

Fire and Dry Forest Landscapes

What Have We Learned?

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Fire: The West's Big Problem

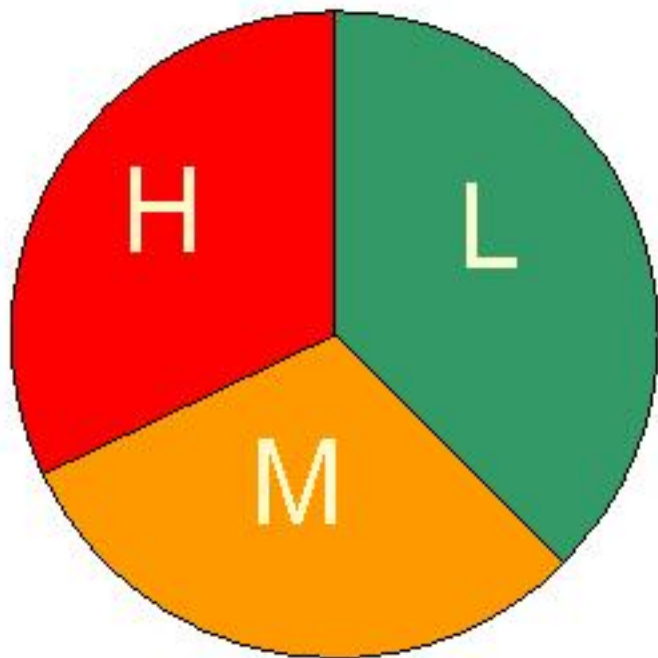
Western U.S. Burned Area – All Sources



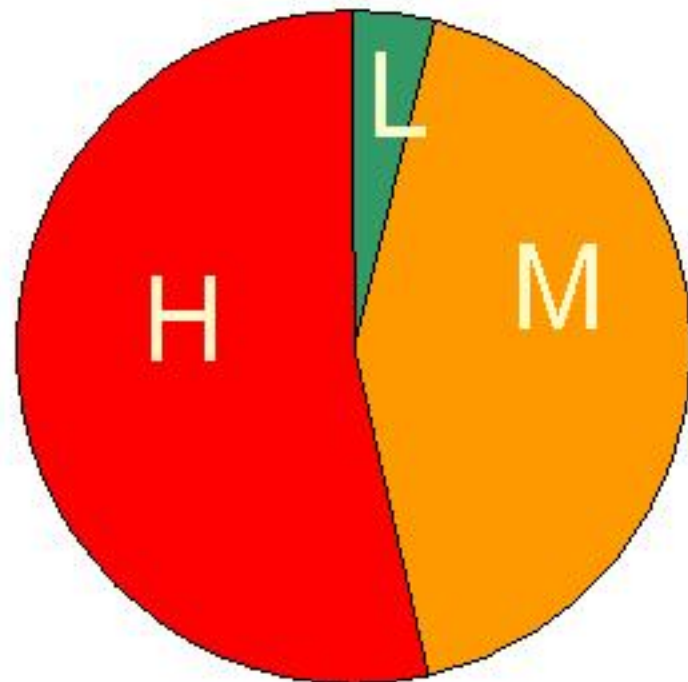
- Strong link between fire **size** and climate
- None of the climate studies have looked at fire **severity**
- Fuels are a major contributor here

Changes in Fire Regimes

Historical



Now



Forest Service Regions 1-6 – FRCC 2000 – All Cover Types

Historical



Low



Mixed



High

Today



Mixed



Mixed/High



High

Historical Fire Effects



Low Severity Regimes



Mixed Severity Regimes



High Severity Regimes

Current Fire Effects

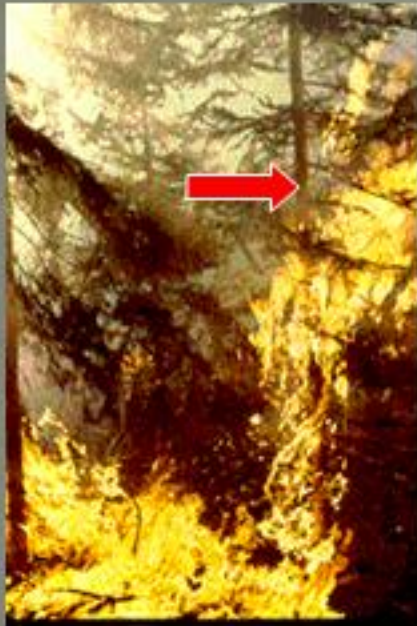


Firesafe Principles at the Stand Level

- Reduce surface fuels
- Reduce ladder fuels
- Keep the large trees
- Reduce crown density

Agee and Skinner 2005. For. Ecol. Manage.

Prescribed Fire Reduces Surface and Ladder Fuels by Killing Small Trees



Arrow Points to Same 2 cm Tree as Fire Moves Along

Torching – Another Stand Scale Process



Torching or Passive

- Two concepts:
 - Passive crown fire
 - Active crown fire
- Passive crown fire – “torching” – fire transitions from surface fire up into the crowns

Prescribed Fire and Ladder Fuels



- Surface Fuels are Reduced
- Height to Live Crown Increased
- Green surface fuels not flammable

Reduce Torching Potential

Keep critical fireline intensity (I_0) high compared to potential I

I_0 is a function of foliar moisture and height to live crown

$$I_0 = (Czh)^{3/2}$$

Where

C = constant (0.01)

z = canopy base height (m)

h = heat of ignition (varies by foliar moisture)

WE CAN MANIPULATE CANOPY BASE HEIGHT

Active Crown Fire



- Active Crown Fire
 - Running crown fire
 - Continuous crown fire

Reduce Active Crown Fire Potential

- Active crown fire a function of rate of spread and canopy bulk density [CBD] (volume of fine crown mass per unit volume)
- Thinning reduces crown mass and therefore CBD and mass flow rate, usually below critical level so that active crown fire cannot be supported
- But it is not always needed!

The Models Seem to Work

- In reality, based on empirical evidence from boreal forests of typically simpler structure than our western dry forests
- Empirical evidence from real fires can be used to validate the models in a general way.
- Examples here:
 - Onion/Megram Fire, N. California
 - Tyee fire, Washington
 - Cone Fire, N. California

Surface and Ladder Fuels Treated Before Wildfire



Onion/
Megram
Fire,
CA
1999

Surface and Ladder Fuels Treated



- 1994 - 80,000 ha Tye fire - Washington State
- Stands Where Prescribed fire and thinning occur survive
- Crown fires become surface fires

This stand had only ladder fuels removed and surface fuels reduced

Cone Fire, CA – Surface, Ladder, and Crown Fuels Removed



Fire Went Out

Thin and Burn – 2 yr Old

Untreated

Scaling up to Landscape Levels

“Where no man has gone before....”



Landscape Fuel Treatment and Fire Behavior

- Largely possible through tools such as FARSITE and FLAMMAP
- FARSITE: “Realtime” fire spread
- FLAMMAP: Instantaneous map of landscape fire potential given pixel fuel model, CBH, CBD, topography and selected weather.
 - Mark Finney, Forest Service, Missoula Fire Lab

