

Does 1% of the land area account for 99% of the wildfire threat?



Joe H. Scott



Don Helmbrecht



Matt Thompson

Joe H. Scott, principal consultant at Pyrologix LLC, gave this presentation at the 5th International Fire Ecology Congress held December, 2012 , in Portland, Oregon. The title of the talk was patterned after the seminal paper titled “Do One Percent of Forest Fires Cause Ninety-Nine Percent of the Damage” (Strauss and others 1989). Their answer was, essentially, “yes”—a relatively few large fires account for the overwhelming majority of area burned. We wanted to see if the same principle applied *spatially* on a landscape.



Pareto Principle

2

- Asymmetry between *number* and *effects*
- The vital few and trivial many (80-20 rule)
- A few large fires account for the vast majority of area burned
- Does the same asymmetry exist for land area and wildfire threat?

The asymmetry between the *number* of things and their *effects* is called the Pareto Principle. In some cases it is also called the 80-20 rule, implying that 20% of the things account for 80% of the effects—the vital few and trivial many.

For wildfire area burned, it is well established that a very small number of the largest fires accounts for the vast majority of area burned if wildfires. The related question is this:

Does a small amount of the landscape represent the vast majority of expected adverse wildfire effects?



$$\sum_j^n \sum_i^6 BP_i * RF_{ij} * \frac{RI_j}{RE_j}$$

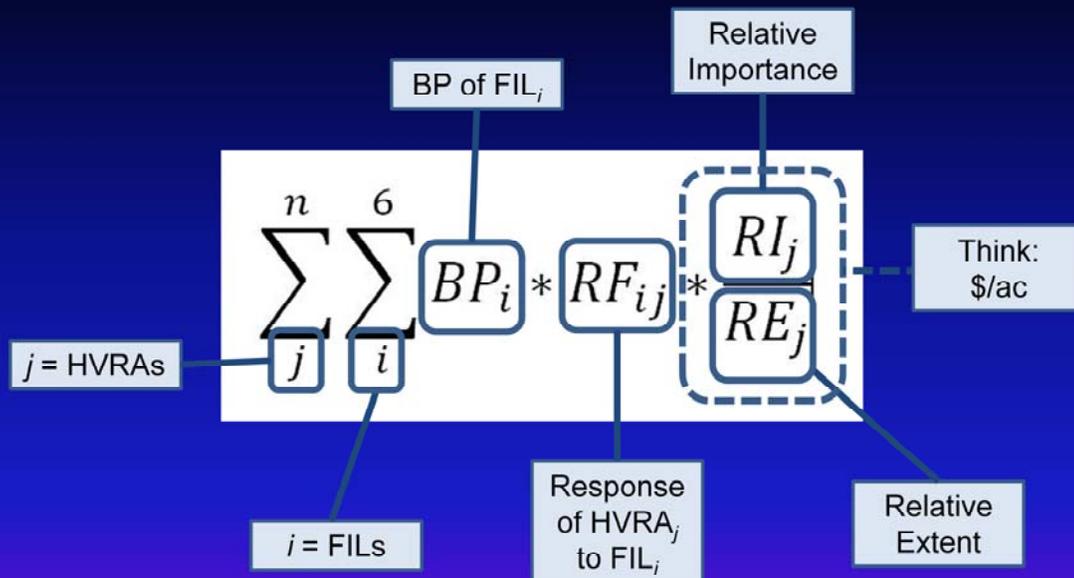
This equation illustrates the quantitative (actuarial) assessment of wildfire risk as expected net value change (eNVC) at a point on the landscape.

Let's break it down...on the next slide.



Wildfire threat

4



i refers to a fire intensity class (here, Fire Intensity Level, or FIL)

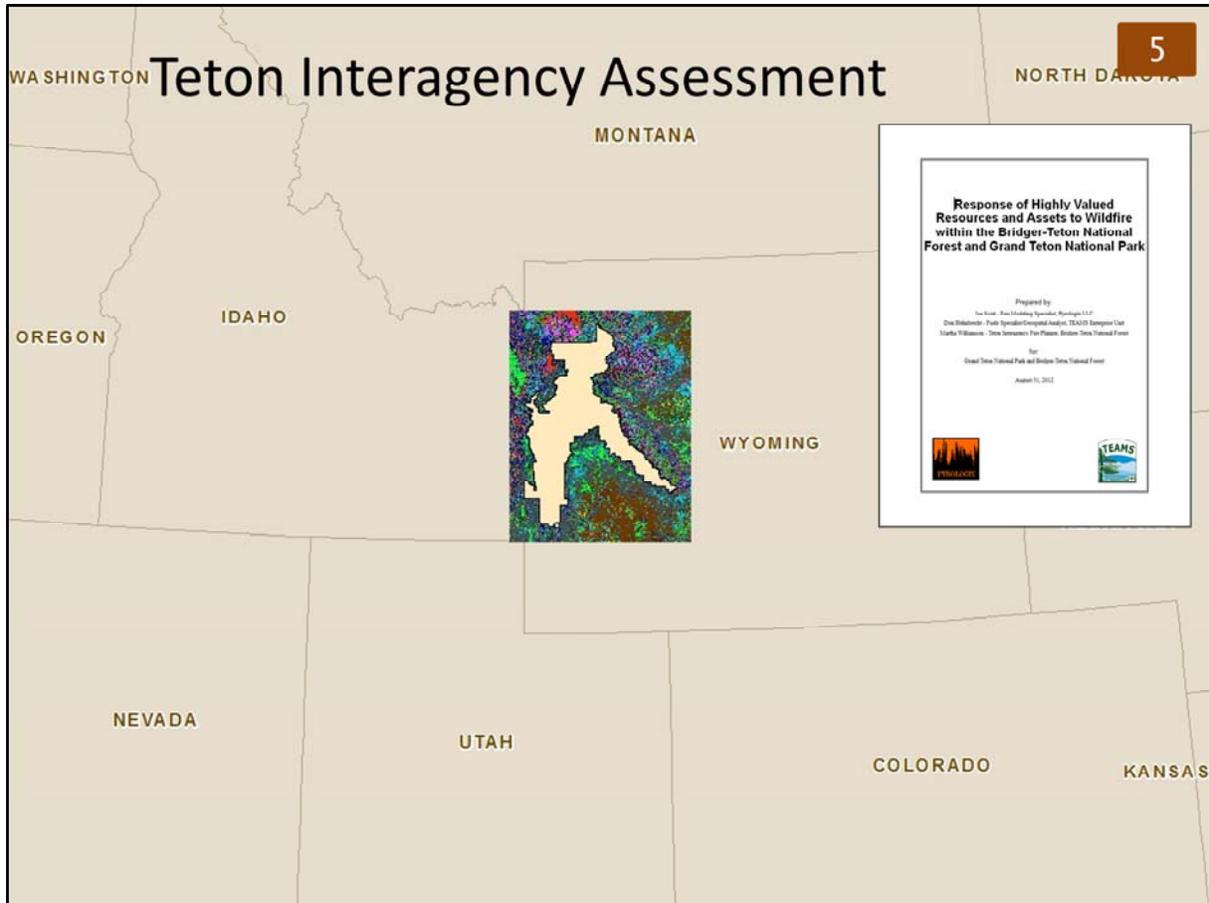
j refers to each highly valued resource or asset (HVRA) that exists at a point

