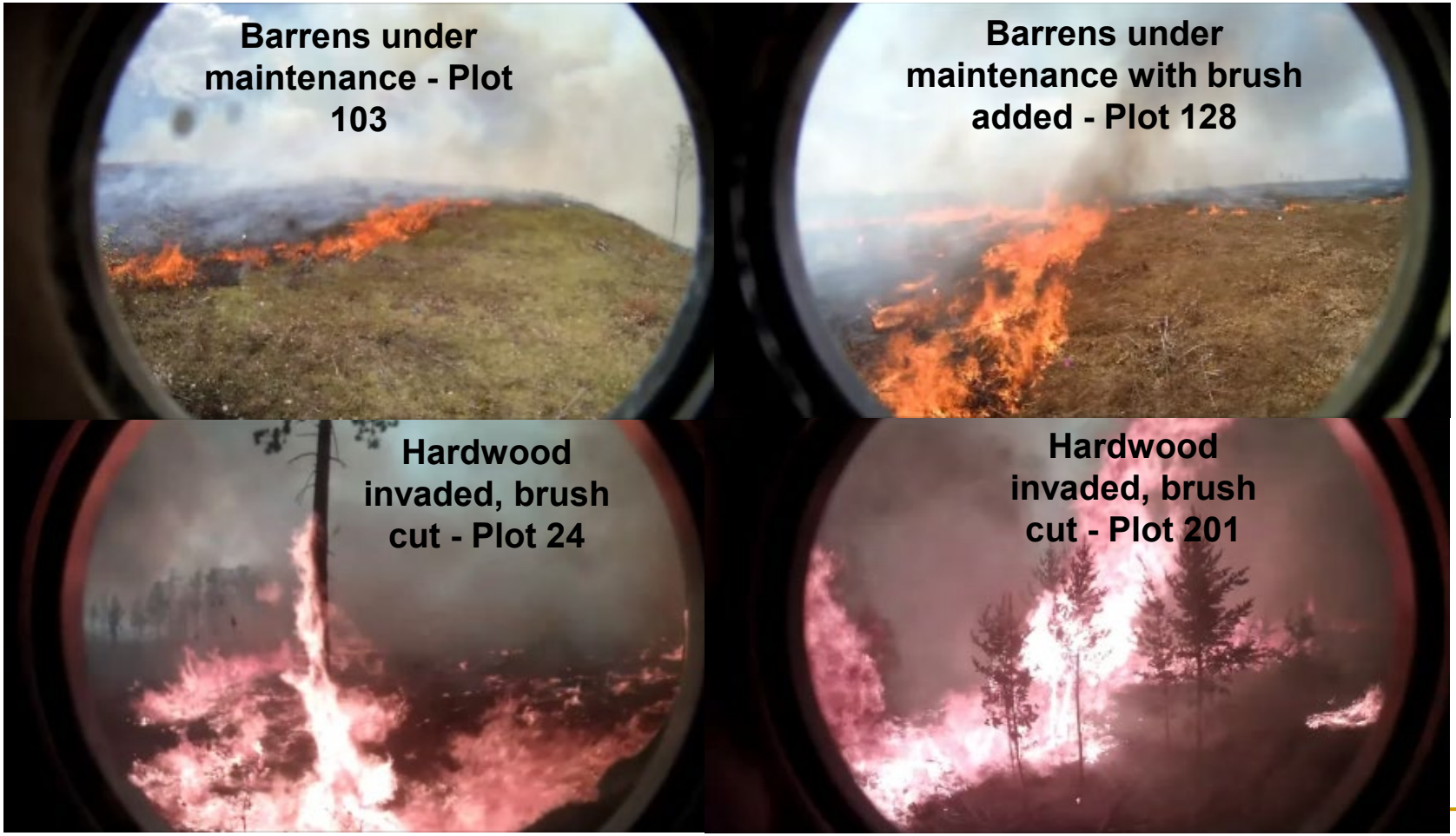

Sharp-tailed Grouse

Northern Research Station
Brian Sturtevant, Christel Kern, Randy Kolka, Matt Dickinson, Deahn Donner
Jessica Miesel: Michigan State

Chequamegon-Nicolet NF
Matt Bushman, Jen Rabuck, Vance Hazelton, Dan Hinson, Brian Heeringa, Michelle Davalos

Experimental fuel treatments:

