Optimal Forest Fire Fuel Management And Timber Harvest In The Face Of Endogenous Spatial Risk

The Next Step

Claire Montgomery

www.mtmultipleuse.org/images/smokey.jpg

FIRE SUPPRESSION POLICY

William Greeley USFS chief 1920-9

“the conviction was burned into me that that fire prevention is the number 1 job of American foresters”
(Greeley, WB. 1951. “Forests and men” NY: Doubleday.)

“10:00 am policy”

Goal – to contain every wildfire by 10:00 am the day after it is reported – regardless of cost.

Lodgepole Pine

- pioneer species
- serotinous cones
- "k-strategy" seed in at great density choking out other species
- don't establish dominance
- overstocked, stagnant stands
- vulnerable to insect and disease

Mountain Pine Beetle

- Large areas of dead trees
- Enormous fuel build-ups

When wildfires DO occur

- Can be catastrophic
- Hard to contain

picasaweb.google.com

helenair.com

Mt. Jefferson Wilderness – 2006

Aftermath of B&B Complex Fire

What is a catastrophic fire?

- Kills all (or most) of the vegetation
- Destroys organic matter in the soil
- “Red soil” – burned so hot that oxidation occurs

Possible Solutions:

To “nudge” these forests back into the “natural range of variation” by
- fuel treatment -- mechanical removal, prescribed burning
- restoration thinning

Problem:

- these treatments don’t pay for themselves
- budget reductions for USFS
- timber sales in PNW reduced from 5 bbf to 0.5 bbf per year with Northwest Forest Plan

Sets the stage for THIS study

- look for ways
  - to strategically place fuel treatment on a landscape
  - in order to minimize fire risk
  - given limited budgets

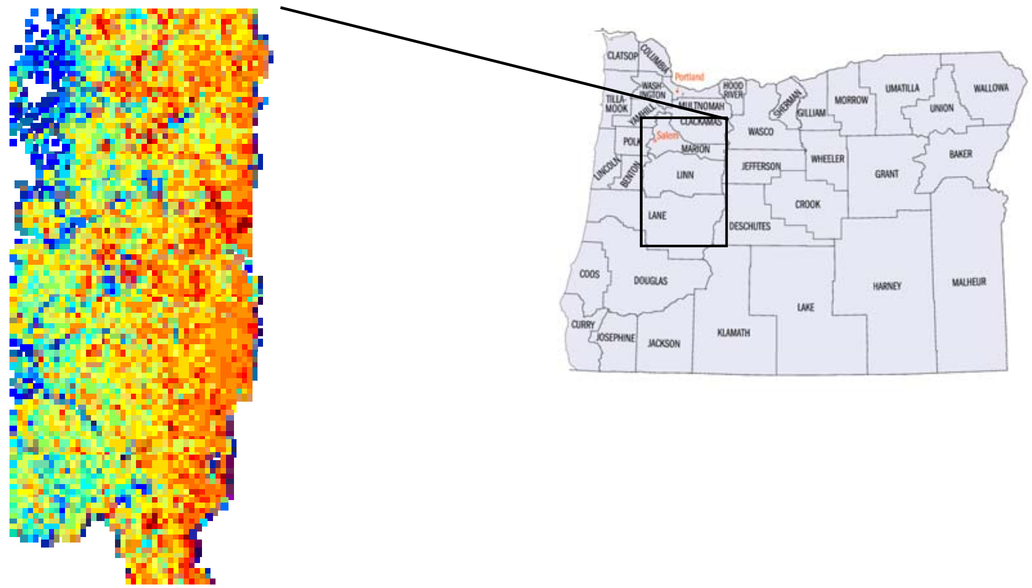
Elements of the problem

- STOCHASTIC – fire occurrence is unpredictable
- DYNAMIC – optimal decisions in period *t* depend on fire occurrence and fuel treatments in previous periods.
- SPATIAL -- activities and events in one place have effects elsewhere
  - fuel treatment affects fire spread rates and, hence, fire risk in adjacent units.
  - damage by fire in one unit may affect values in other units e.g. Grizzly corridors

These elements (stochastic, dynamic, spatial) are shared by fire and biodiversity.