Bp_i = annual probability of burning at FIL_i

RF_{ij} = net value change (response function) for resource j and intensity i

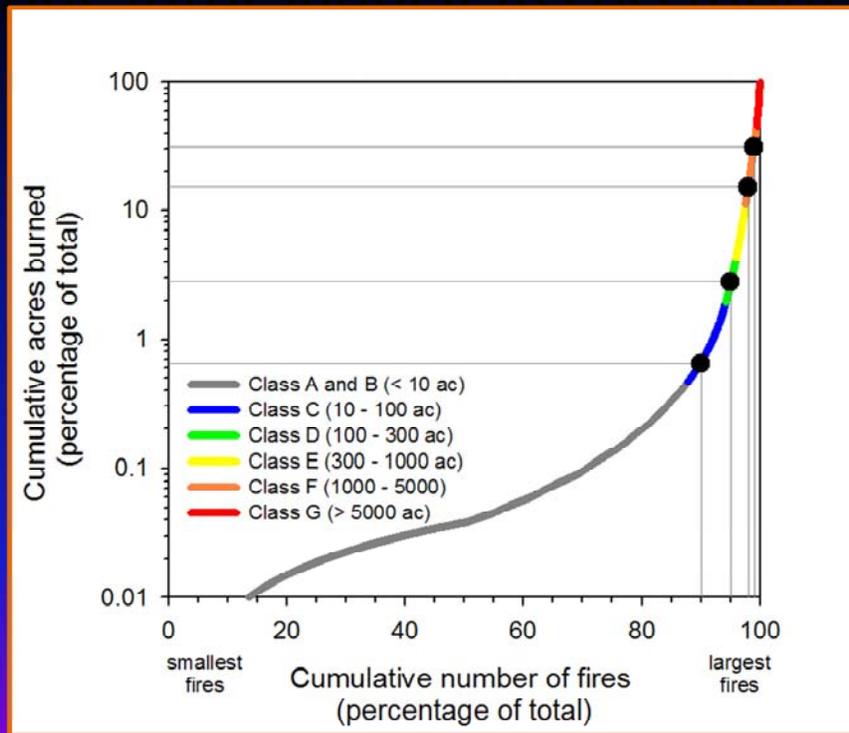
RI_j/RE_j = the relative importance per unit area (extent) of resource j . This is analogous to the value per acre of the HVRA. Think \$/ac.





In the remainder of this presentation I will refer to the Tetons Interagency Risk Assessment, or TIARA, which was conducted for the Bridger-Teton National Forest and Grand Teton National Park.





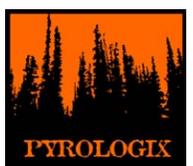
This Lorenz Chart of historical fire occurrence on the TIARA landscape illustrates the Pareto Principle: 90% of the smallest fires account for only 1 percent of the cumulative acres burned, and 95% of fires account for just 3 percent of acres. That's a stronger asymmetry than 80-20, but not quite as strong as 99-1 implied by the title of the Strauss and others paper.

