HOW MIGHT DIFFERENT WILDFIRE RESPONSE POLICIES AFFECT THE LANDSCAPE OVER TIME?

CAN WE SAVE MONEY ON WILDFIRE SUPPRESSION BY INVESTING IN FUEL TREATMENTS AND PRESCRIBED FIRE INSTEAD?

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HOW MIGHT DIFFERENT WILDFIRE RESPONSE POLICIES AFFECT THE LANDSCAPE OVER TIME?

MODELING ALTERNATIVE FIRE RESPONSE

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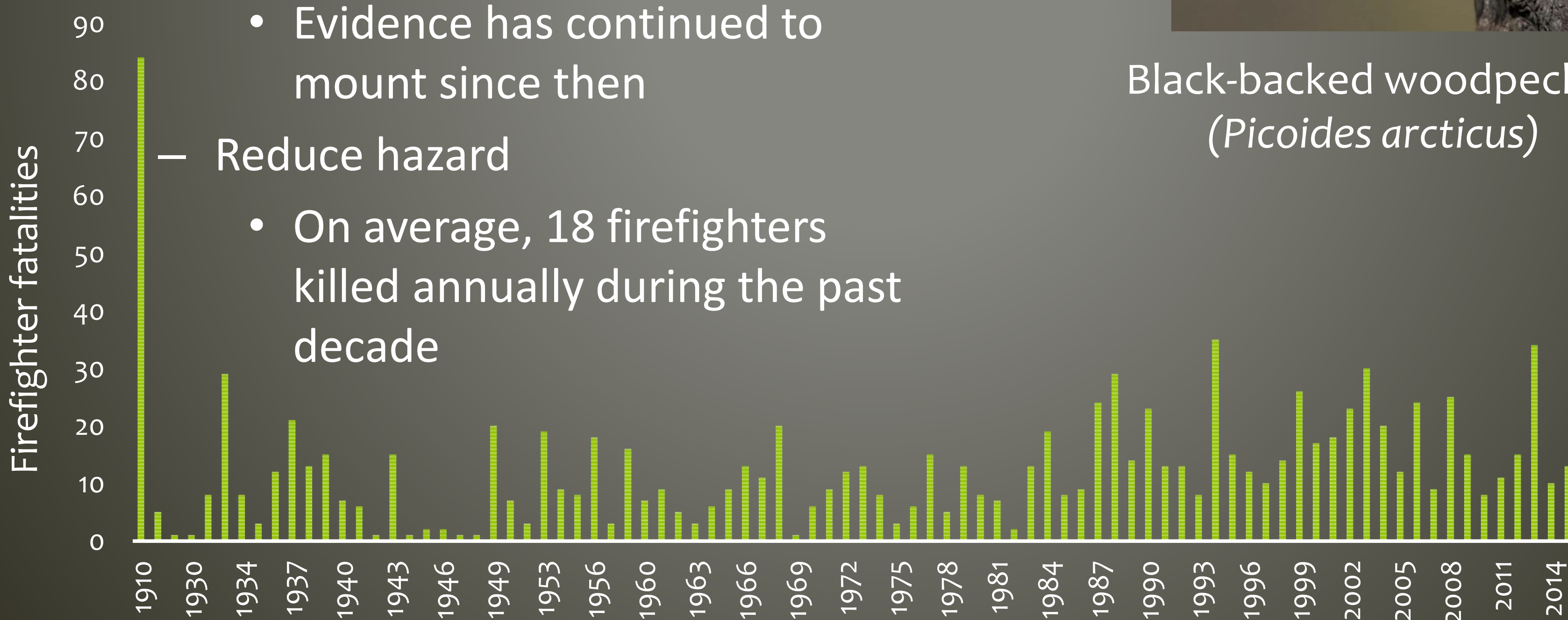
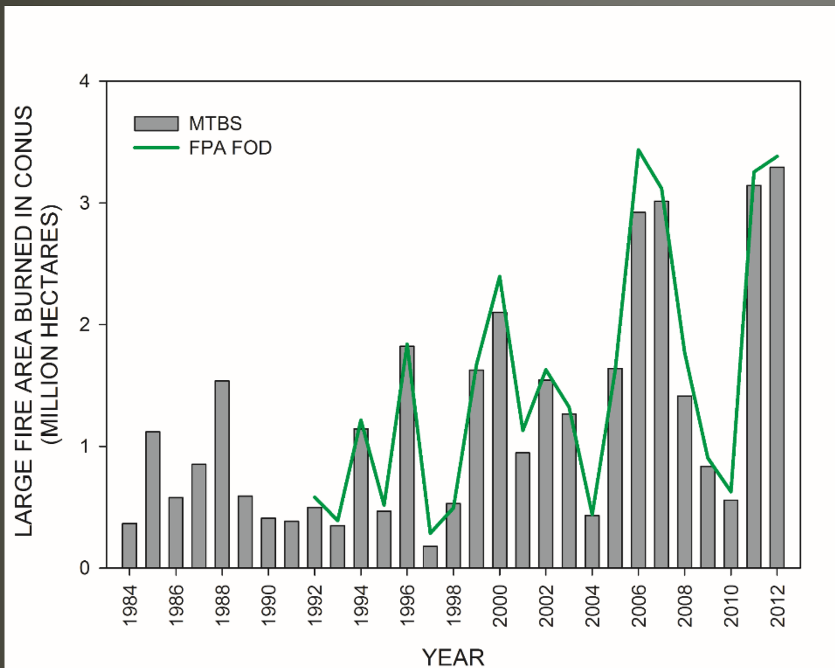
THE NEED TO EXPAND THE FOOTPRINT OF MANAGED FIRE