Theory: Fragmented Fuels Slow Fire Spread

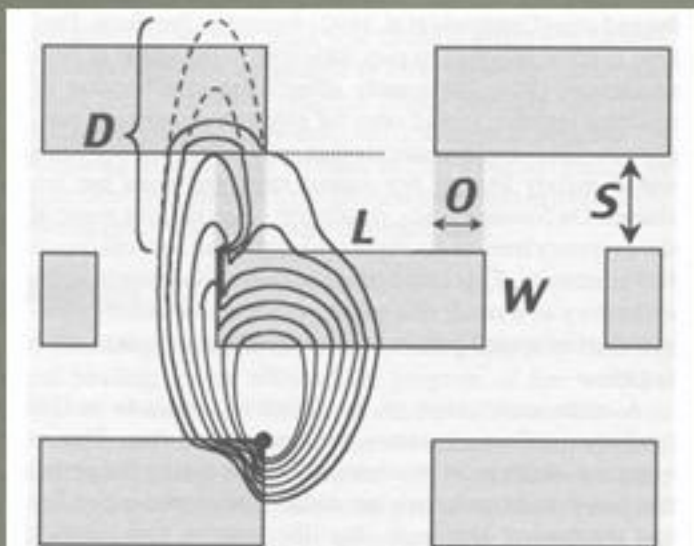
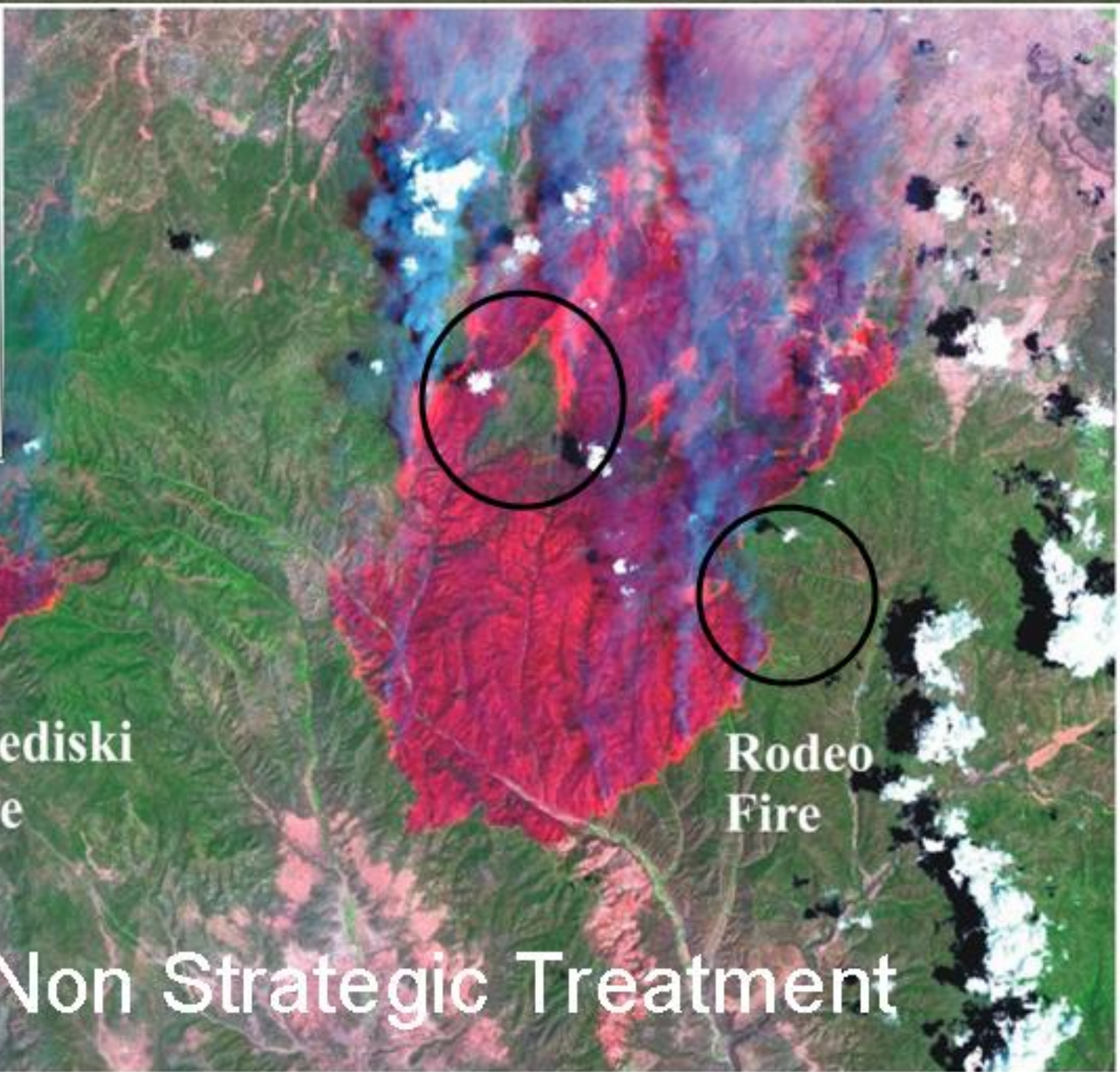
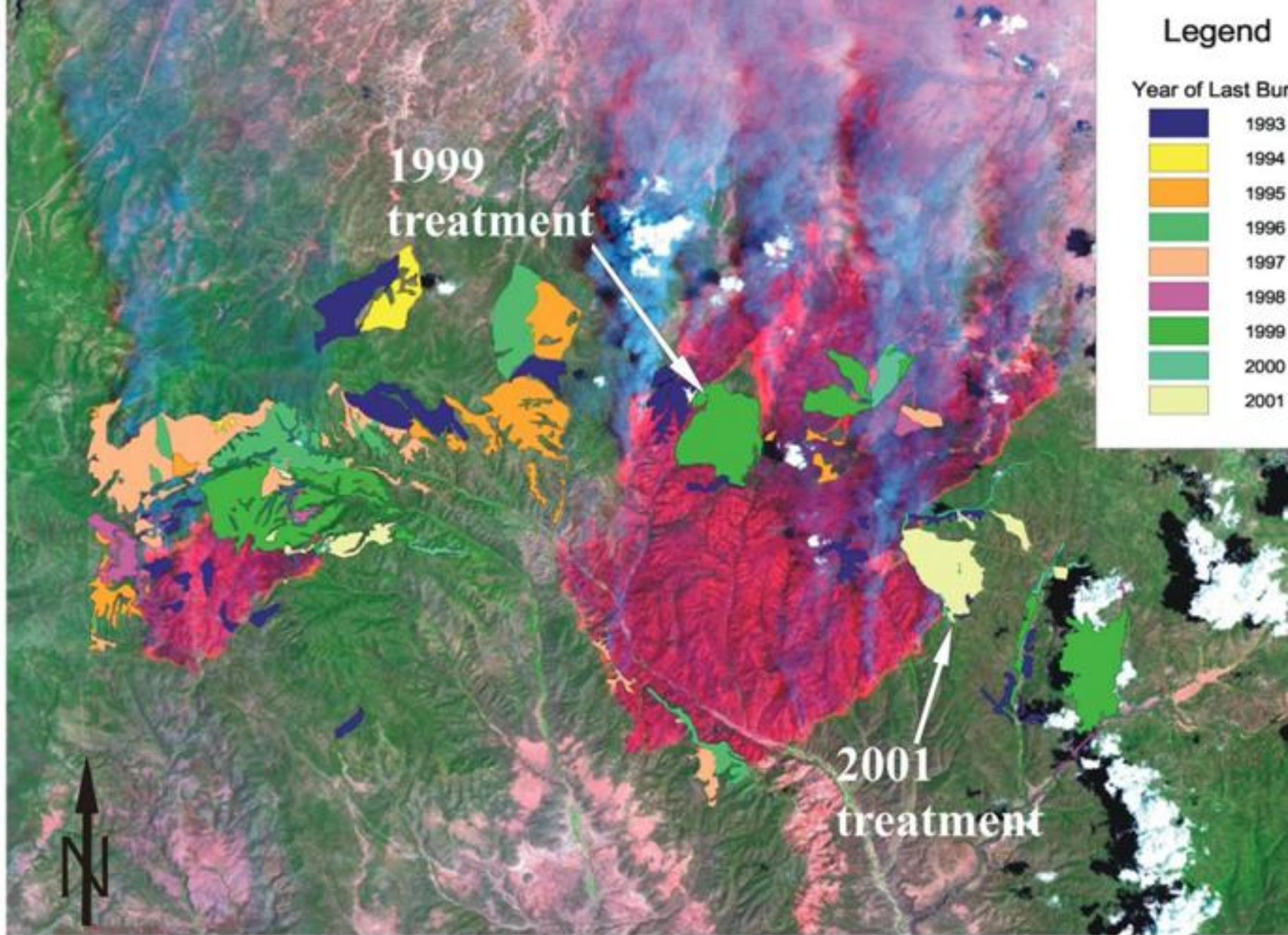


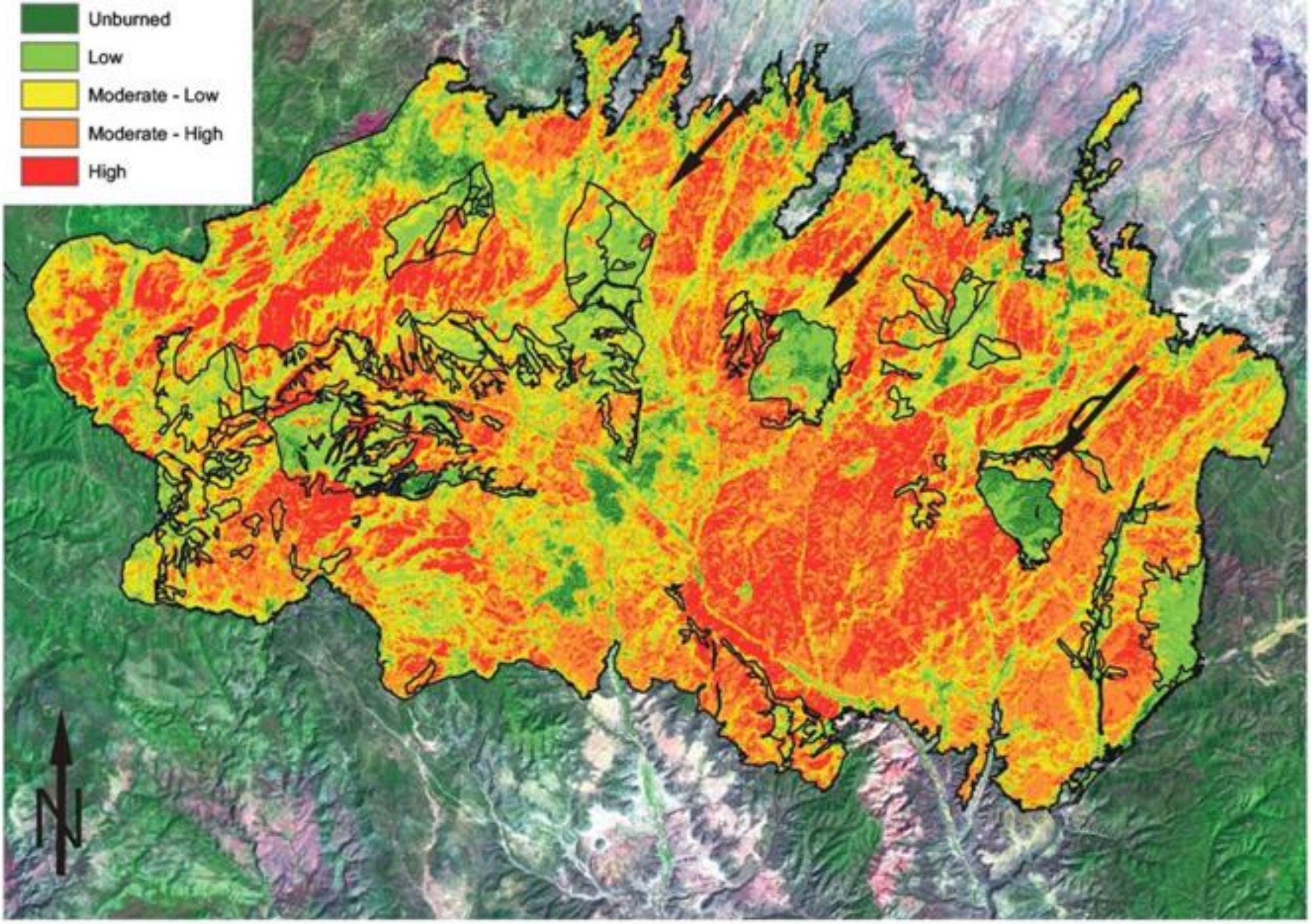
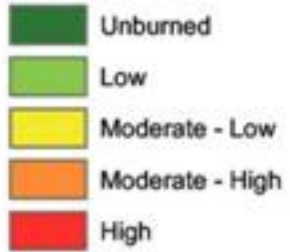
Figure 5. By embedding a single treatment unit in a regular pattern of identical units, W delays fire growth during flanking around two sides of the unit. The spread rate of the fire moving around the units is, therefore, equivalent to the spread rate through the units only if the effect of W on O is reduced by one-half [Equation (10)]. Dashed lines indicate the hypothetical forward spread distance D with no treatment.