Case study set in Cascade Range of Oregon

1992 Owl habitat map
Red range is best habitat



Developing a production possibility set of wildlife species persistence and timber harvest value using simulated annealing
Calkin, D., Montgomery, C.A., Schumaker, N.H., Polasky, S., Arthur, J.L, Nalle, D.J. *Can J For Res* (2002)

Modeling joint production of wildlife and timber in forests
Nalle, D.J., Montgomery, C.A., Arthur, J.L., Schumaker, N.H., and Polasky, S. *JEEM* (2004)

Tradeoffs between

timber production and population size for two species – great horned owl, common porcupine

1) Maximize T

subject to $E[\text{Pop Owl}] \geq P^{owl}$

$E[\text{Pop Porc}] \geq P^{porc}$

T = Timber value = Present value of consumer (wood processors) producer (timber land owner) surplus over time horizon

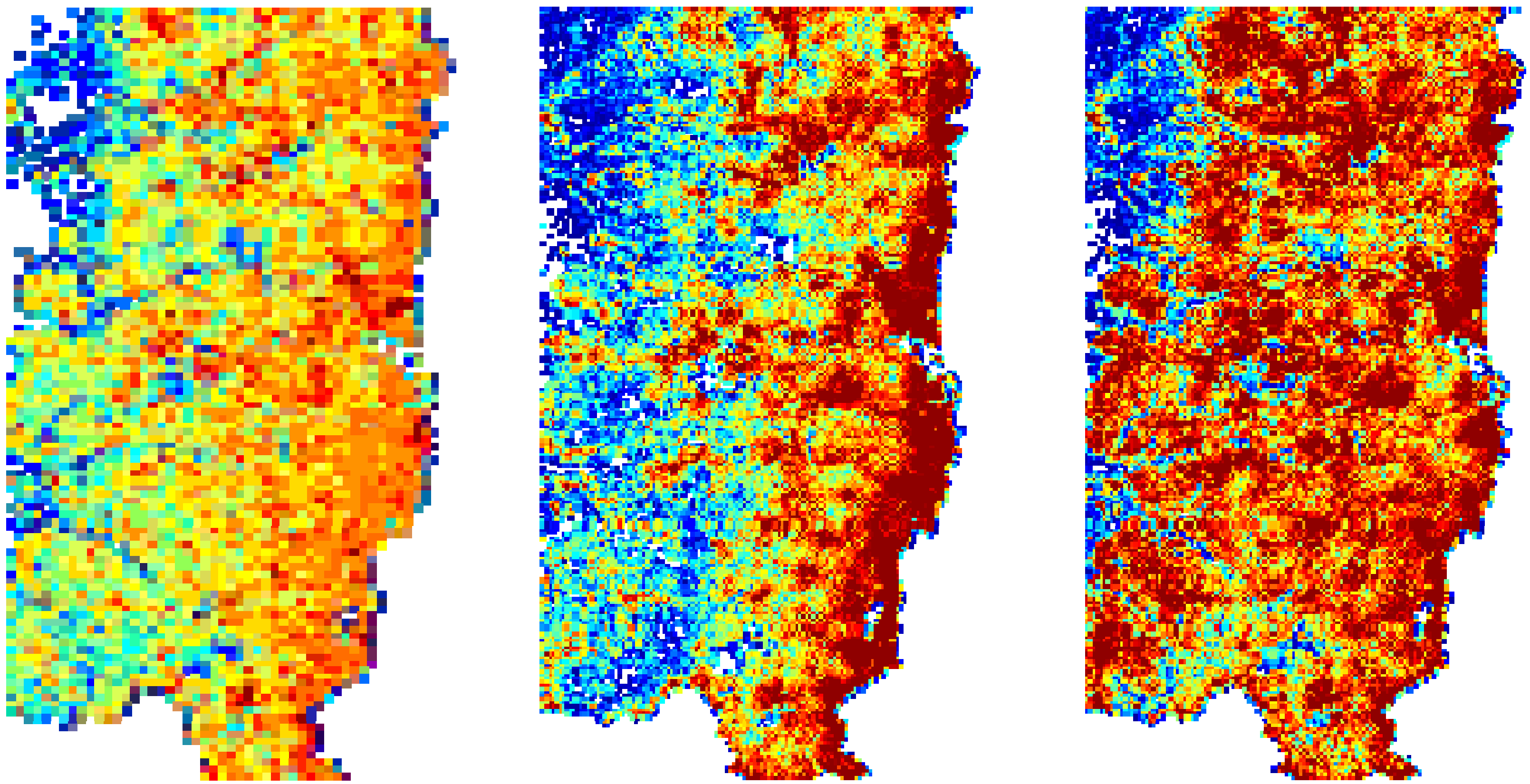
E[Pop owl] and E[Pop porc] = ending expected population size as estimated from spatial and dynamic wildlife population model PATCH

