<u>Computational Sustainability</u>:

Computational Methods for a Sustainable Environment, Economy, and Society

Optimal Forest Fire Fuel Management and Timber Harvest In The Face Of Endogenous Spatial Risk
The Next Step

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What's the PrOBLEM and how did we get here?

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.

Fire in the western U.S.

NATURAL regime – frequent (15-20 years) low-intensity fires

favors PONDEROSA PINE

thick bark to survive low-intensity fire

take out weaker trees -- "natural thinning“

stronger trees establish dominance

RESULT -- open stands of big trees.

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

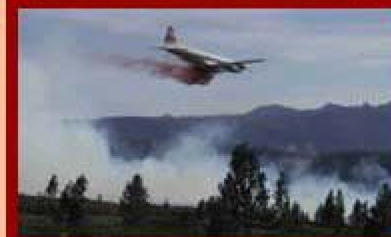
- Can be catastrophic
- Hard to contain

picasaweb.google.com

helenair.com

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**



Potential OBJECTIVES
of fire fuel management

<u>Existing analyses</u>:

- maximize minimum travel time across a landscape
- minimize expected loss from a fire
- maximize expected net present value
  of timber harvest
  less treatment cost on a landscape

<u>My desired objective</u>:

- maximize expected net present value
  of timber harvest
  less treatment and suppression cost

- subject to
  - wildlife habitat goal
  - ending forest condition in which
    natural fire regime is restored.

Potential **A**ctivities for each unit:

<u>**Existing Analyses**</u>

- **Do Nothing**
- **Treat fuels (mechanical removal, prescribed burning)**

- **Timber harvest**

<u>**I'd like to add**</u>**:**

- **Modified fire suppression**
  (e.g. let fire burn in moderate weather)

Assessing CONSEQUENCES:

Integration of simulation models into optimization:

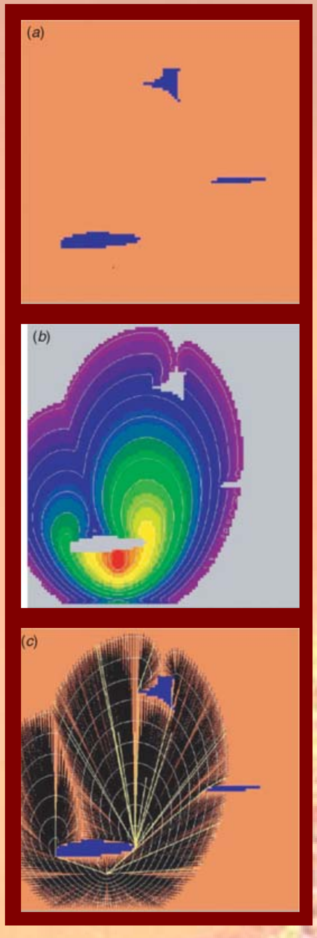
1) **Vegetation and fuels**
   FOREST VEGETATION SIMULATOR (FVS)
   with FOREST FUELS EXTENTION (FFE)

2) **Fire behavior – FLAMMAP (Finney 2006) predicts**

   FIRE SPREAD – as a function of:
   - **vegetative cover and fuels**
   - **topography -- slope, aspect**
   - **weather – wind, fuel moisture**

   using minimum travel time algorithm

   FIRE INTENSITY-- flame length and other attributes
   as a function of:
   - **vegetative cover and fuels**
   - **topography**
   - **weather**



Trade-offs and Optimization

Elements of the problem

- **STOCHASTIC**

  – fire occurrence and extent is unpredictable

- **DYNAMIC**

  – optimal decisions in period *t* depend on fire occurrence and fuel treatments in previous periods.

- **SPATIAL**

  -- 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

Emphasize DECISION MODEL

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

Specifies decision model as stochastic dynamic program
Simplifies specification of the problem to make it tractable

Emphasize PROBLEM SPECIFICATION

Finney, M. 2007. A computational method for optimizing fuel treatment locations. *International Journal of 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*.

Chung, W., et al. 2009. OptFuels: a decision support system to optimize spatial and temporal fuel treatments. presented at Symp.on Systems Analysis in Forest Resources.