Contrasts in fire behavior and severity




Moquah
Post-Burn
5/21/16
Plot 36
Q2
N

	Forests		Grasslands	
	Substrate	**Vegetation**	**Substrate**	**Vegetation**
Unburned (5)	**not burned**	**not burned**	**not burned**	**not burned**
Scorched (4)	Litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	foliage scorched and attached to supporting twigs	litter partially blackened; duff nearly unchanged; leaf structures unchanged	foliage scorched
Lightly Burned (3)	litter charred to partially consumed; upper duff layer may be charred but the duff layer is not altered over the entire depth; surface appears black; woody debris is partially burned; logs are scorched or blackened but not charred; rotten wood is scorched to partially burned	foliage and smaller twigs partially to completely consumed; branches mostly intact	litter charred to partially consumed, but some plant parts are still discernible; charring may extend slightly into soil surface, but soil is not visibly altered; surface appears black (this soon becomes inconspicuous); burns may be spotty to uniform depending on the grass con- tinuity	grasses with approximately two inches of stubble; foliage and smaller twigs of associated species partially to completely consumed; some plant parts may still be standing; bases of plants are not deeply burned and are still recognizable
Moderately Burned (2)	litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches still present	leaf litter consumed, leaving coarse, light gray or white colored ash immediately after the burn; ash soon disappears leaving bare mineral soil; charring may extend slightly into soil surface	unburned grass stubble usually less than two inches tall, and mostly confined to an outer ring; for other species, foliage completely consumed, plant bases are burned to ground level and obscured in ash immediately after burning; burns tend to be uniform
Heavily Burned (1)	litter and duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs are deeply charred, and rotten logs are completely consumed. This code generally applies to less than 10% of natural or slash burned areas	all plant parts consumed, leaving some or no major stems or trunks; any left are deeply charred	leaf litter completely consumed, leaving a fluffy fine white ash, this soon disappears leaving bare mineral soil; charring extends to a depth of 1 cm (0.5 in) into the soil; this severity class is usually limited to situations where heavy fuel load on mesic sites has burned under dry conditions and low wind	no unburned grasses above the root crown; for other species, all plant parts consumed leaving some or no major stems or trunks, any left are deeply charred; this severity class is uncommon due to the short burnout time of grasses

USDI National Park Service. 2003. Fire Monitoring Handbook. Boise (ID): Fire Management Program Center, National Interagency Fire Center. 274p.

Comparing Severity Indices

National Park Service (NPS) Severity Class

Soil Post-Fire Index (SPFI)

	1	2	3	4	5	Total
0					3	***3***
1	2	48	140	86	4	***280***
2.1		2	2	4		***8***
2.2		20	5			***25***
2.3		8	1			***9***
3.2		7				***7***
3.3	1	1				***2***
3.4		1				***1***
4.2	1	1				***2***
Total	***4***	***88***	***148***	***90***	***7***	***337***

Soil Burn Severity

- Burned Area Emergency Response (BAER)
- Focus = Soil Stability
- Relate to Burned Area Reflectance Classification (BARC)

Ground Cover Amount & Condition

Ash Cover & Depth

Soil Structure

Roots

- Also Water Repellency

Composite Burn Index

- Composite Burn Index (CBI)
- Focus: Primarily Vegetation
- Designed to Relate Burn Impacts to Remote Sensing
- Also related to BARC

Landscape Assessment (LA)