P^{owl} and P^{porc} = range of target values

Owl Habitat Maps – Red is good

at 50 years, timber value = $23.7 billion

Current | **Static Reserve solution** Owls = 5640 | **PPF Solution** Owls = 9000



Maximize Expected Value

$$\max_{c_1, c_2} \quad R(c_1, S_1) + \beta E\left[R(c_2, S_2)\right]$$

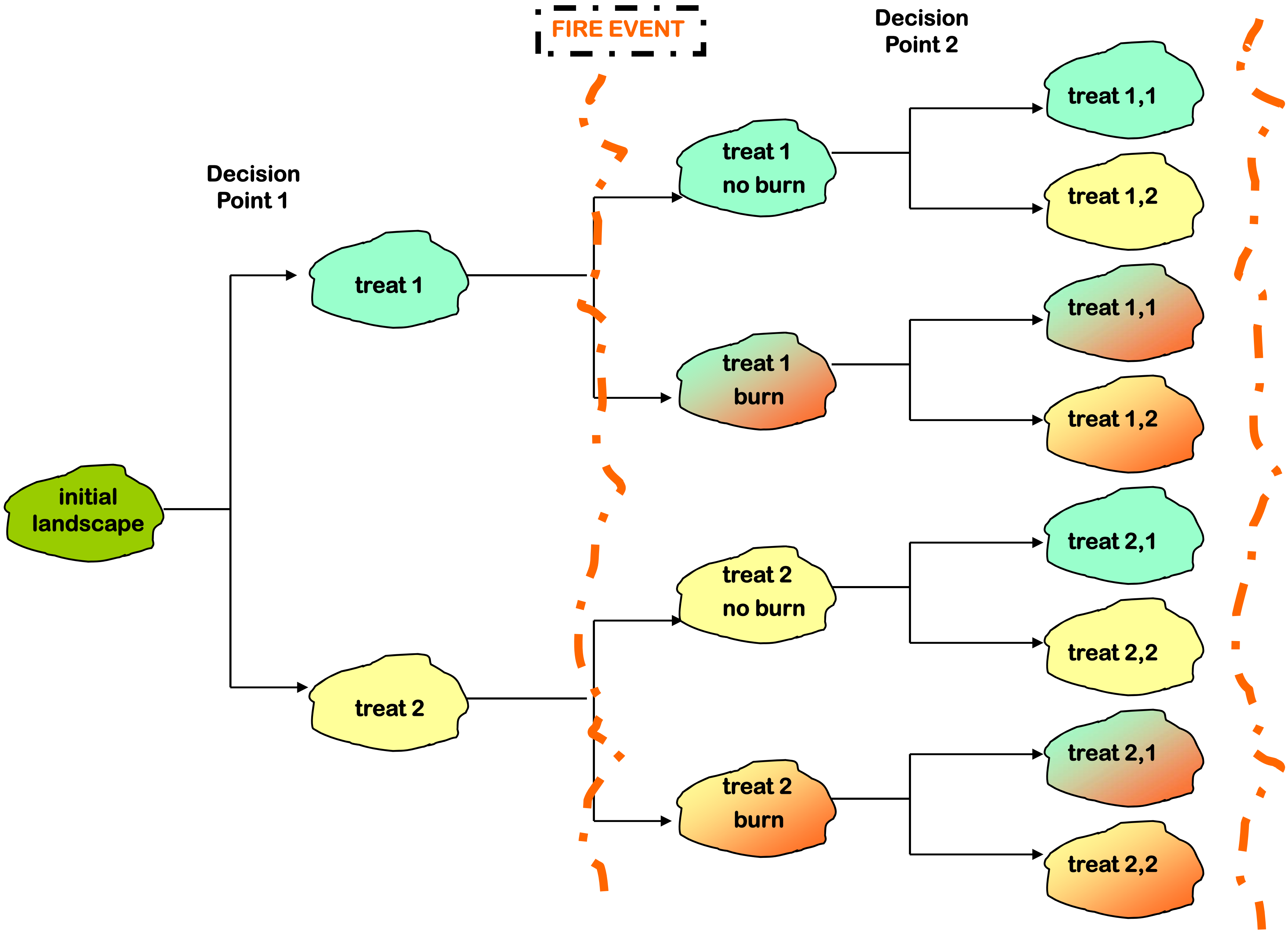
$$= R(c_1, S_1) + \beta\left[\rho R(c_2, S_2^{fire}) + (1-\rho) R(c_2, S_2^{no\ fire})\right]$$