- Fires slow within treated areas
- Move faster between treated areas
- What configuration is best?



(b)





0 2.5 5

Finney Landscape Study



- Three study areas
- Sanders Co, MT
- Blue Mtns, OR
- Sierra NF, CA
- How much of a landscape needs to be treated, and where?

Model Logic

- Start with stand polygons, FARSITE layers and Treelists for each
- Grow stand with FVS, create custom fuel models
- Apply TOM (and treatment)
 - Prescribed fire
 - Thin if BA >130 ft²/ac
- Run worst case wildfire through landscape, measure potential size
- Grow stands through next time increment, repeat process

Use of Tom

“TOM” is short for “Treatment Optimization Model”

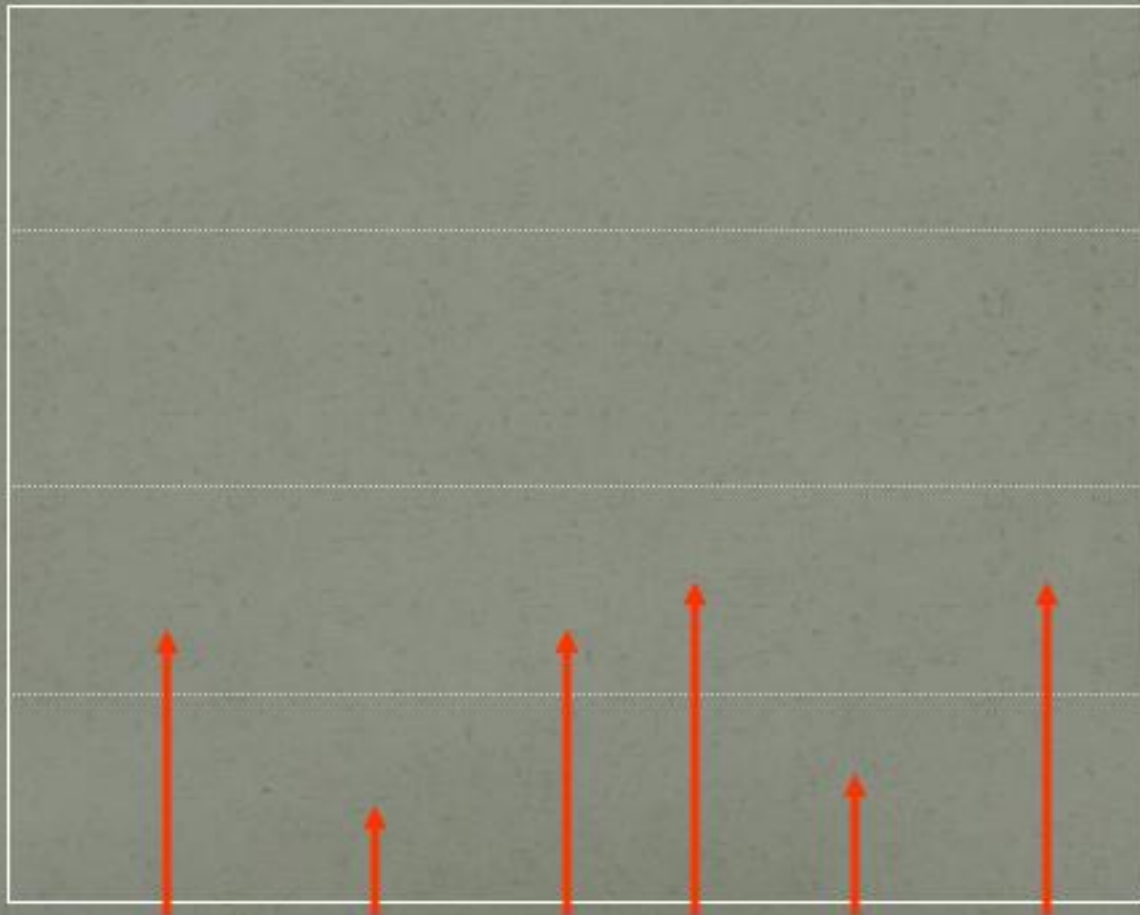
It takes a slice of landscape in the first downwind direction and treats the areas of highest rate of spread, fragmenting the movement of fire.

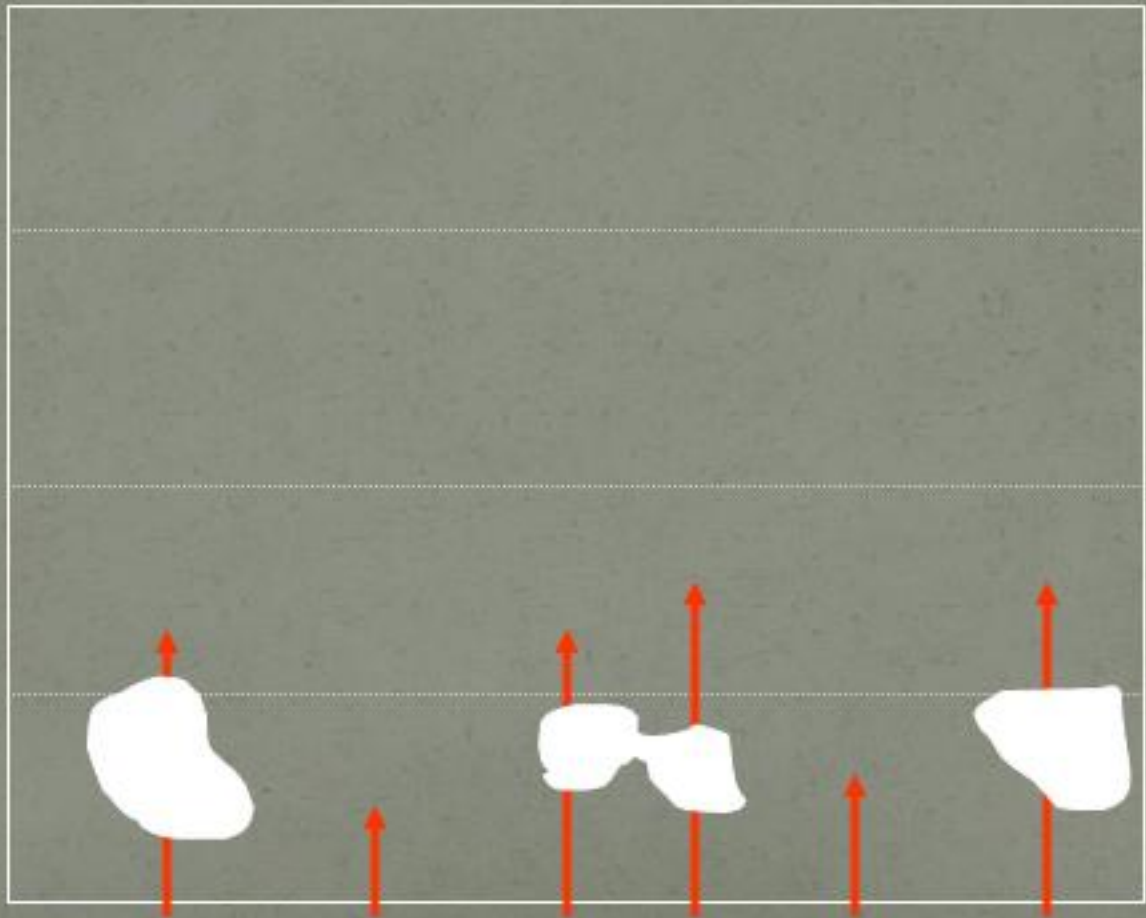
It then takes the second slice, given the treatment in the first slice, and treats around the revised vectors of fastest rate of spread.