- Increasingly recognized by land managers
- Reasons
  - Ecological benefits
    - Widely recognized since the 1972 Leopold Report
    - Evidence has continued to mount since then
  - Reduce hazard
    - On average, 18 firefighters killed annually during the past decade

Black-backed woodpecker
(Picoides arcticus)



TRENDS IN AREA BURNED AND COST



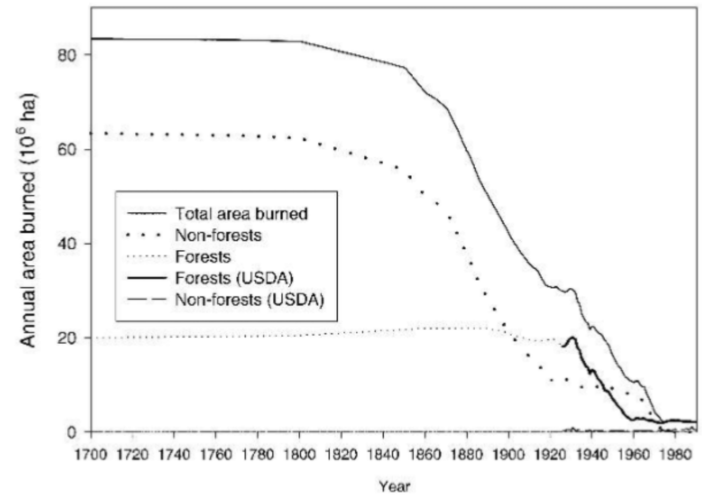
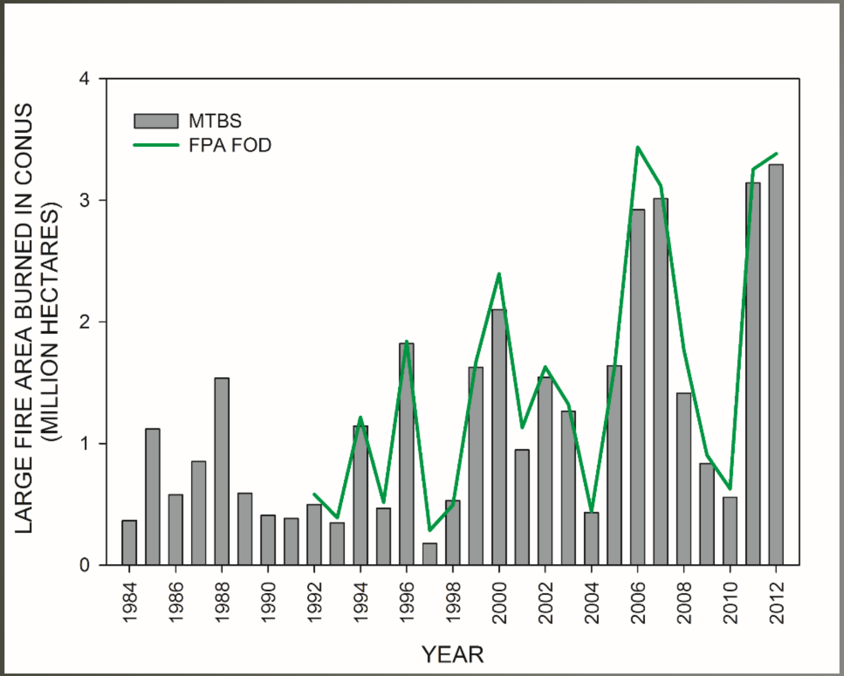
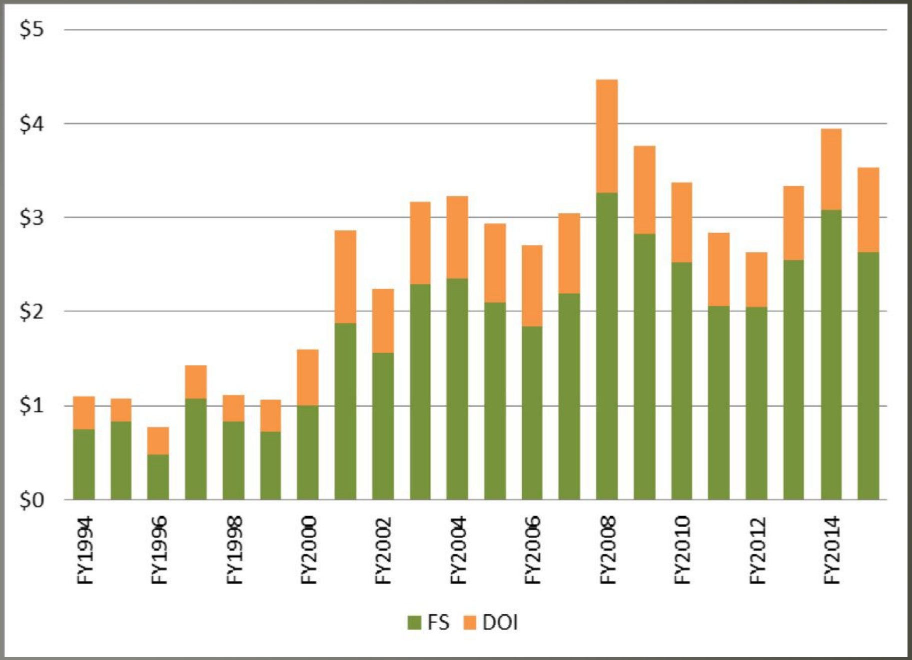