Stochastic Dynamic Programming

$$\max_{c_1} \quad R(c_1, S_1) + \beta E\left[\max_{c_2} R(c_2, S_2)\right]$$

$$= R(c_1, S_1) + \beta\left[\rho \max_{c_2} R(c_2, S_2^{fire}) + (1-\rho) \max_{c_2} R(c_2, S_2^{no\ fire})\right]$$

$$s.t. \quad S_2^i = f\left(S_1, c_1\right), \quad i = fire, no\ fire$$


FIRE EVENT
Decision Point 2
Decision Point 1
initial landscape
treat 1
treat 2
treat 1 no burn
treat 1 burn
treat 2 no burn
treat 2 burn
treat 1,1
treat 1,2
treat 1,1
treat 1,2
treat 2,1
treat 2,2
treat 2,1
treat 2,2

Curse of dimensionality:

- For each initial state in period *t*, conditional on previous treatments and occurrence of stochastic event, there are $(\#\ treatments)^{\#\ units}$ possible choices.
- And there are $(\#\ fuel\ conditions)^{\#\ units}$ possible initial states

Previous approaches

“STYLIZED” <----------------> “REALISTIC”

Konoshima, M, et al. 2008. Spatial endogenous fire risk and efficient fuel management and timber harvest. *Land Economics*.

Finney, M.A. 2007. A computational method for optimizing fuel treatment locations. *International J Wildland Fire*.

Wei, Y., et al. 2008. An optimization model for locating fuel treatments across a landscape to reduce expected fire losses. *Canadian Journal of Forest Research*.

Konoshima, M, et al. 2008.
Spatial endogenous fire risk and
efficient fuel management and timber harvest.
Land Economics.