Splits landscape up into segments – treats them
in order of wind direction

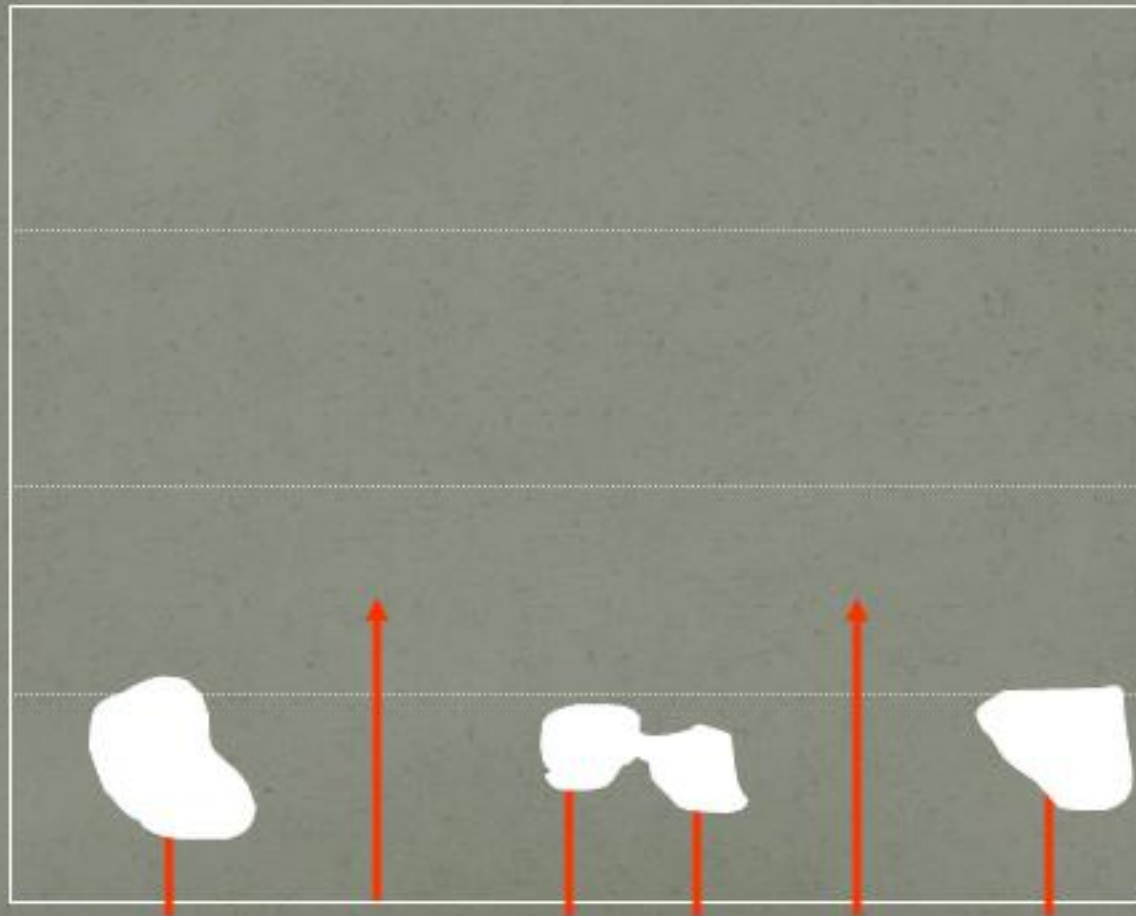


↑
Fire spread rate without treatment

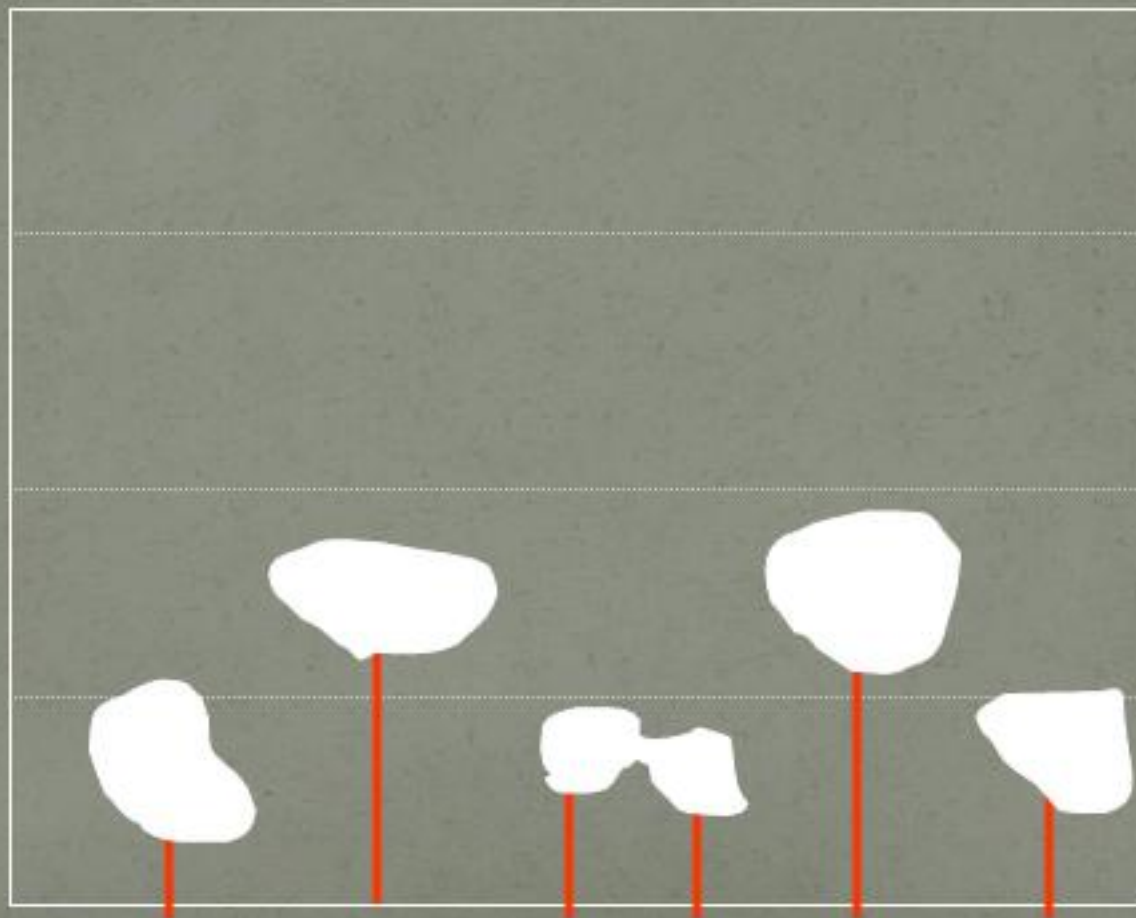




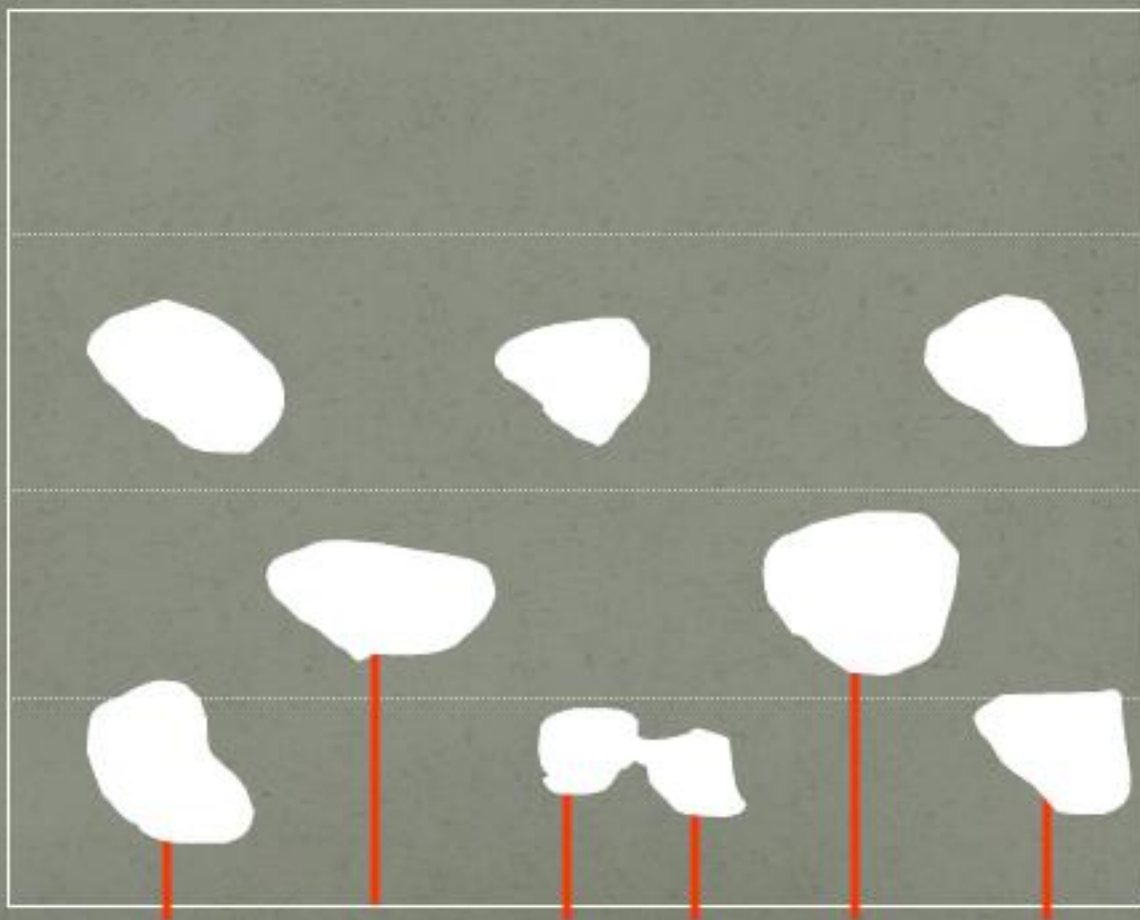
In Next Slice of Landscape,
New "Fastest Spread" Vectors are Identified