Fig. 6 Areas of the United States (forest, non-forest and total) estimated to have burned annually in wildfires. Early rates of burning were based on pre-European burning rates reported in the literature; areas of forest burned after 1926 were obtained directly from USDA (1926–90). The methods for estimating the transition between pre-European and post-1926 rates are described in the text.

Left: Short, Karen C. 2014. A spatial database of wildfires in the United States, 1992-2011. Earth System Science Data 6, 1-27.
Right: Houghton, R.A., J.L. Hackler, and K.T. Lawrence. 2000. Changes in terrestrial carbon storage in the United States. 2: the role of fire and management. Global Ecology and Biogeography 9, 145-170.

TRENDS IN AREA BURNED AND COST



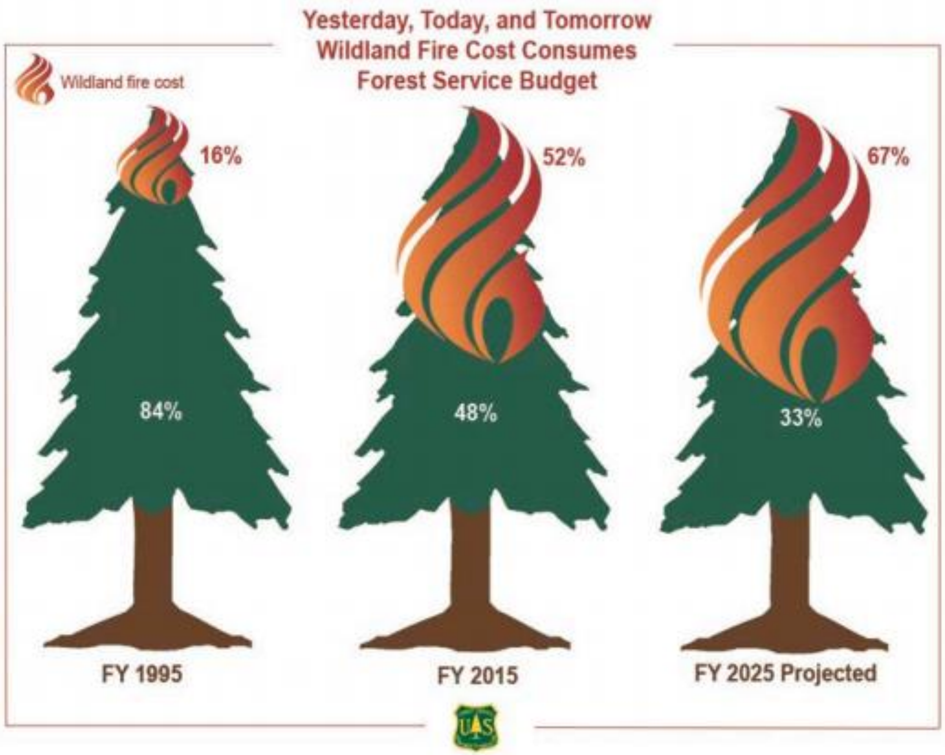


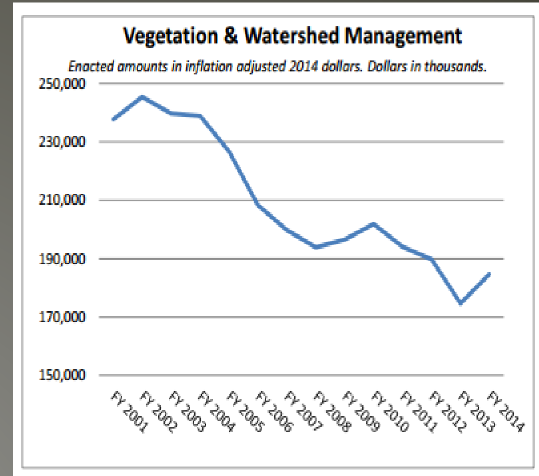
Area burned:
Likely increasing but variable

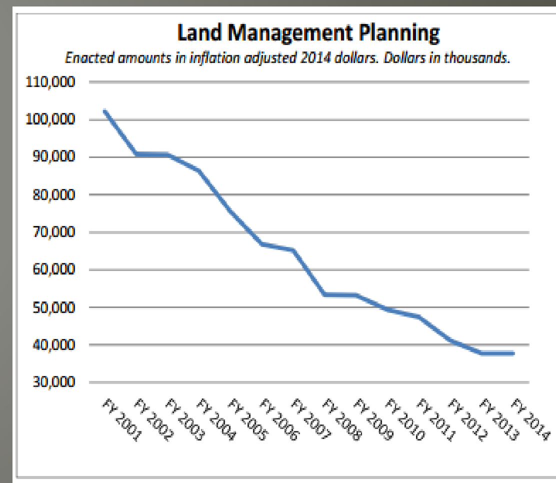
Federal fire costs (billions US $):
Increasing and less variable

IMPACT TO FOREST SERVICE'S PUBLIC LAND MANAGEMENT MISSION

Figure 1: The Cost of Wildland Fire (Preparedness, Suppression, FLAME, and related programs) as a Percentage of the Forest Service's Annual Budget