Method – stochastic dynamic program

-- "curse of dimensionality" SO kept it SIMPLE

2 periods

Stylized landscape

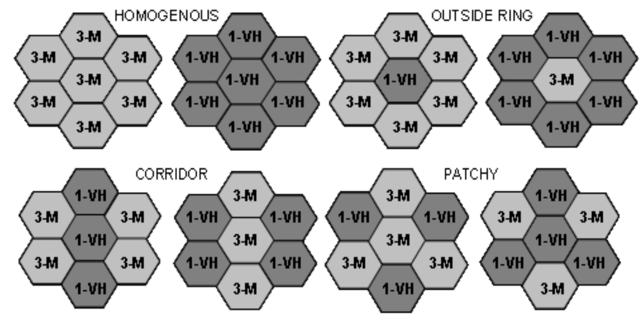
- **7 identically shaped units**
- **2 initial states**
- **4 decisions – treat, cut, treat&cut, leave**

Stochastic weather (2) and ignition points (7)

Determistic fire spread model, FARSITE

Bellman equation

Solve by complete enumeration



Look at the results
to draw out generalities:

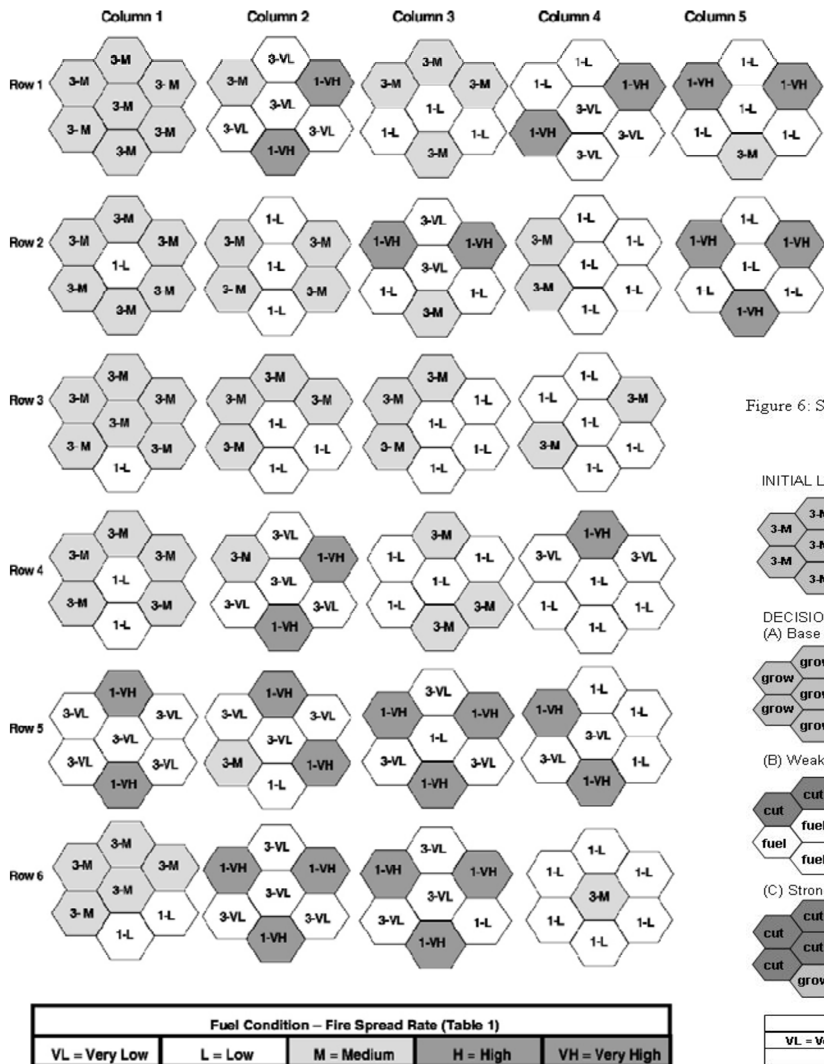


Figure 7: Spatial configuration of age class and fuel condition class for 8 selected initial landscapes labeled "age class – fuel condition" and optimal decisions labeled "action" for (A) the base model with no slope, (B) low slope, and (C) steep slope.