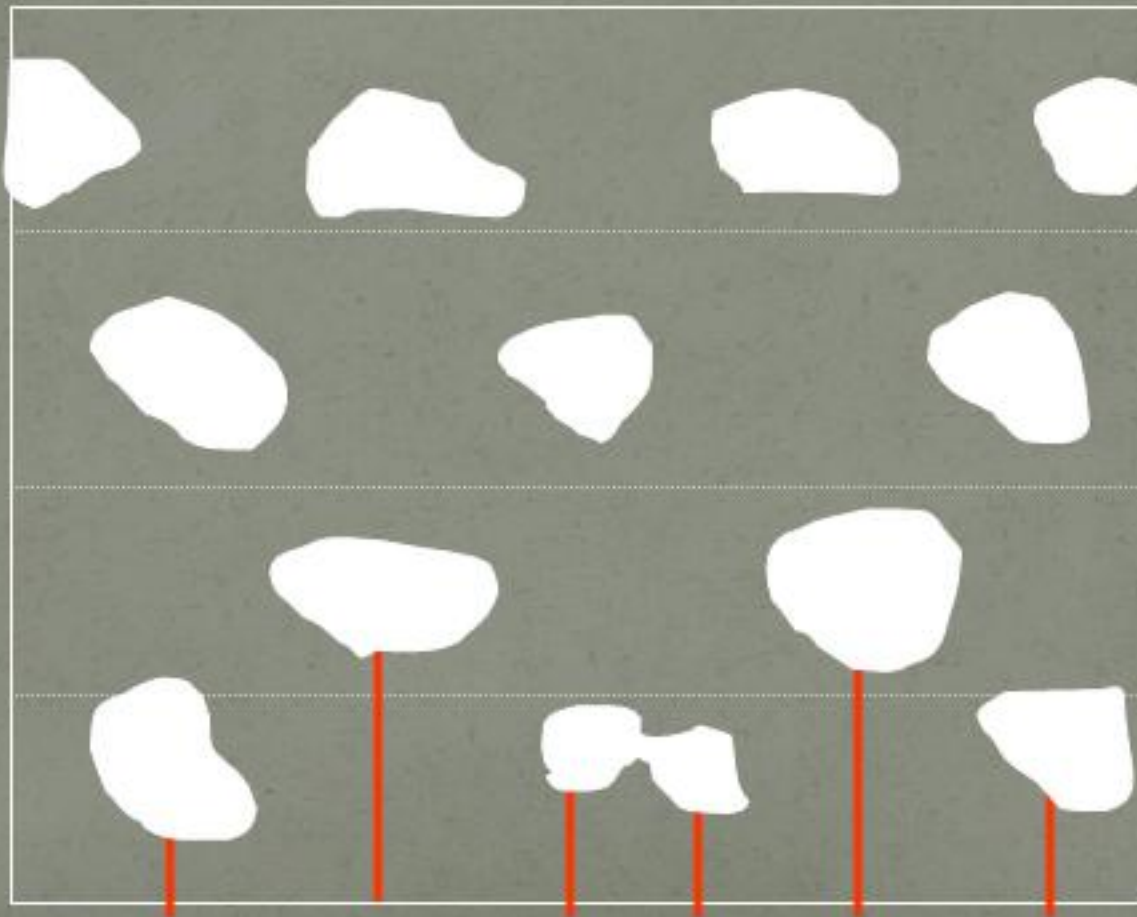
Next Set of “Splats” is Placed to
Block Those Vectors



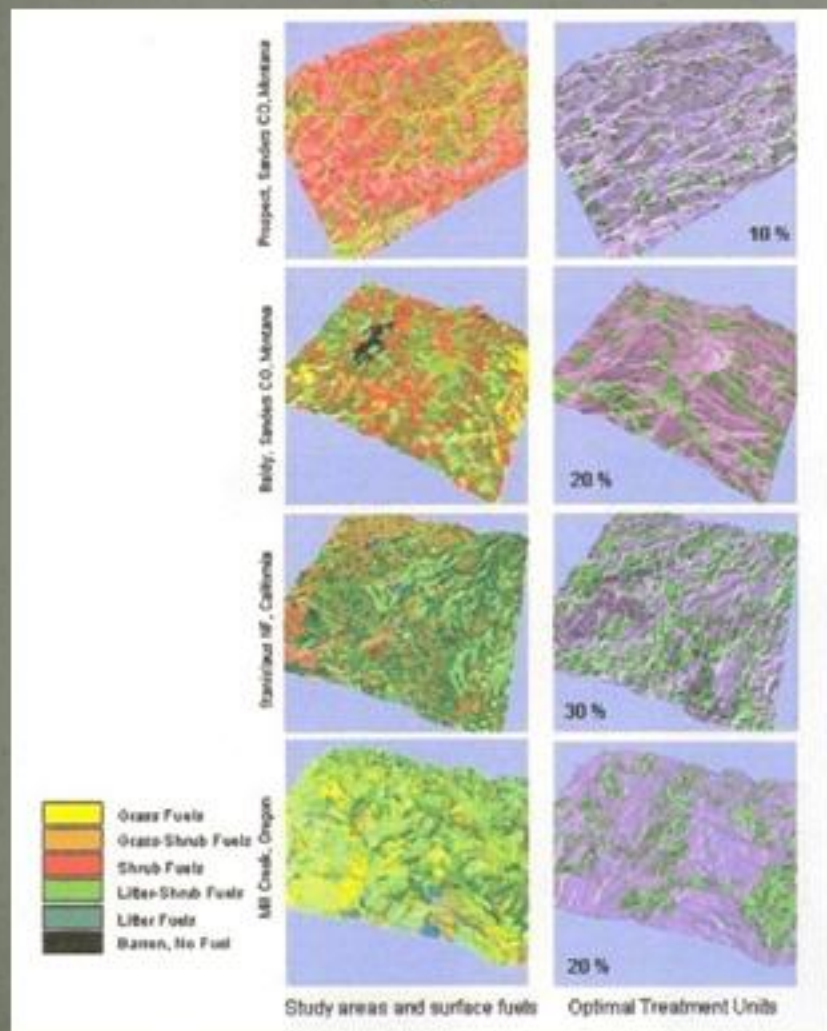
And So On...



Until the Landscape is Splatted – User Controls Percent of Landscape that can be Treated



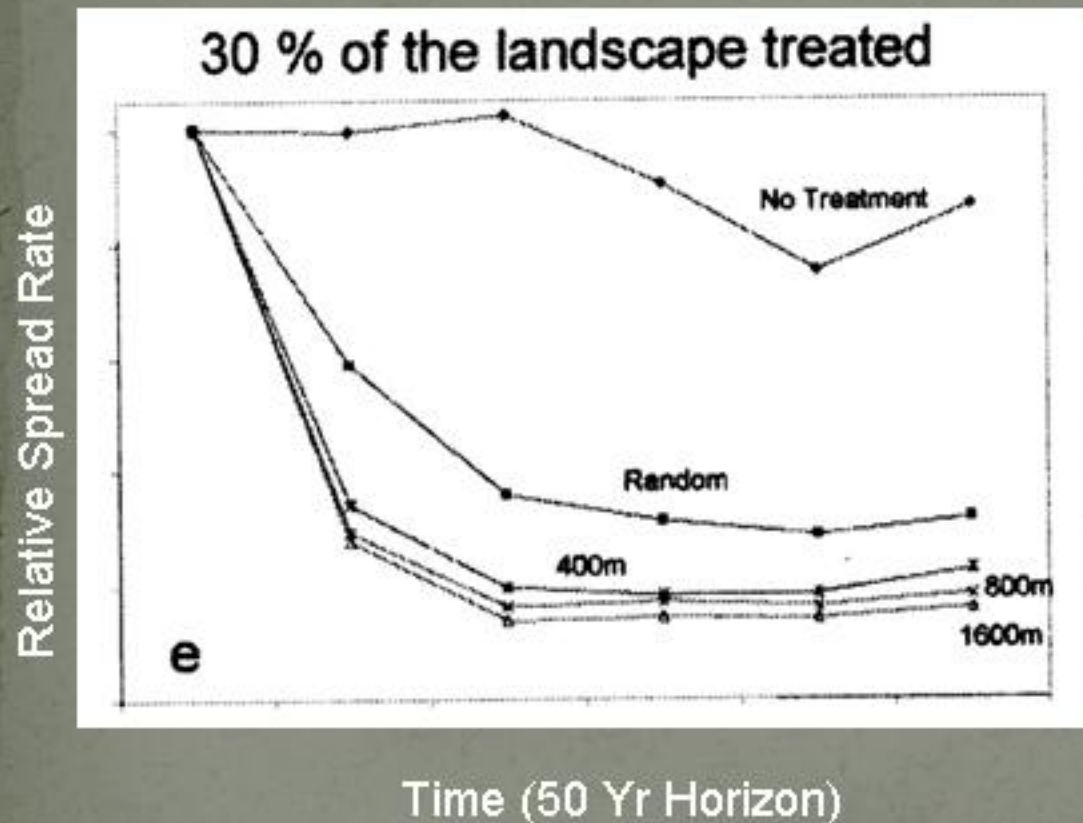
Finney Landscape Study



- Two Montana sites
- One Oregon site
- One California site
- How much to treat?
- Where to treat?
- How long will it last?