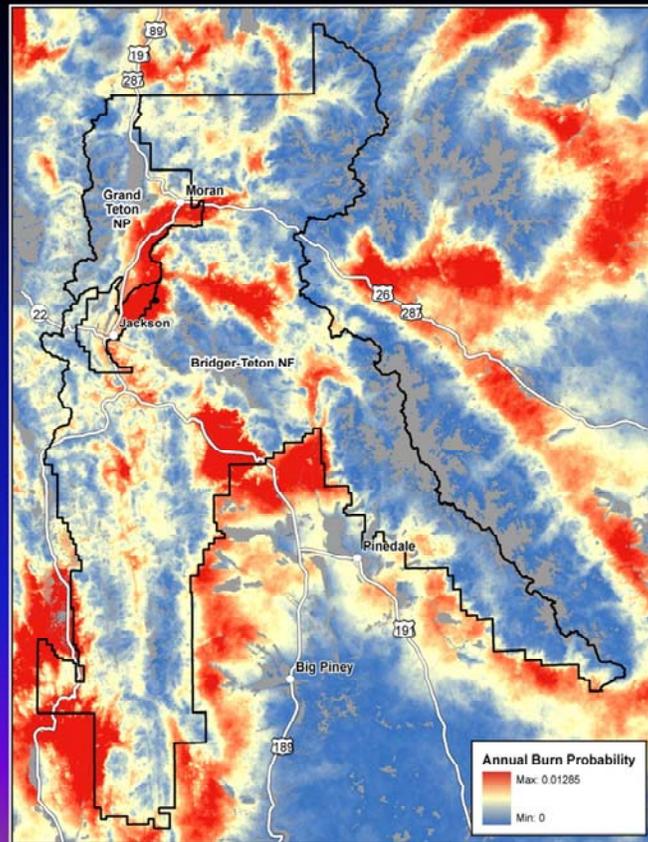
Teton Interagency Assessment

7

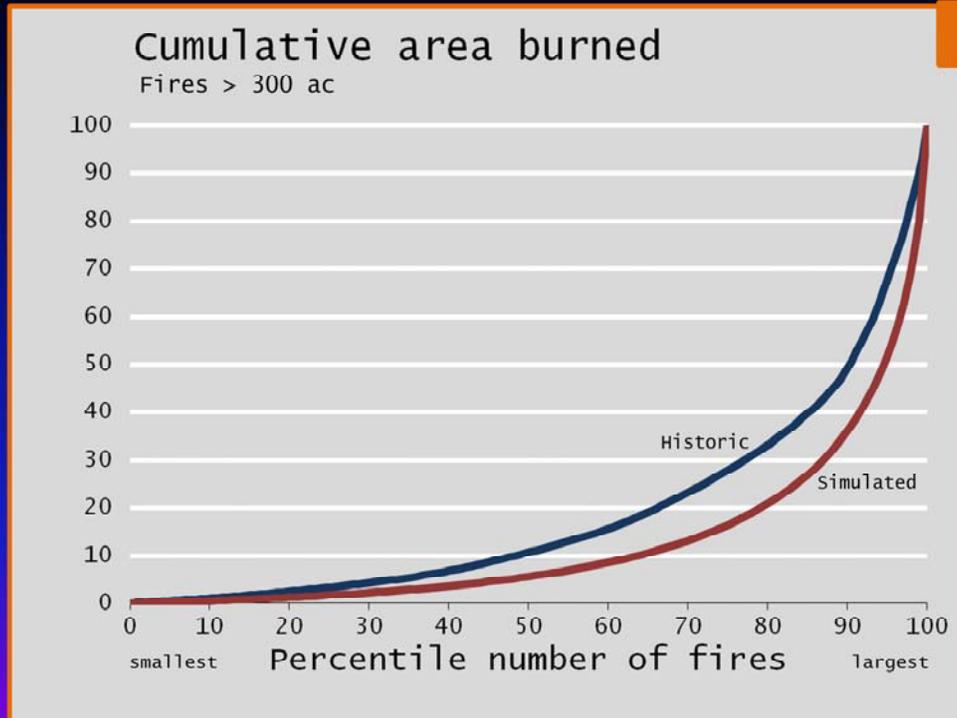
- Simulated BP_i with FSim
- Characterized HVRAs (location, susceptibility, importance)
- Calculated wildfire threat and benefit

For TIARA, we simulated the annual probability of burning by Fire Intensity Level with the FSim large-fire simulator. We then worked with representatives of the Forest to identify and characterize the resources and assets on the Forest. Finally, we calculated wildfire risk—threat and benefit separately, then combined into a net value change—using the equation we showed in slides 3 and 4.





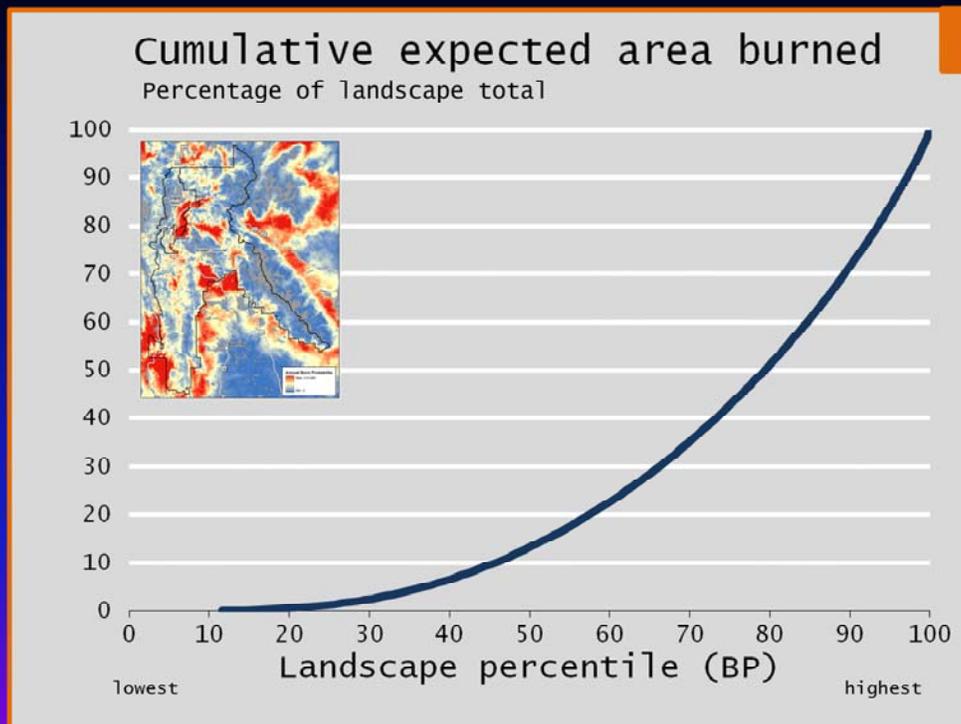
Burn probability modeling with Fsim produced this map of total annual BP, regardless of fire intensity. The “bathtub ring” of relatively high BP, shown in red on the map, corresponds to sagebrush-grasslands that surround the prominent mountain ranges.



Here we have a different form of a Lorentz curve showing the cumulative area burned in large fires (>300 acres) against the number of fires. We see that the historical and simulated distributions are similar, both showing a strong influence of a relatively few large fires.

This is how the Pareto Principle is usually applied to wildland fire. Next, let's see how inequality plays out across the landscape.





The most basic landscape-level assessment of inequality can be calculated from the BP grid we showed earlier. The land area of each pixel times its BP is the expected annual area burned. By ordering the pixels by increasing BP, we already see some of the inequality we're looking for, but not much. One thing we notice right away is that almost 12 percent of the landscape is non-burnable, so that area doesn't contribute to expected area burned. Here, the top 30% of the landscape (by BP) accounts for about 70% of the expected area burned.

Note that this inequality, represented by the bendiness of the curve, is simply a result of *variability* in BP across the landscape.

Next, we'll look for other forms of variability and inequality on the landscape.