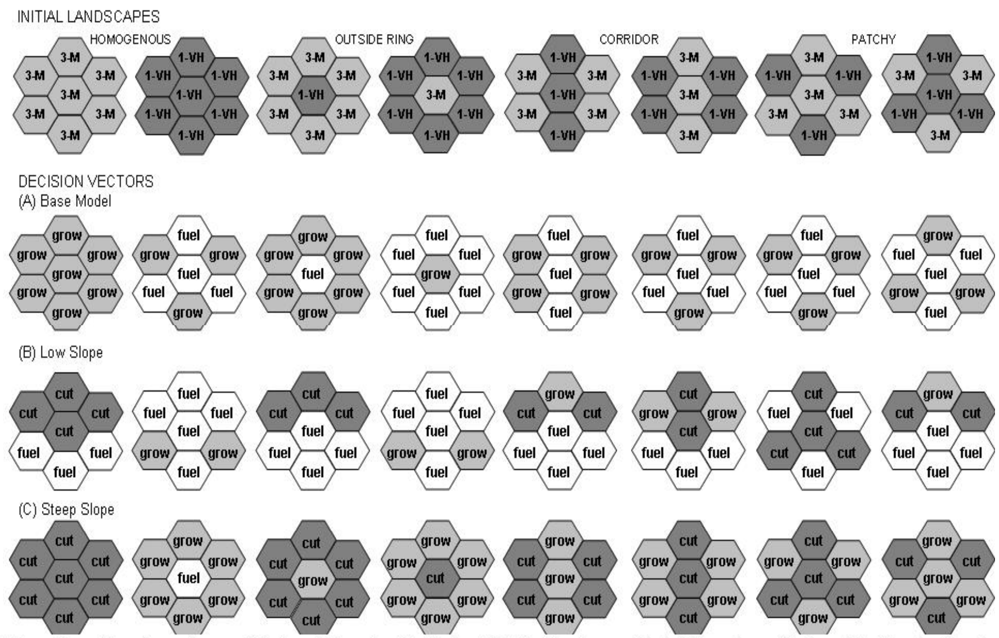
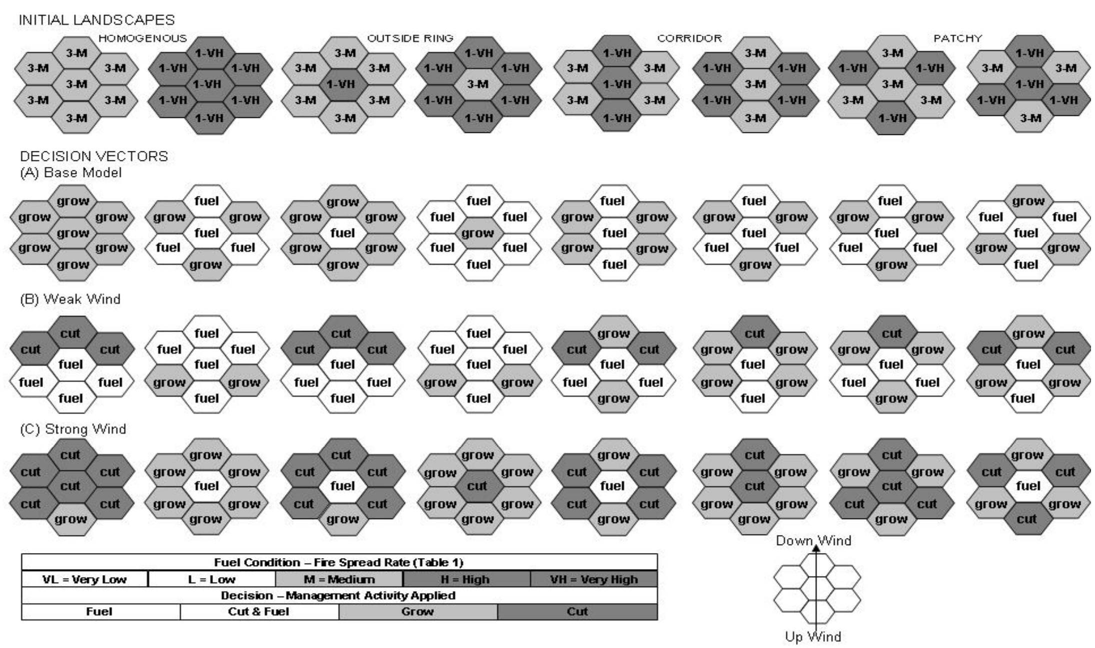