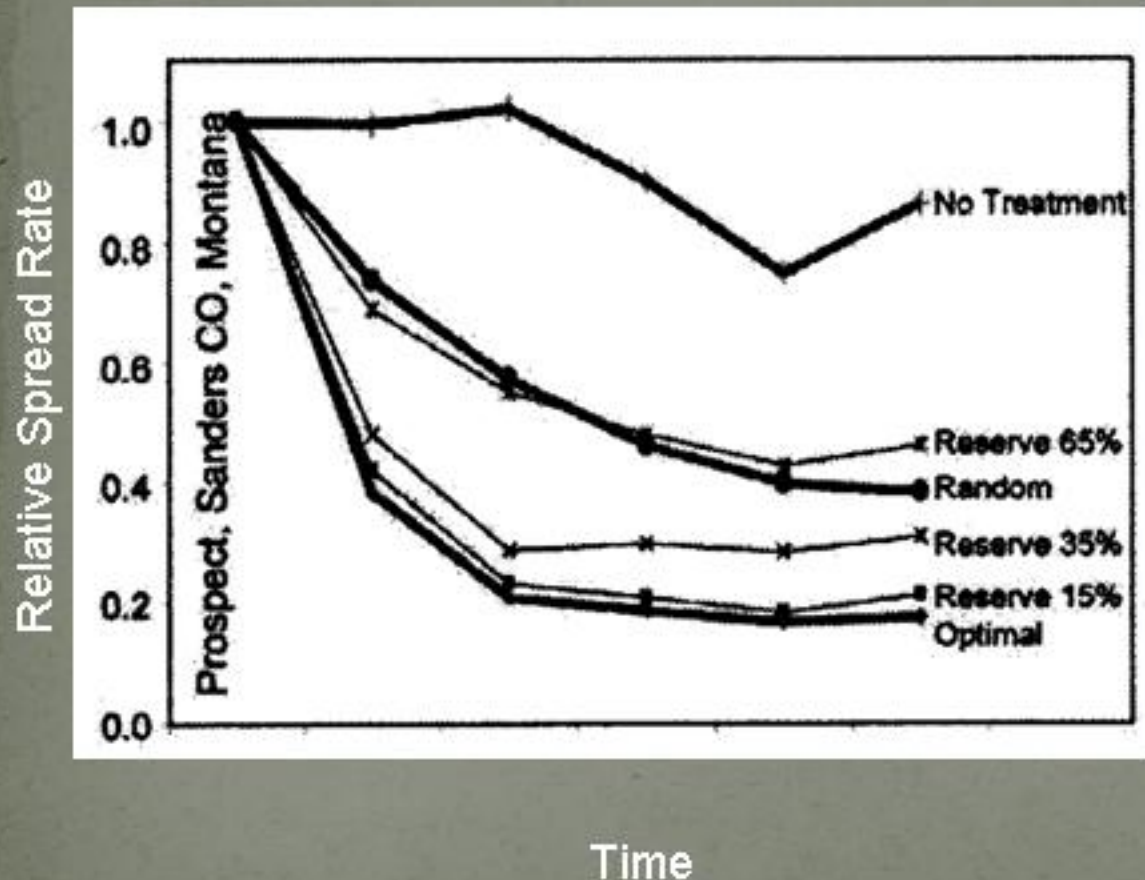
(Green)

Treatment Unit Area Flexible



- All treatments reduced fire area burned compared to either:
 - No treatment
 - Random treatment
- Unit size had little effect on treatment

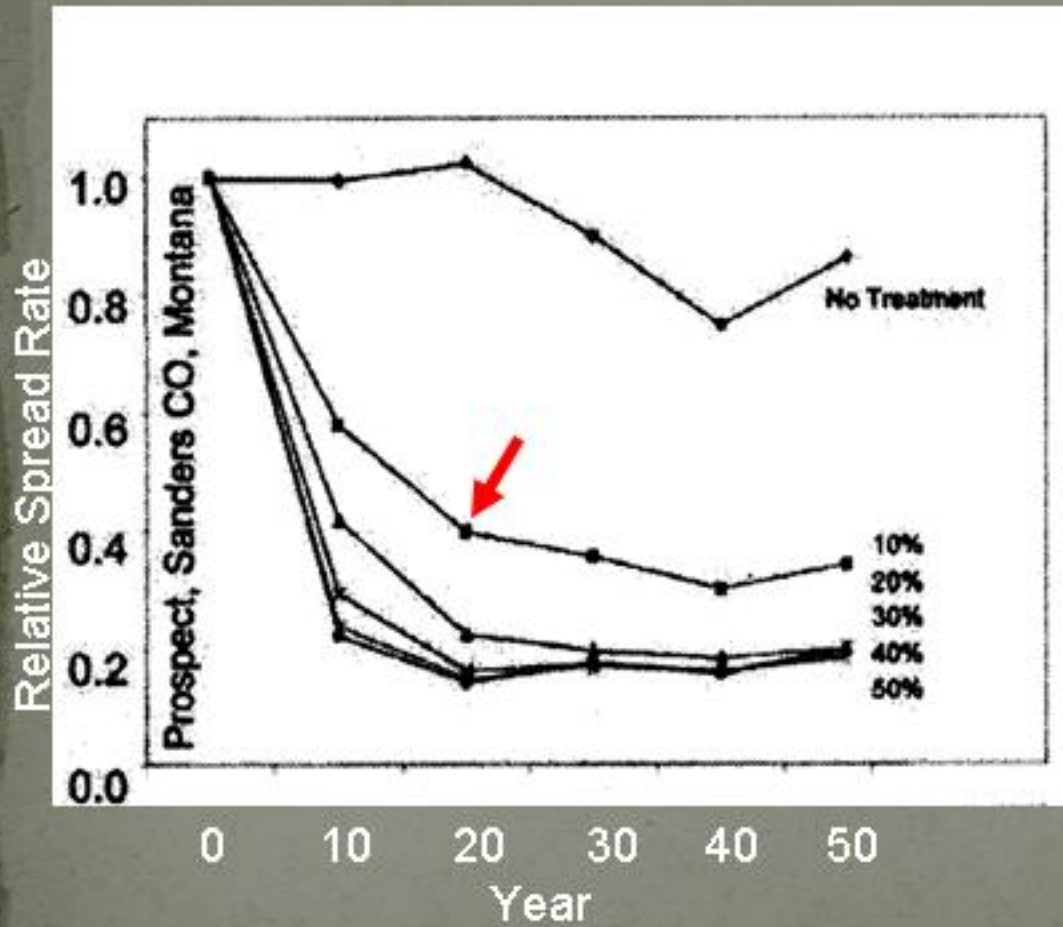
Effect of Reserves



Where areas of the landscape are designated as “no treatment” regardless of their strategic location, treatment effectiveness declines

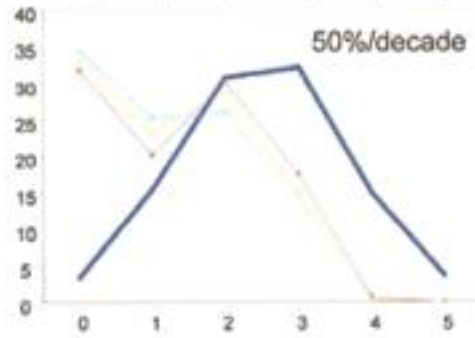
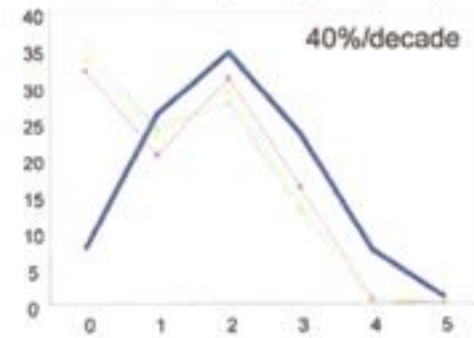
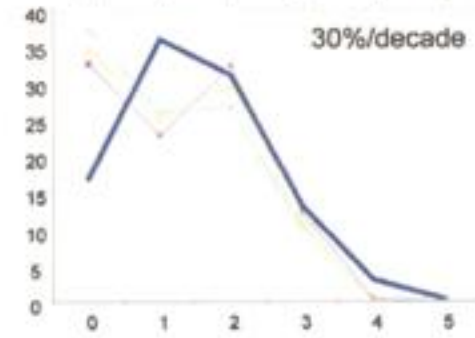
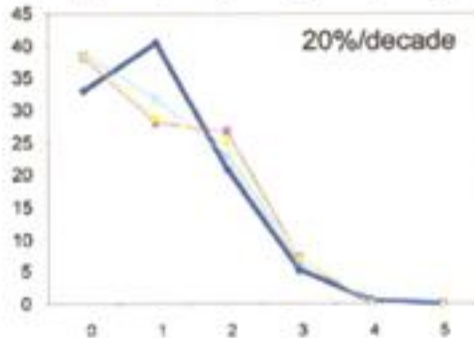
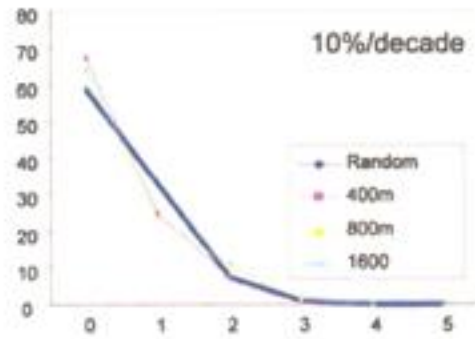
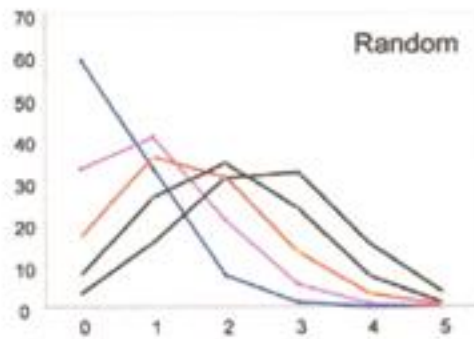
45-65% reserve about the same as random