Simplifies decision model
Simulates fire on landscape as realistically as possible






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 vegetation states**
- **4 decisions – treat, cut, treat&cut, leave**

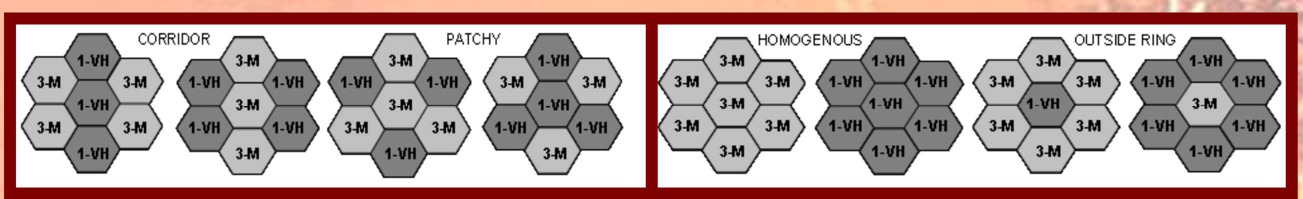
Stochastic weather (2) and ignition points (7)

Simulated fire spread

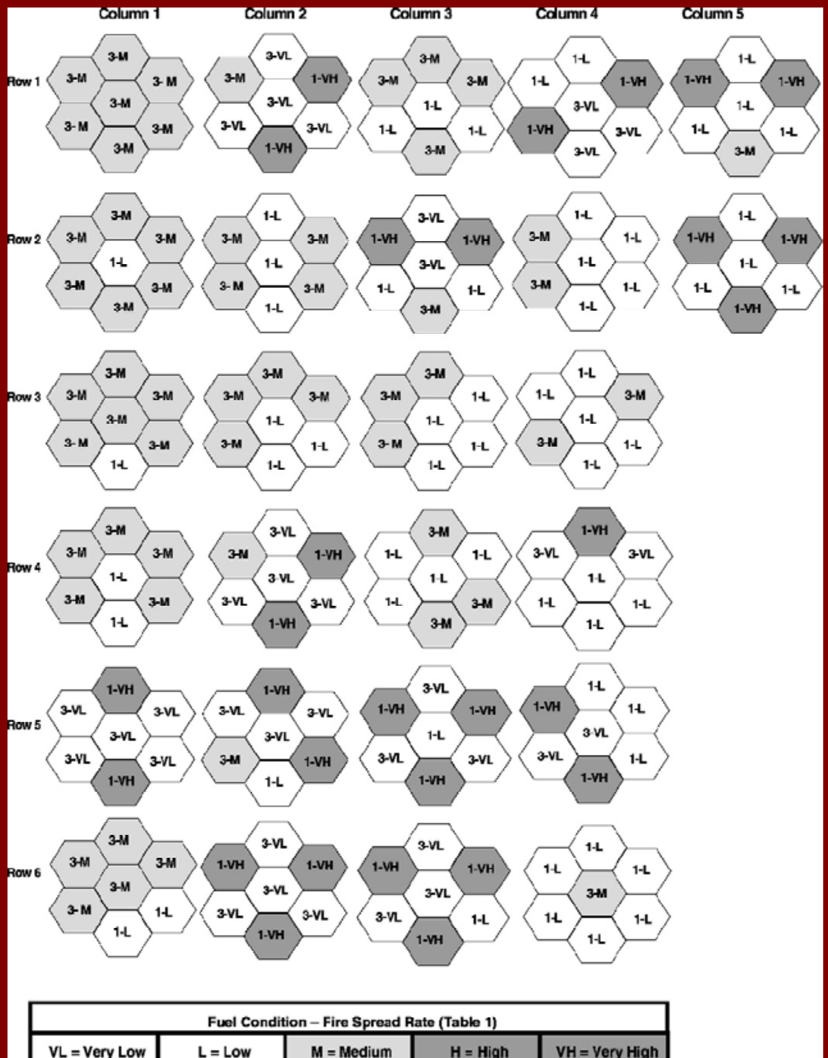
initially – no wind, no slope

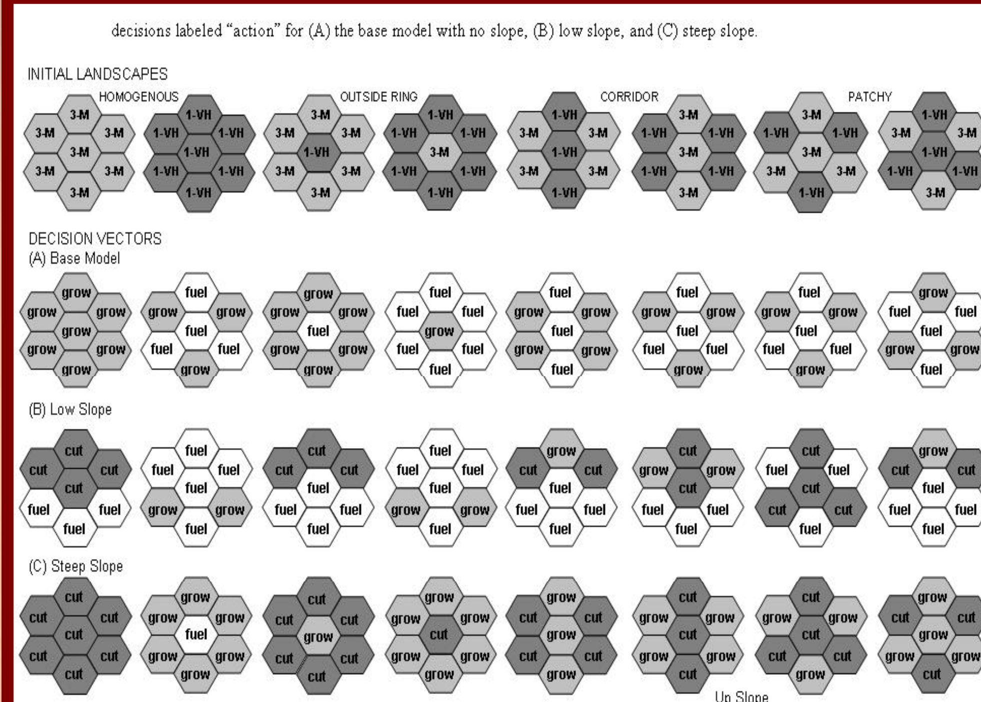
added slope and wind individually

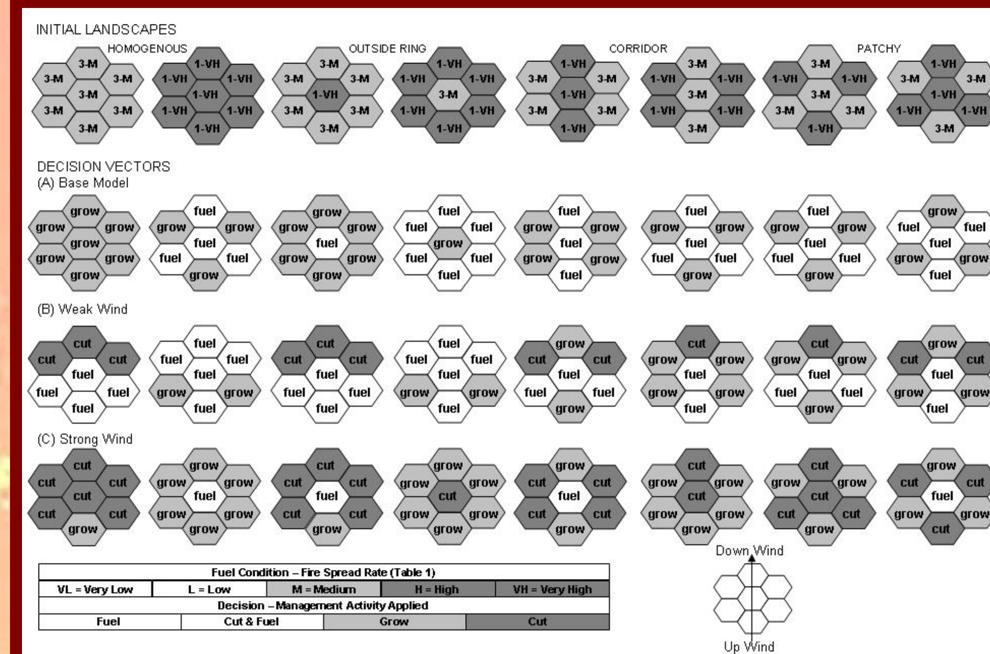
Solve by complete enumeration



Look at the results to draw out generalities:







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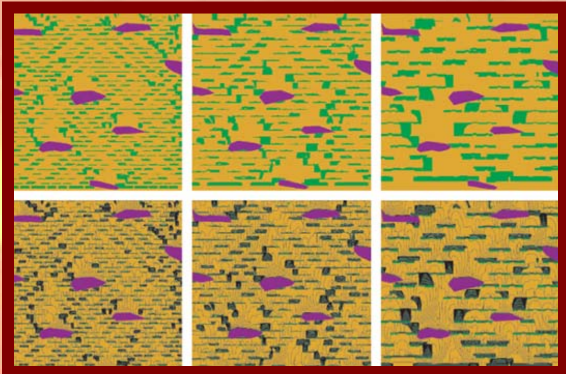
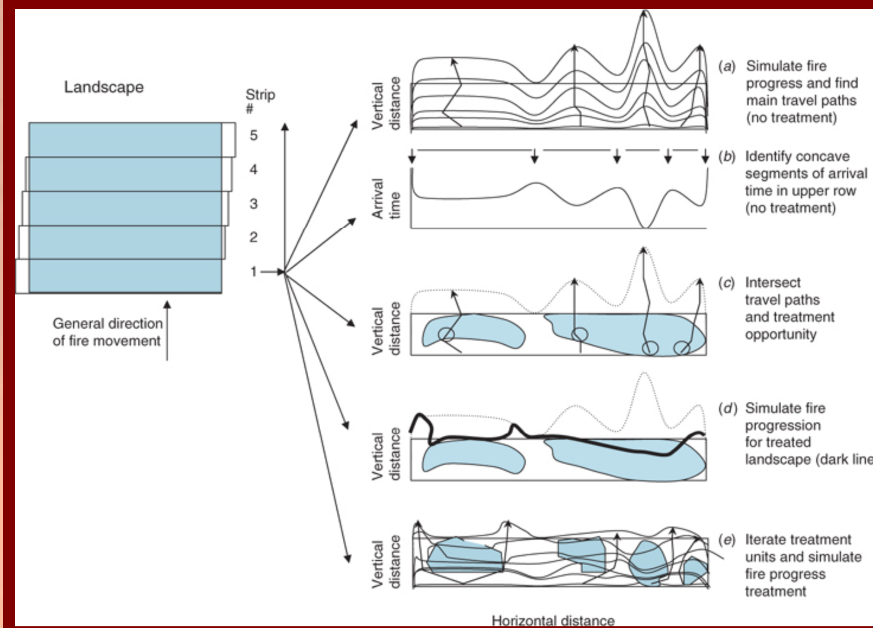




Not dynamic
Not stochastic
Spatial risk

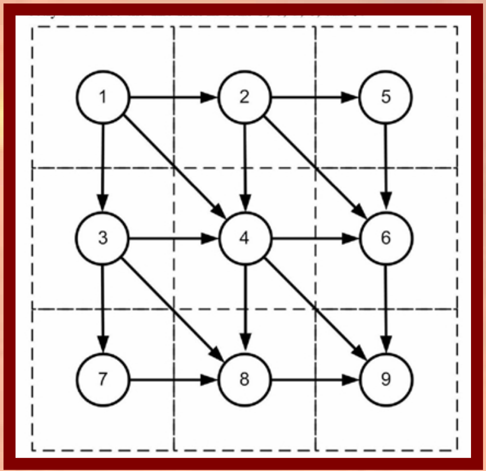
Maximize minimum travel time of fire across landscape