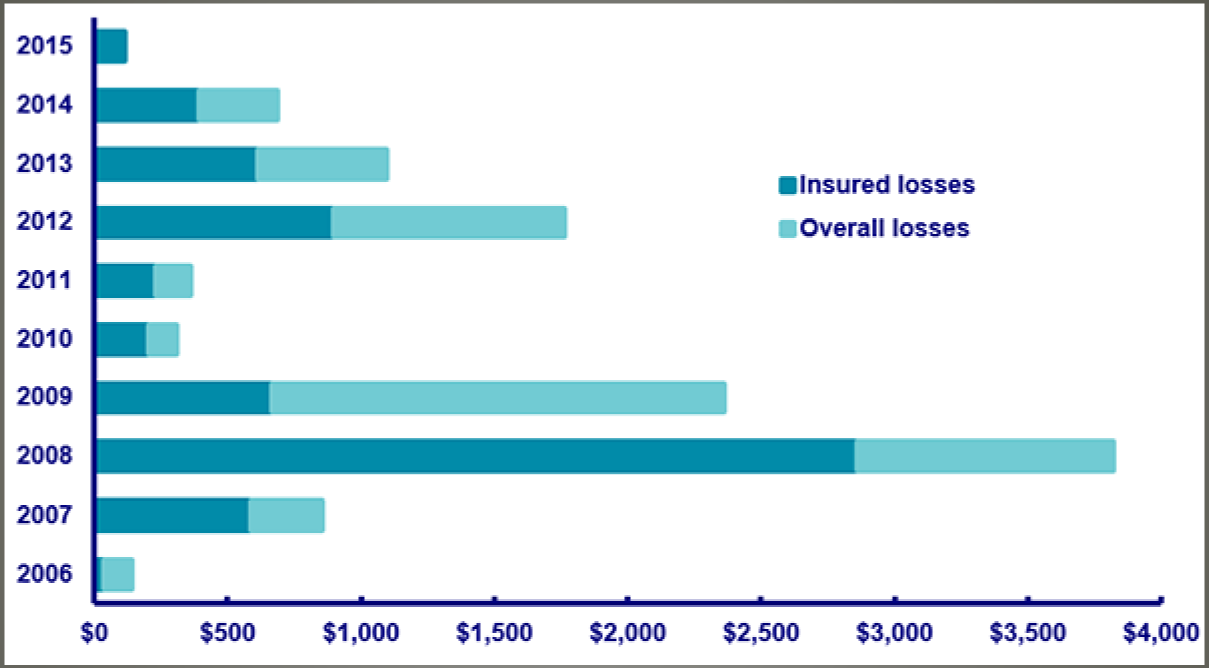




Effect on other USFS programs

Veg management	-22%
Facilities	-67%
Roads	-46%
Deferred maintenance	-95%

WILDFIRE STRUCTURE LOSS (MILLION US $, 2015)



2002-2011 saw 7x increase in insured loss compared with prior decade

THE FIRE PARADOX

- *Decades of fire suppression efforts* → *increased fuel loads and continuity in many forested landscapes.*
- *Increasing ex-urban development* → *substantially increased human values that may be negatively affected by fire.*
- *Climate change* → *increased fire season length.*
- *Result: increased loss and associated management cost.*
- *Firefighter fatalities do not appear to be declining, despite focused investment in safety.*

CHALLENGES IN EXPANDING THE FOOTPRINT OF MANAGED FIRE