20% per decade about right



- There was no much difference between spread rates after 2 decades at 20% of the landscape strategically treated per decade
- Total $>20\%$

Percentage of Stands



Number of Treatments in Five Decades

Re-Treatment?

At treatment levels of 20% and greater per decade, optimal treatment strategies consistently excluded some areas from treatment more often than random selection and refused frequent treatment for other areas.

“Fuelsolve” Objectives

- David Ford and others, University of Washington
- Wenatchee Forest Sciences Lab
- What is optimal amount of treated forest (for fire hazard) to:
 - Minimize spotted owl nest “core” area burned
 - Minimize LSR watershed area burned
 - Minimize cost (treated area of forest)
- Real landscapes are rarely managed to achieve only one objective
 - Kennedy et al. *J. Applied Ecology* (in review)
 - Lehmkuhl et al (in press) *For. Ecol and Manage.*

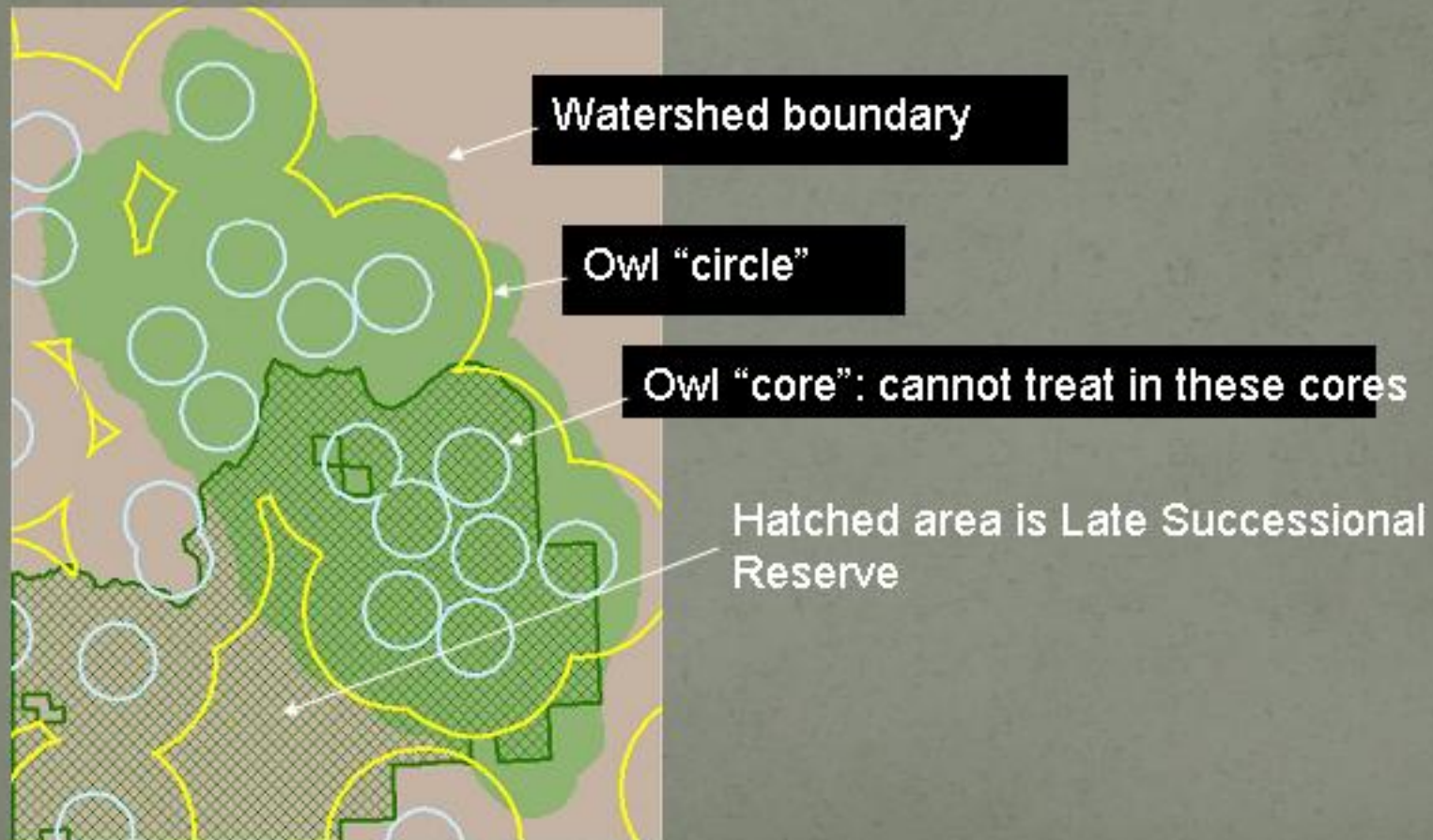
“Pareto Evolve” Program

- Program that essentially treats randomly chosen polygons of forest to treat, then runs fire through it, calculates parameters of interest, then repeats many, many times, each time selecting the superior sets of solutions based on the one to many criteria.
- Program uses a customized variant of a FLAMMAP-type program to evaluate area burned by wildfire of each priority habitat, plus cost

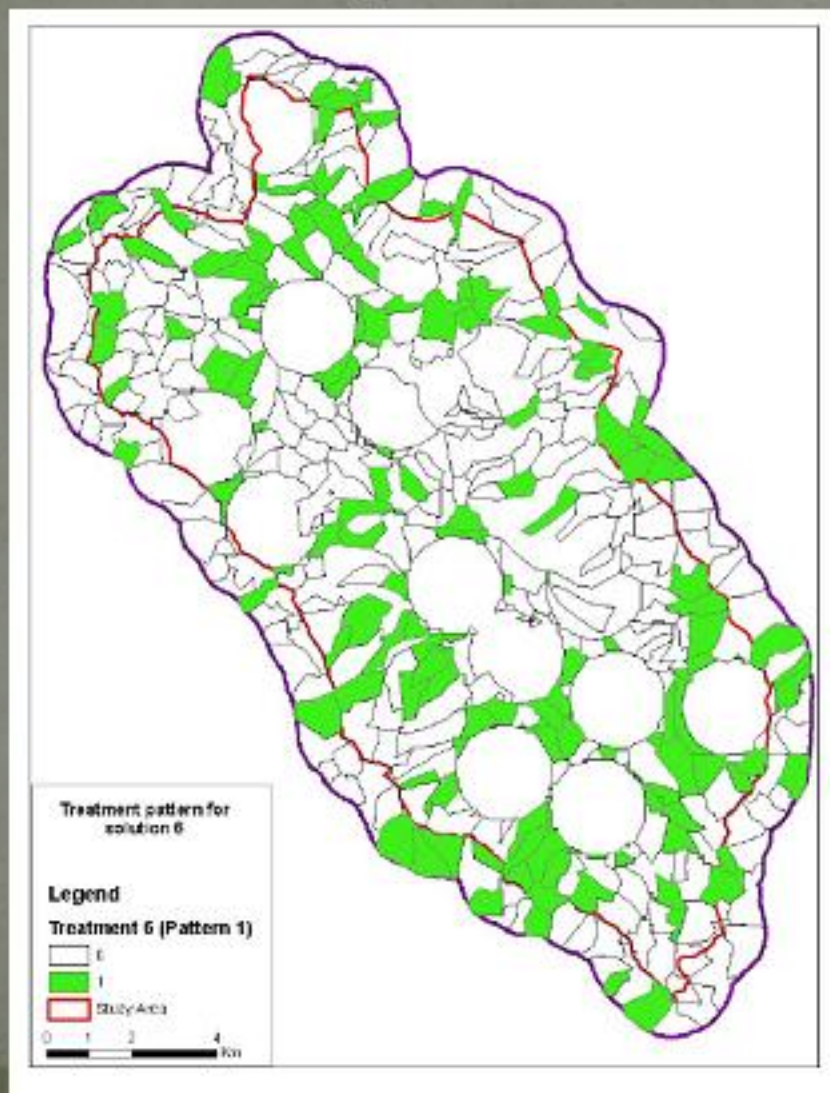
Assumptions

- All area treated at once (not temporally capable at this time)
- Treatment is “intensive”, resulting in
 - $C_{bh} = 5 \text{ m}$
 - $C_{bd} = 0.03 \text{ kg m}^{-3}$
 - Fuel Model = TL1
- Could do “lighter” treatment, too