Figure 6: Spatial configuration of age class and fuel condition class for 8 selected initial landscapes labeled "age class – fuel condition" and optimal decisions labeled "action" for (A) the base model with no wind, (B) weak wind, and (C) strong wind.



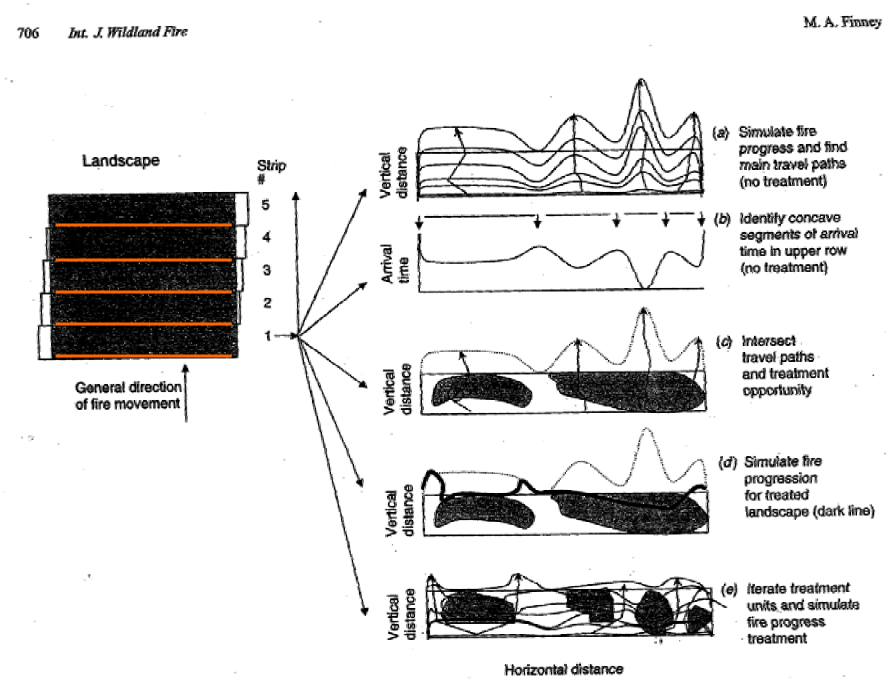
Results:

- **Use treatment to separate high spread rate units**
- **Extend rotations to reduce risk to adjacent units**
- **Priority for treatment should not be assigned based on "on-site" fire risk alone, but should consider value to be protected on adjacent sites.**

The "Realistic" approach -- Start with an actual landscape

Finney 2007

- **uses an heuristic approach assuming a prevailing wind direction and fire duration**
- **places fuel treatments to slow fire movement across landscape compared to random or rule of thumb treatments**



Assumes a particular fire
Treatment only, no timber harvest
Doesn't consider values at risk
Not dynamic
Not optimal (but improves over standard practice)

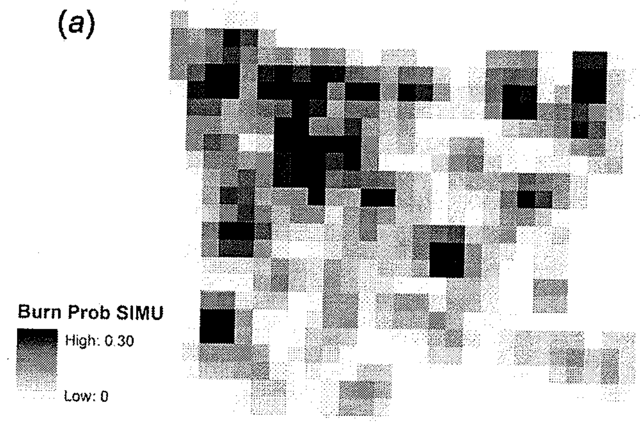
Wei, Rideout, Kirsch 2008.