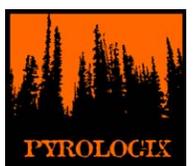


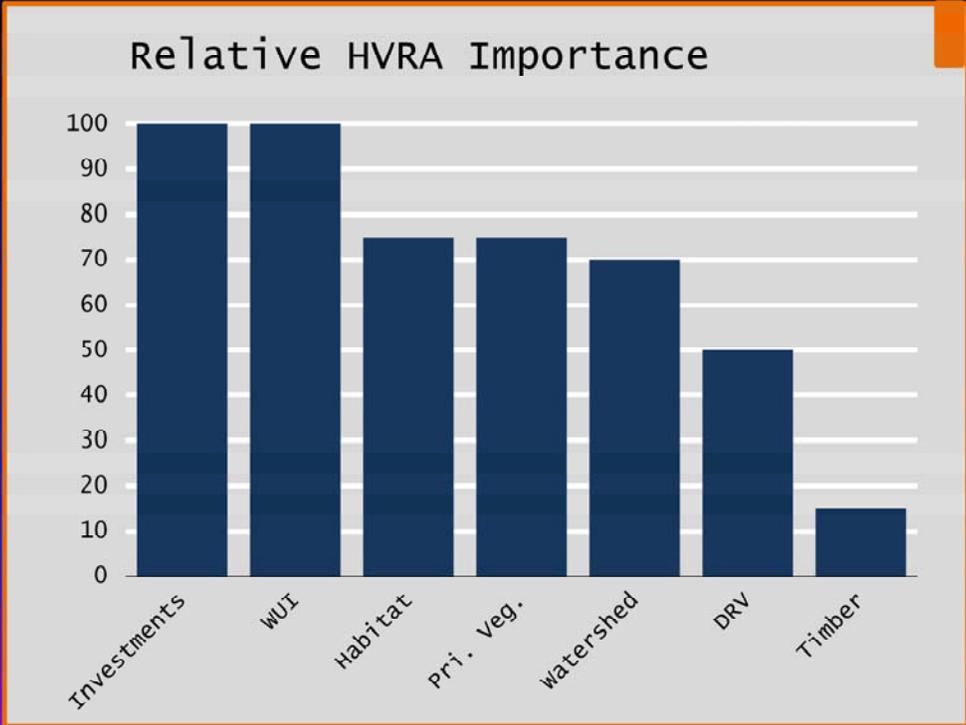
HVRA characterization

11

- Forest investments
- Wildland-Urban Interface
- Critical Fish and Wildlife Habitat
- Priority Vegetation
- Municipal Watersheds
- Diverse and Resilient Vegetation Composition
- Timber Base

But first, we have to lay some foundation by talking about the seven main HVRAs that were characterized on the Forest.



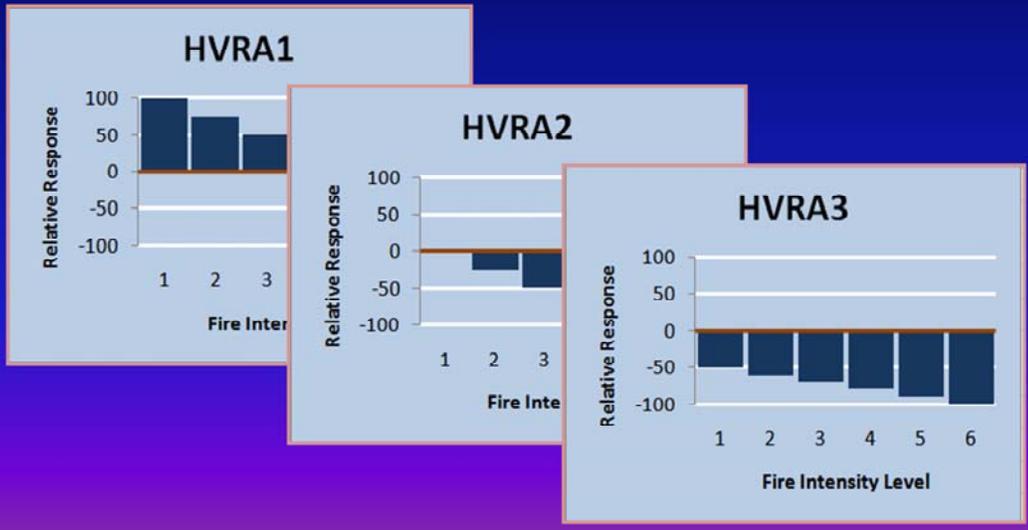


Matthew P. Thompson of the Rocky Mountain Research Station Human Dimensions Program led a workshop at which the Forest Leadership team assigned a relative importance value to each of the seven HVRA. This is what they produced.



Susceptibility

Fire Intensity Level	1	2	3	4	5	6
Flame length range (feet)	0-2	2-4	4-6	6-8	8-12	12 +
HVRA1	100	75	50	25	0	-25
HVRA2	0	-25	-50	-75	-100	-100
HVRA3	-50	-60	-70	-80	-90	-100