Sampling and Analysis Methods

Carl H. Key
Nathan C. Benson

USDA Forest Service Gen. Tech. Rep. RMRS-GTR-164-CD. 2006

Composite Burn Index

STRATA RATING FACTORS	BURN SEVERITY SCALE							FACTOR SCORES
	No Effect	Low		Moderate		High		
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	
A. SUBSTRATES								
% Pre-Fire Cover: Litter =	**Duff =**		**Soil/Rock =**	**Pre-Fire Depth (inches): Litter =**		**Duff =**	**Fuel Bed =**	
Litter/Light Fuel Consumed	Unchanged	--	50% litter	--	100% litter	>80% light fuel	98% Light Fuel	
Duff	Unchanged	--	Light char	--	50% loss deep char	--	Consumed	
Medium Fuel, 3-8 in.	Unchanged	--	20% consumed	--	40% consumed	--	>60% loss, deep ch	
Heavy Fuel, > 8 in.	Unchanged	--	10% loss	--	25% loss, deep char	--	>40% loss, deep ch	
Soil & Rock Cover/Color	Unchanged	--	10% change	--	40% change	--	>80% change	
B. HERBS, LOW SHRUBS AND TREES LESS THAN 3 FEET (1 METER):								
Pre-Fire Cover =			**% Enhanced Growth =**					
% Foliage Altered (blk-brn)	Unchanged	--	30%	--	80%	95%	100% + branch loss	
Frequency % Living	100%	--	90%	--	50%	< 20%	None	
Colonizers	Unchanged	--	Low	--	Moderate	High-Low	Low to None	
Spp. Comp. - Rel. Abund.	Unchanged	--	Little change	--	Moderate change	--	High change	
C. TALL SHRUBS AND TREES 3 to 16 FEET (1 TO 5 METERS):								
Pre-Fire Cover =			**% Enhanced Growth =**					
% Foliage Altered (blk-brn)	0%	--	20%	--	60-90%	> 95%	Signifcnt branch loss	
Frequency % Living	100%	--	90%	--	30%	< 15%	< 1%	
% Change in Cover	Unchanged	--	15%	--	70%	90%	100%	
Spp. Comp. - Rel. Abund.	Unchanged	--	Little change	--	Moderate change	--	High Change	
D. INTERMEDIATE TREES (SUBCANOPY, POLE-SIZED TREES)								
Pre-Fire % Cover =	**Pre-Fire Number Living =**				**Pre-Fire Number Dead =**			
% Green (Unaltered)	100%	--	80%	--	40%	< 10%	None	
% Black (Torch)	None	--	5-20%	--	60%	> 85%	100% + branch loss	
% Brown (Scorch/Girdle)	None	--	5-20%	--	40-80%	< 40 or > 80%	None due to torch	
% Canopy Mortality	None	--	15%	--	60%	80%	%100	
Char Height	None	--	1.5 m	--	2.8 m	--	> 5 m	
Post Fire: %Girdled =			**%Felled =**		**%Tree Mortality =**			
E. BIG TREES (UPPER CANOPY, DOMINANT, CODOMNANT TREES)								
Pre-Fire % Cover =	**Pre-Fire Number Living =**				**Pre-Fire Number Dead =**			
% Green (Unaltered)	100%	--	95%	--	50%	< 10%	None	
% Black (Torch)	None	--	5-10%	--	50%	> 80%	100% + branch loss	
% Brown (Scorch/Girdle)	None	--	5-10%	--	30-70%	< 30 or > 70%	None due to torch	
% Canopy Mortality	None	--	10%	--	50%	70%	%100	
Char Height	None	--	1.8 m	--	4 m	--	> 7 m	
Post Fire: %Girdled =			**%Felled =**		**%Tree Mortality =**			

Community Notes/Comments:

CBI = Sum of Scores / N Rated:	Sum of Scores	N Rated	CBI
Understory (A+B+C)			
Overstory (D+E)			
Total Plot (A+B+C+D+E)			

Mix and Match according to Objectives

e.g., Substrate Severity Assessment

Quadrat 1 (Instrument)							
Substrate (% cover code)	**Unburned**	**Scorched**	**Lt. Burn**	**Mod. Burn**	**Heavy Burn**		**Total Cover Code**
Litter + 1hr fuel		lt black	charred	No litter	No litter		
Duff		unchanged	surf char	deep char	No duff		
Mineral Soil		unchanged	black	grey	orange		
Remainder of categories: Absence (--) Presence (X) Dominance (D) or Not Applicable (NA) column						***NA***	***record if >10%***
Moss, Lichen, Liverwort		brown	charred	None	None		
Low Vascular (apply grassland rules)		brown	~5cm left	< 5cm left	consumed		
10hr Fuel (0.6 - 2.5 cm)			black	charred	None		
100hr Fuel			black	charred	charcoal		
Coarse WD (> 7.6 cm) + Stumps			black	charred	charcoal		Sound% Decayed%
Quadrat 1 Comments:							

When coupled with typical vegetation indicators (i.e., scorching, top-kill, and consumption of different strata), enables the calculation of multiple severity indices

- Tree Burn Index
- Soil Post Burn Index
- Composite Burn Index

Lessons Learned & Recommendations

- Substrate fire severity indicators are ephemeral
  - Rapid response
  - Window of opportunity is system dependent
  - Account (where possible) for effects of time
- Where possible, record the components rather than the index
  - Supplement assessments with digital photos
- Expect fine-scaled heterogeneity
  - Match the scale of direct effects with that of the assessment
  - Multi-scale assessment can enable scaling of effects
- Methods may need refinement for controlled burn applications
  - Finer resolution of low-severity spectrum

Fire Severity Methods

- Jain, T. B. and R. T. Graham. 2007. The relation between tree burn severity and forest structure in the Rocky Mountains. Pages 213-250 in R. F. Powers, technical editor. Restoring fire-adapted ecosystems: proceedings of the 2005 National Silviculture Workshop. USDA Forest Service, Albany, California, USA.
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- Key, C. and N. Benson. 2006. Landscape assessment (LA) sampling and analysis methods. USDA Forest Service, Rocky Mountain Research Station. Gen. Tech. Rep. RMRS-GTR-164-CD.
- Parson, A., P. R. Robichaud, S. A. Lewis, C. Napper, and J. T. Clark. 2010. Field guide for mapping post-fire soil burn severity. Gen. Tech. Rep. RMRS-GTR-243. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p.
- USDI National Park Service. 2003. Fire Monitoring Handbook. Boise (ID): Fire Management Program Center, National Interagency Fire Center. 274p