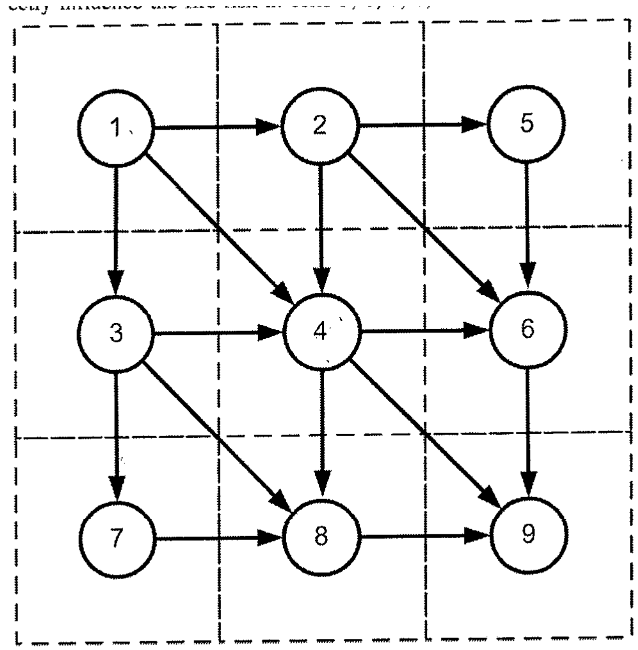
Minimize expected loss
Integer programming
Conditional probabilities developed from:
- **Risk map based on ...**
- **Assumed ignition probabilities**
- **direct relative to lateral spread rates**

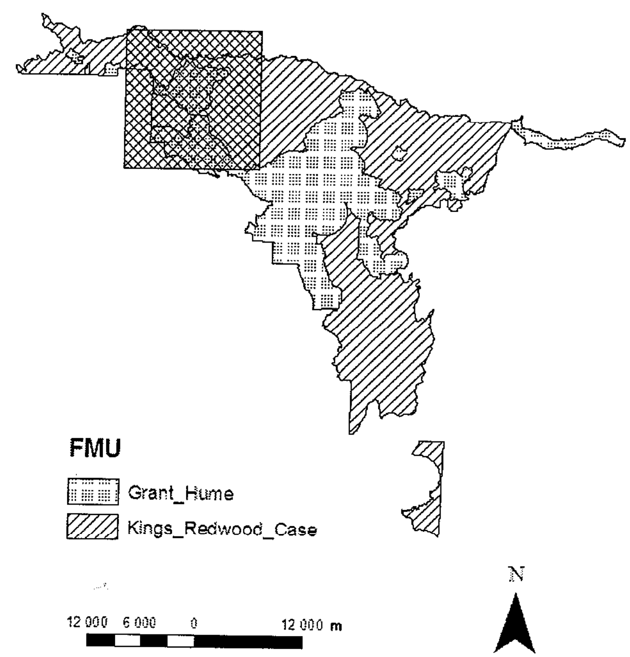
Values at risk are not spatial
Prevailing wind direction
An array of fuel treatments

Positive side – spatial externality associated with fire spread

(a)







OBJECTIVES

- a real landscape
- spatial externalities in
    - fire spread
    - values protected
- dynamic decision process

CHALLENGES

- exact or approximate optimization?
- integration of fire simulation
- representation of the spatial externalities
- dynamic decision process
    - e.g. stochastic dynamic programming framework

Do we start by making Konoshima "bigger"?

Or by adding to the decision framework in the "ad hoc" approaches?