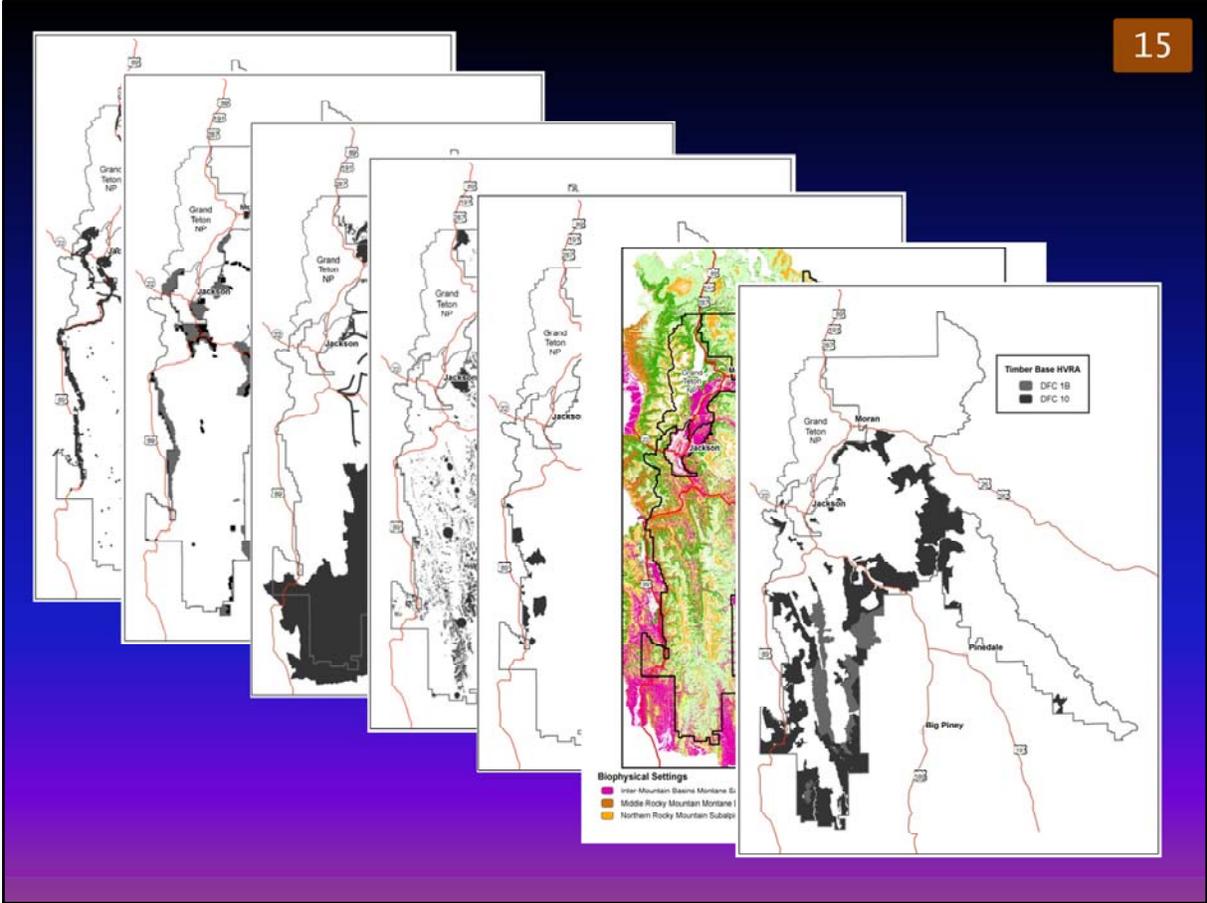
At a simultaneous workshop , Forest resource specialists developed response functions for each HVRA, including the many “sub-HVRAs” and “covariates” within each.



HVRA Name	HVRA RI	Sub-HVRA Name	Sub-HVRA RI	Covariate	FIL 1	FIL 2	FIL 3	FIL 4	FIL 5	FIL 6	
Investments	100	Wyoming Game and Fish feedgrounds	60		-50	-70	-90	-100	-100	-100	
		special use permit areas	100		-50	-70	-90	-100	-100	-100	
		trailheads/outrun sites	85		0	-10	-20	-30	-40	-50	
		campgrounds/picnic areas	85		0	-10	-20	-30	-40	-50	
		cabins/guard stations/lookouts	100		-50	-70	-90	-100	-100	-100	
		oil and gas development leases	100		-10	-20	-40	-80	-100	-100	
		communication sites	100		0	-30	-60	-80	-100	-100	
		power lines	100		-10	-20	-40	-80	-100	-100	
		whitebark pine plus trees	60		-10	-70	-100	-100	-100	-100	
		WUI defense zone	100		0	-50	-75	-100	-100	-100	
Wildland Urban Interface (WUI)	100	protection fire management unit	70		10	0	-25	-50	-50	-50	
		lynx areas	12.5		-20	-75	-100	-100	-100	-100	
Critical Fish and Wildlife Habitat	75	lynx analysis units with over 30% vegetation in stand initiation phase	15		foraging	100	100	100	100	100	100
		lynx analysis units with 20-30% vegetation in stand initiation phase	10		non-foraging	100	100	100	100	100	100
		pronghorn antelope migration routes	30		nut-scatterer	50	35	15	0	-30	-70
		pronghorn antelope migration routes	30		conifer	100	100	100	100	100	100
		bighorn sheep migration routes	60			100	100	100	100	100	100
		moose thermal cover in Teton Wilderness	70			50	0	-30	-70	-90	-100
		sagegrouse core areas	100			-50	-100	-100	-100	-100	-100
		sagebrush within two miles of occupied sagegrouse lakes	80			20	-20	-100	-100	-100	-100
		cutoff trout and leatherside chub streams	50			50	25	0	-40	-80	-90
		whitebark pine - A	100			0	-50	-100	-100	-100	-100
Priority Vegetation	75	whitebark pine - B	20		0	-50	-100	-100	-100	-100	
		whitebark pine - C	80		0	-50	-100	-100	-100	-100	
		whitebark pine - D	0		0	-50	-100	-100	-100	-100	
		sensitive plants	30		positive response	20	20	20	50	50	20
		aspen in close proximity to elk feedgrounds	17		negative response	0	0	-10	-20	-25	-30
		aspen with high priority for restoration treatment	86			0	0	-20	-40	-50	-60
						20	30	60	75	100	100
						20	0	-20	-50	-75	-100
						40	40	-20	-30	-30	-30
						30	16	-10	-60	-70	-80
Municipal Watersheds	70	Rocky Mountain subalpine dry-mesic spruce-fir forest and woodland	30	SclassA-Surplus	30	30	15	0	-60	-70	
				SclassB-Deficit	50	50	15	0	-70	-80	
				SclassC-Similar	30	30	15	0	-60	-70	
				SclassD-Surplus	10	20	40	40	20	10	
				SclassU	30	30	15	0	-60	-70	
		Inter-Mountain Basins montane sagebrush steppe	100	SclassA-Deficit	-30	-40	-50	-50	-50	-50	
				SclassB-Surplus	50	50	60	60	50	40	
				SclassB-Similar	40	40	60	60	40	30	
				SclassC-Deficit	0	20	40	40	30	20	
				SclassU	-30	-40	-50	-50	-50	-50	
Diverse and Resilient Vegetation	50	Northern Rocky Mountain subalpine woodland and parkland	70	SclassA-Surplus	30	30	-10	-20	-20	-20	
				SclassB-Deficit	30	40	0	-70	-80	-80	
				SclassC-Similar	20	30	0	-60	-70	-70	
				SclassC-Deficit	30	40	0	-70	-80	-80	
				SclassD-Surplus	10	20	40	60	20	0	
		Rocky Mountain subalpine mesic-wet spruce-fir forest and woodland	20	SclassE-Similar	30	20	0	-60	-90	-90	
				SclassE-Deficit	40	30	-10	-70	-100	-100	
				SclassU	30	30	-10	-20	-20	-20	
				SclassA-Surplus	30	30	-20	-30	-30	-30	
				SclassA-Similar	30	40	0	-70	-50	-50	
Rocky Mountain aspen forest and woodland	100	SclassD-Surplus	10	20	40	60	20	0			
		SclassB-Deficit	40	30	-10	-70	-100	-100			
		SclassA-Deficit	0	0	-10	-30	-50	-70			
		SclassB-Deficit	-10	-10	-20	-40	-60	-80			
		SclassC-Similar	20	20	0	-20	-40	-60			
		SclassC-Deficit	10	10	-10	-30	-50	-70			
		SclassD-Surplus	10	20	40	100	100	100			
		SclassE-Similar	10	10	10	10	10	10			
		SclassE-Deficit	0	0	0	0	0	0			
		SclassU	-10	-10	-20	-40	-60	-80			
SclassA-Surplus	30	30	-20	-30	-30	-30					