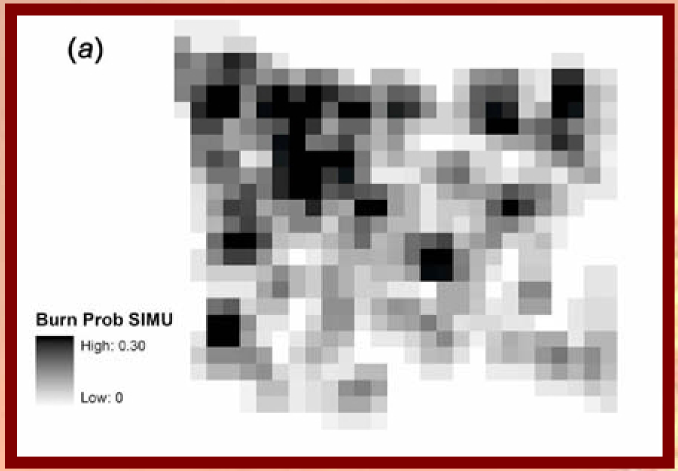
Given fire ignition point – upwind
Given weather conditions – prevailing wind
- severe weather (low fuel moisture)

No values assigned to cells
One decision period

Heuristic approach – solve iteratively for strips across landscape

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*.**





Not dynamic **Stochastic** **Spatial risk**

Minimize expected loss plus treatment cost

Derives "spread" probabilities" from map of "burn" probabilities
Treatments affect spread probabilities

Given weather conditions – **prevailing wind**
- **severe weather (low fuel moisture)**

Value matrix – not spatial
One decision period

Integer programming

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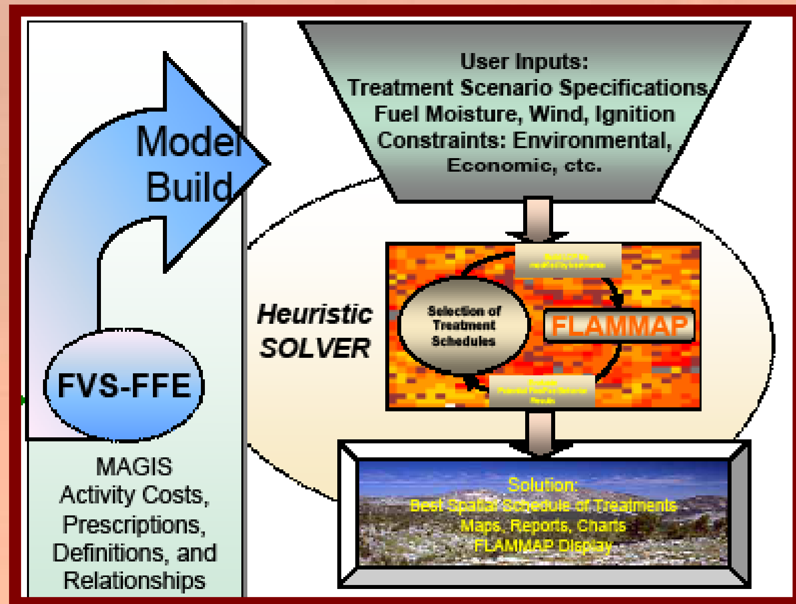

Intertemporal
but not dynamic
Stochastic
Spatial risk

Uses existing simulation
models for FUEL,
Vegetation,
Fire Behavior
into heuristic optimization framework

- **choose a 5-decade fuel treatment trajectory**
- **to minimize expected loss plus cost**
- **for given budgets**

Fire risk is computed on landscape as fuels evolve
given that NO FIRE OCCURS

What do I want to do to move forward?

Actual Landscape

Spatial Externalities:
fuel treatment on fire risk
habitat loss on habitat objectives
(e.g. wildlife populations)

Dynamic Decision Process
decisions in next period depend on treatments and
realization of fire event in previous periods

Endogeneity of Fire Suppression Cost

Desired Ending Condition
to reach a "natural state" (e.g. natural fire regime)
at minimum expected loss + cost during the
transition period

Think about how to LEARN from the optimization results

Potential Study Area

Data currently available:
- Vegetation cover/forest types (LEMMA)
- Ecology Plot Data (IMAP)
- Land ownership (FS)

Areas we would like to partner:
- Designing dynamic fuel models