Constraints on treatment

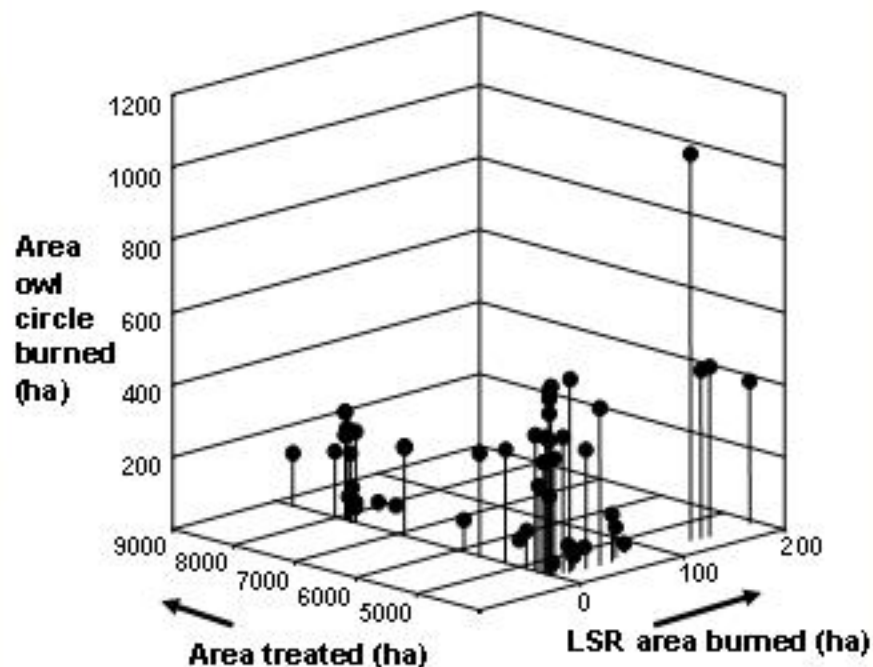


Example of One Solution



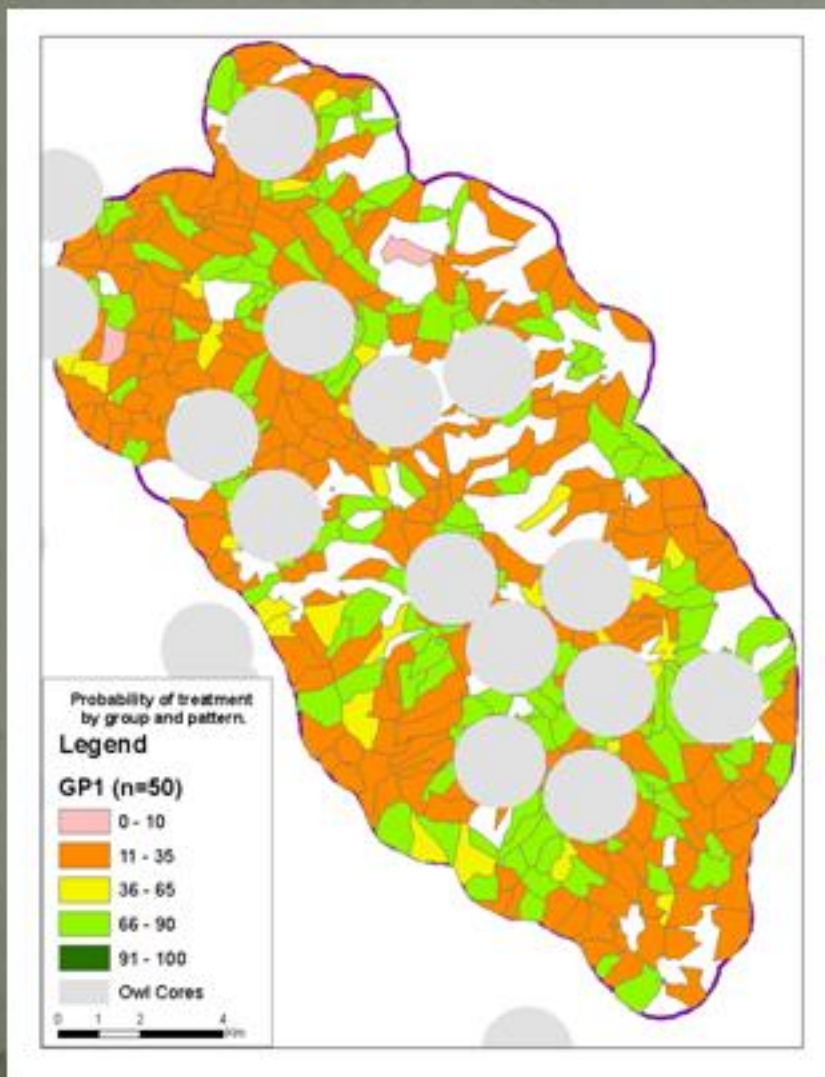
- Objective:
 - Minimize area treated (a cost function)
 - Minimize core area burned
 - Minimize LSR burned

Tradeoffs in Optimization



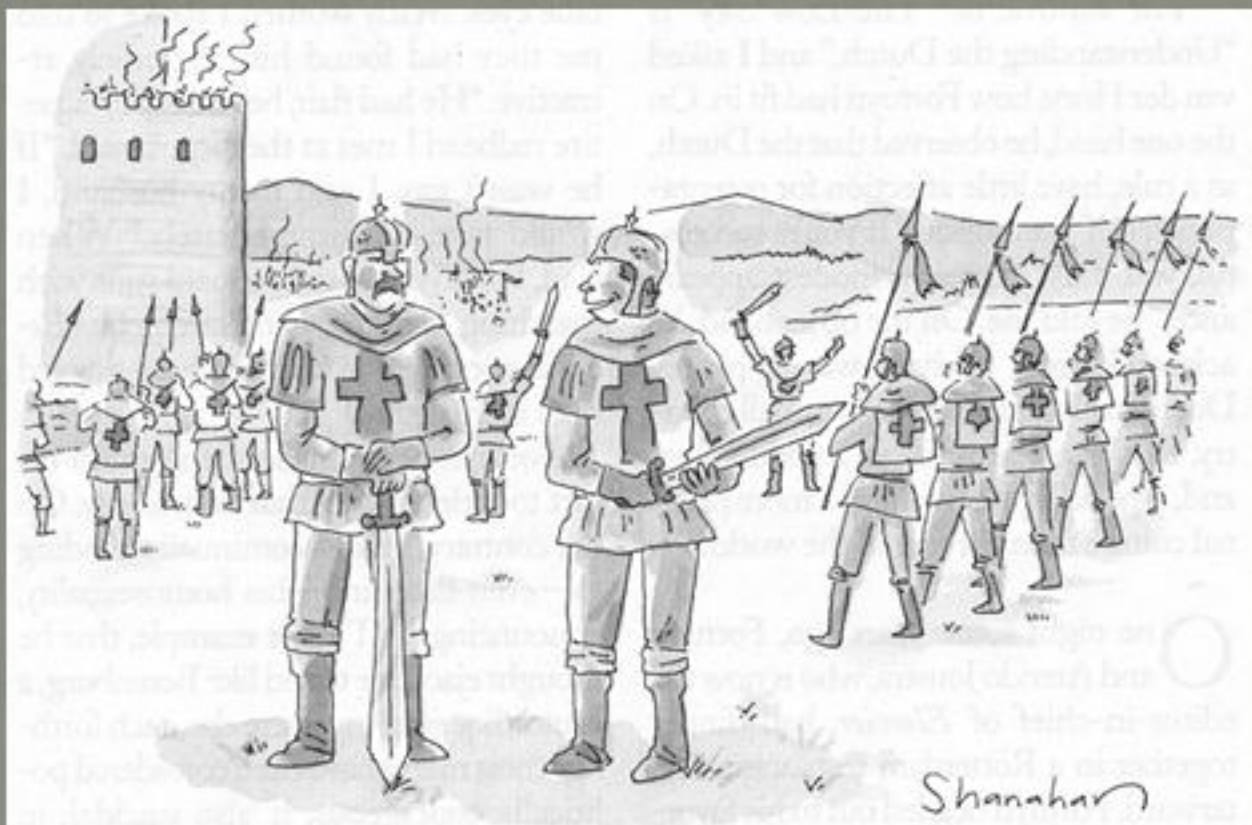
- LSR burn declines with treated area
- Owl circle burn declines with treated area
- Cost goes up with treatment
- Looks like a stabilization above about 7000 ha (15%)

Probability of Treatment



- Core areas (grey circles) not available
- 50 different “optimal” solutions!
- Preponderance of orange suggests that many different solutions are possible

We Need Real Applications



*"I've never actually stormed a castle, but I've taken
a bunch of siege-management courses."*