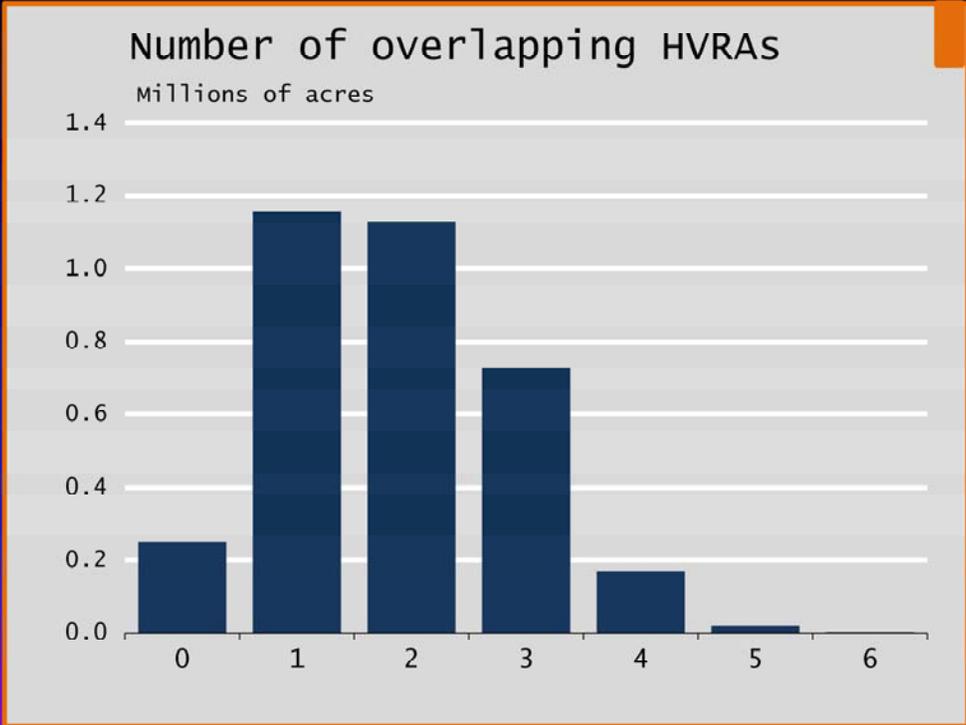
The complete list of HVRA, sub-HVRA and variates is long. Let's not get stuck in the weeds...



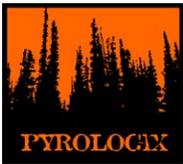


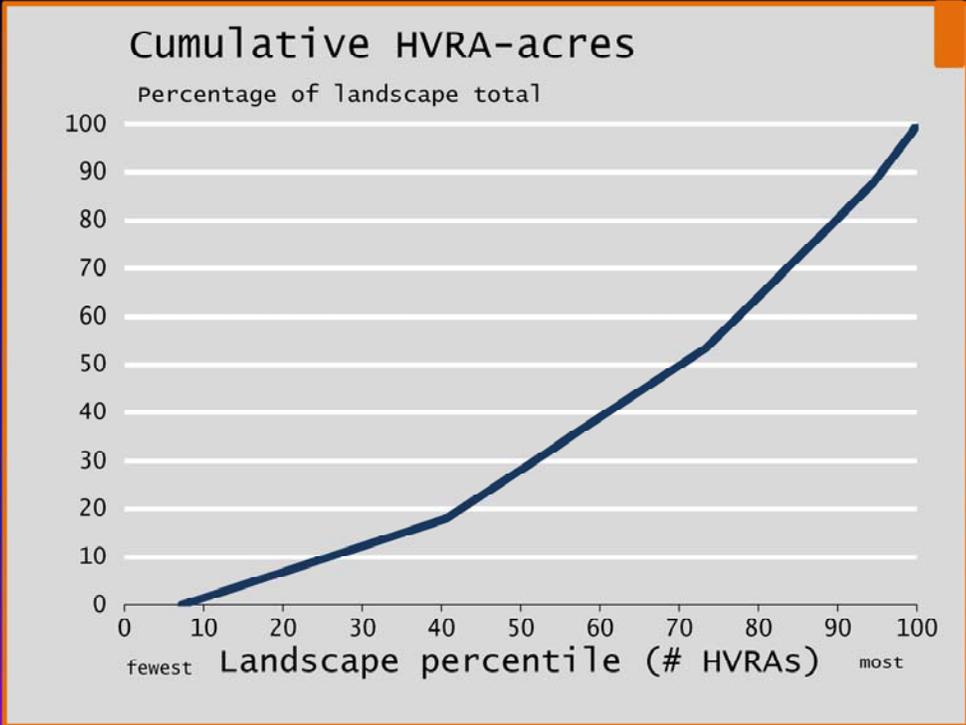
The Forest provided the geospatial data to go along with the response functions and relative importance scores we developed at the workshops.





Another simple assessment of variability and inequality across the landscape is the distribution of overlapping HVRAs.