Break-Out Group Exercise

- *Estimate CBI using plot photos*

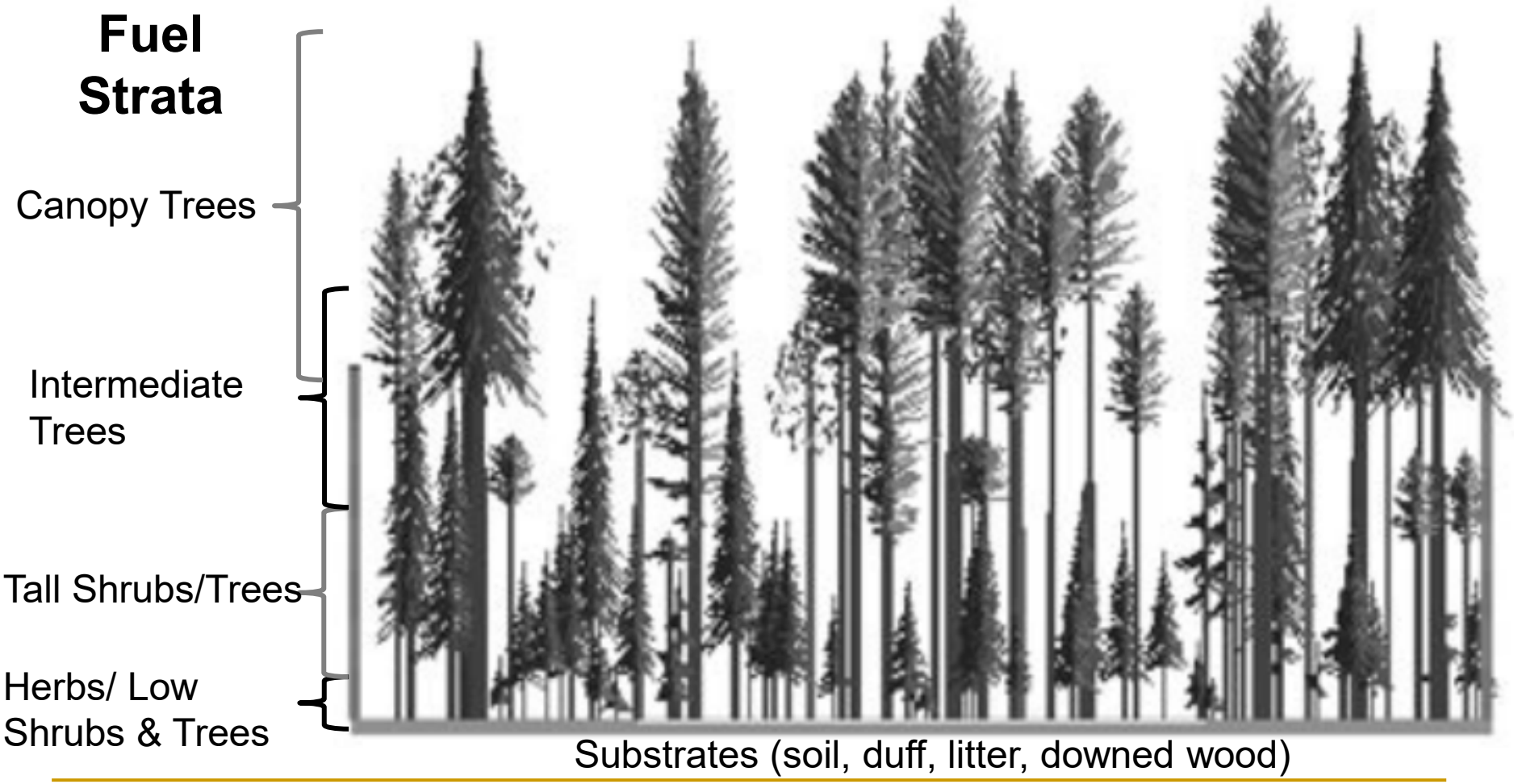

Image Source: Peterson et al. 2005. PNW-GTR-628.

Break-Out Group Exercise

- *Estimate CBI using plot photos*

- Pagami Creek Wildfire
  - N Minnesota near-boreal
  - Early wildland fire use = low-intensity (August)
  - Escaped crown fire (mid-Sept)
  - Photos taken late October
- Moquah controlled burn
  - Mid-May late dormant season burn
    - Early bud-break
  - Photos taken 1-day post-burn
  - Examples are from pine woodlands
    - Jack Pine vs Red Pine
    - Fuel addition contrasts

Thank you!

Joint Fire Science Program

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

THE UNIVERSITY of WISCONSIN MADISON

NSF

NASA

MICHIGAN STATE UNIVERSITY

Field Support: To numerous to list!!

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