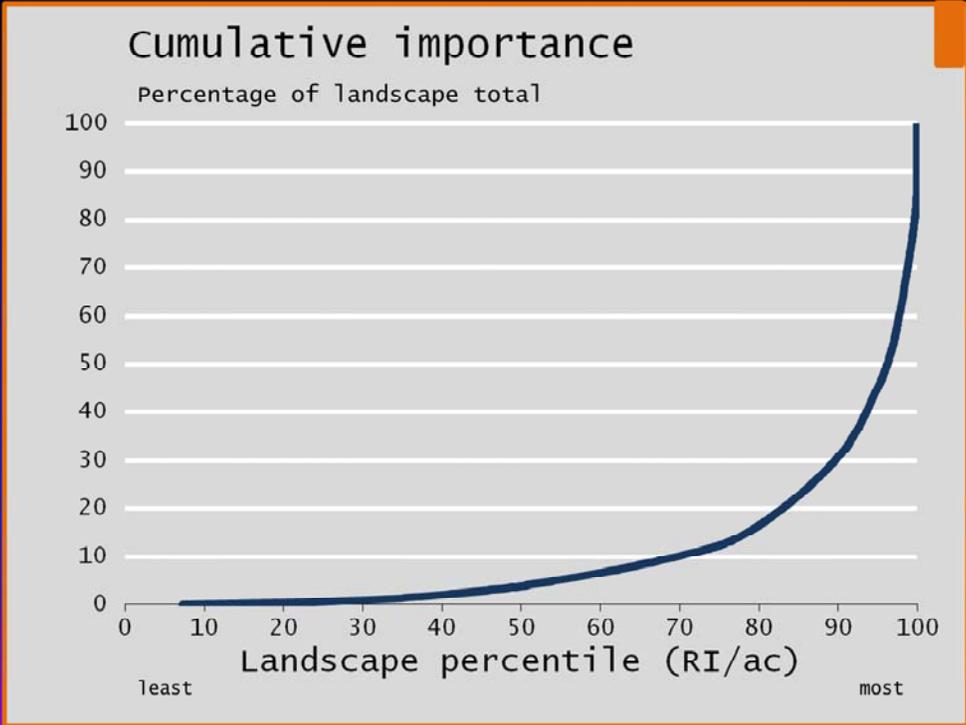




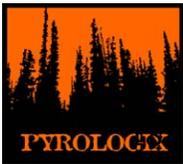
By assuming that each HVRA is of equal value, we produced this Lorenz chart. Here we can see that only 8 percent of the landscape is not covered by any HVRA. This curve isn't that bendy at all, roughly 60-40.

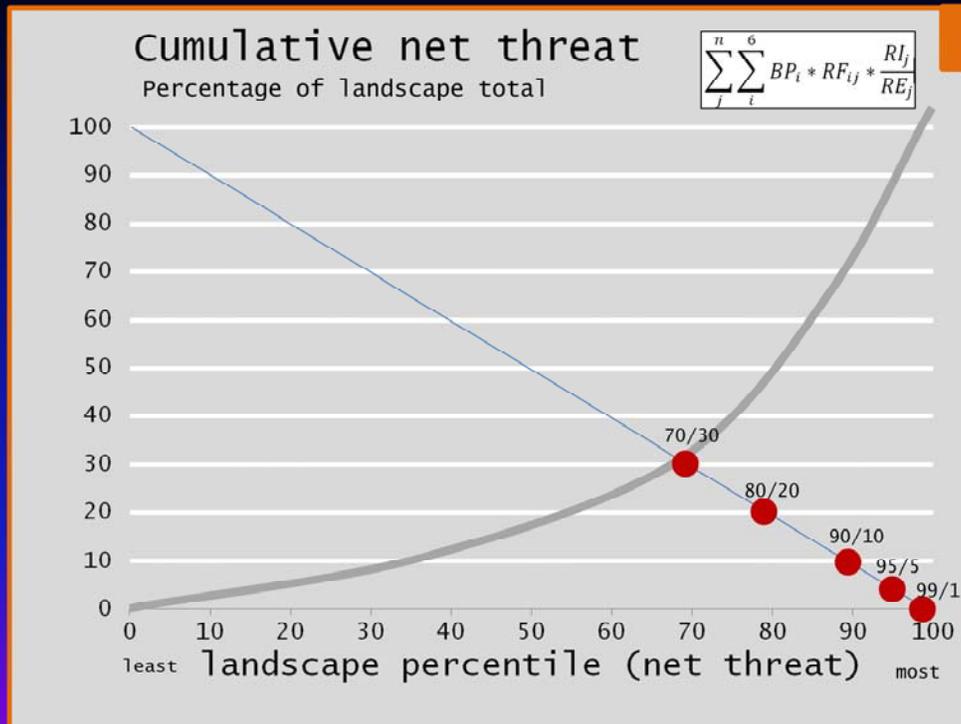
But we know that each HVRA is not of equal value. So let's account for that...





By summing the relative importance per pixel across all HVRA's present at each pixel and the sorting them from least important to most, we produce this Lorentz chart, showing a stronger than 80-20 asymmetry.





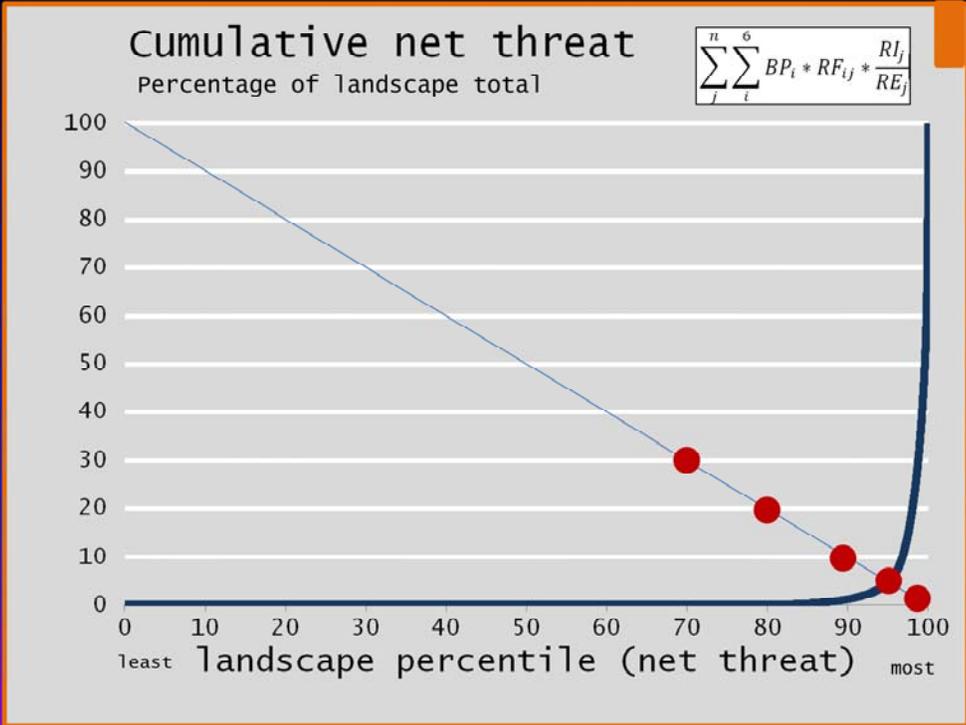
It's quite challenging to deal with both positive and negative effects on a Lorenz chart, so, for the moment, let's concentrate just on the land area where there is a net threat, corresponding to the red areas of the previous map.

But, before we show you the actual result, let's see if you've been paying attention... Which point would you estimate the curve goes closest to?

- a) 70-30
- b) 80-20
- c) 90-10
- d) 95-5
- e) 99-1

Ready?



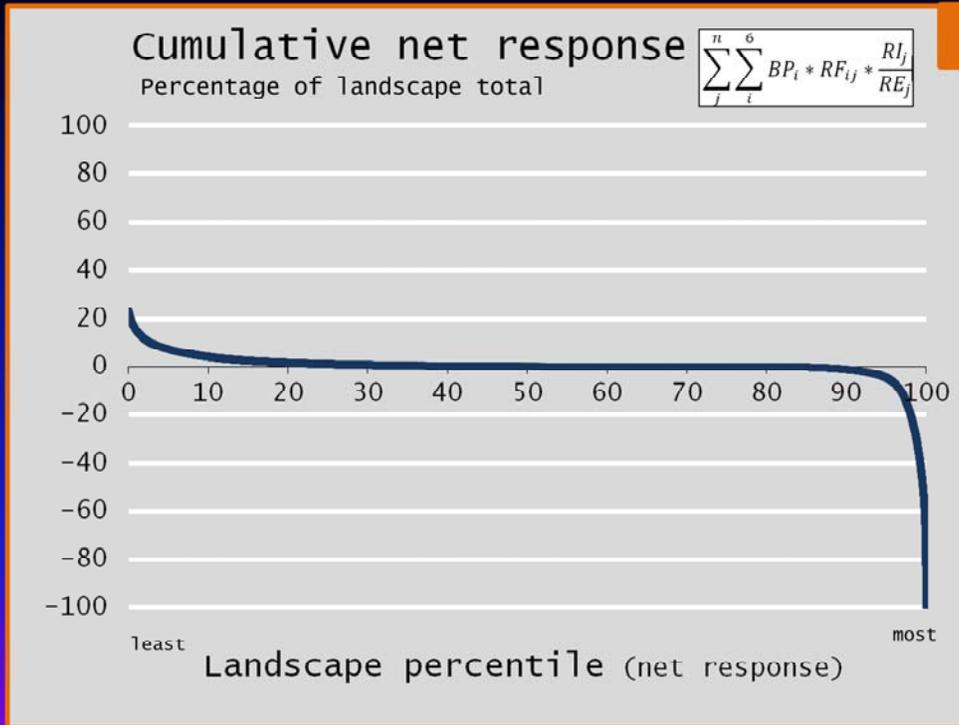


The answer, for this landscape, is that 95% of the cumulative expected adverse effects of wildfire are found on just 5% of the landscape.

Let that sink in a moment. Fire can do bad things to resources and assets, but when we take into account HVRA exposure, susceptibility and relative value, most of the bad things are occurring on a very small portion of the landscape.

That's an astounding result, because it means that we don't have to think about managing fuel across the entire landscape; we can instead focus on the most threatened portion of the landscape...if we can find it.





Now let's take a look at the Lorentz chart that includes both threat and benefit. Somewhere in the middle of the curve are the non-burnable pixels, and the pixels that can burn but there are no HVRAs present. Those are right on 0 on the Y-axis. Threat accumulates to the right and downward toward negative numbers; benefit accumulates leftward and upward.

From this chart we see that the cumulative benefit on this landscape was about 20 percent of the cumulative threat, and is less concentrated than the threat.

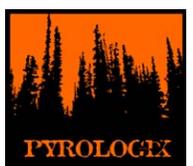


Does 1% of the land area
account for
99% of the wildfire threat?

No, but 5% of the land
area accounts for 95%
of the wildfire threat.

So, does 1% of the land area account for 99% of the wildfire threat?

No, not quite, but you probably get the point.



What does this mean?

- The landscape is non-uniform
 - Hazard (probability, intensity)
 - HVRA (extent, importance, susceptibility)
 - Threat and benefit
- Suggests a risk management strategy
 - Prioritize the most-threatened areas
 - Can we find those highly threatened acres?

What does this result mean?

Simply, the landscape is not uniform in hazard (BP, intensity) or in HVRA location, susceptibility or value. This variability leads to variability in expected NVC (threat and benefit).

This result suggests an alternative wildfire risk management strategy: rather than attempt to manage fuel across the entire landscape, prioritize the most-threatened areas of the landscape first. Of course, that requires that we be able to find those acres, which may be scattered about in small patches.



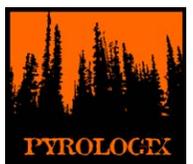
What does this mean?

25

- What are the characteristics of the 5%?
 - Multiple HVRAs?
 - High susceptibility?
 - High value?
 - High hazard?

The next step in this analysis is to determine the characteristics of these most-threatened areas. Are they highly susceptible to fire? Are there lots of HVRAs present at the same location? Is the relative importance per area high? Is the hazard high?

Chances are good that at least two or three of these factors will be present among the 5%.





joe.scott@pyrologix.com
@pyrologix
facebook.com/pyrologix