- Challenges: a system of perverse incentives
  - Managers tend to face retribution if a fire damages homes or infrastructure
  - However, they tend to be rewarded for aggressively fighting fires
  - Pay is often linked to fighting fire
  - Public opinion

"Old Faithful Lodge during firestorm", 1988

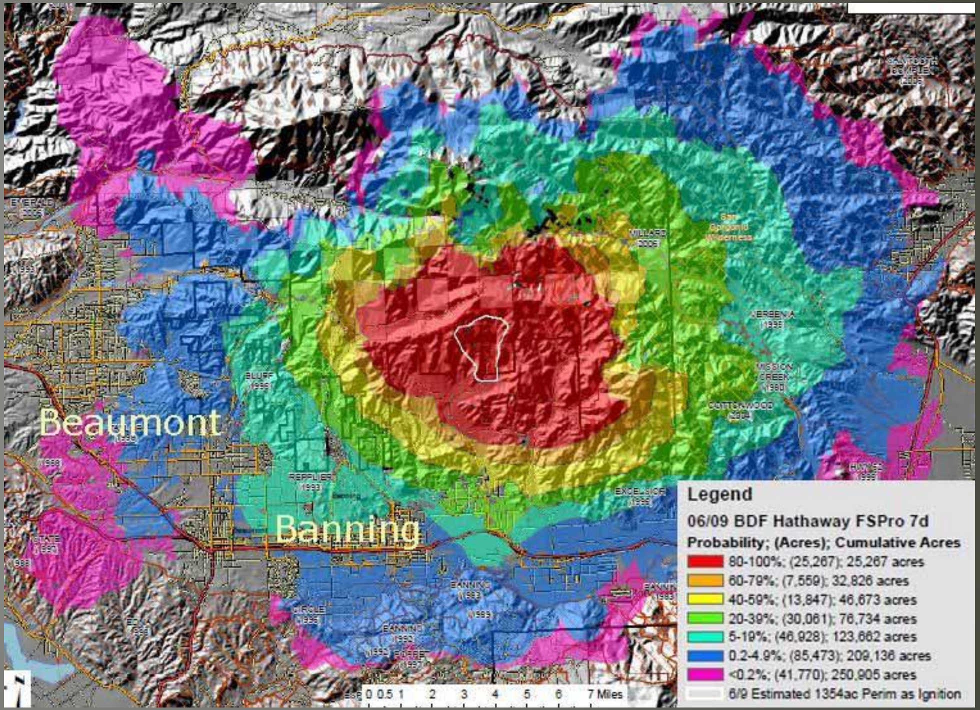
STRIDES IN EXPANDING THE FOOTPRINT OF MANAGED FIRE

- Currently, spatial fire planning is now being integrated into:
  - landscape assessment and planning efforts
  - Land and Resource Management Plans (many National Forests are entering Forest Plan revision process)

- Current fire simulation models and risk assessment methods make this possible

THE ROLE OF FIRE MODELING AND RISK ASSESSMENT

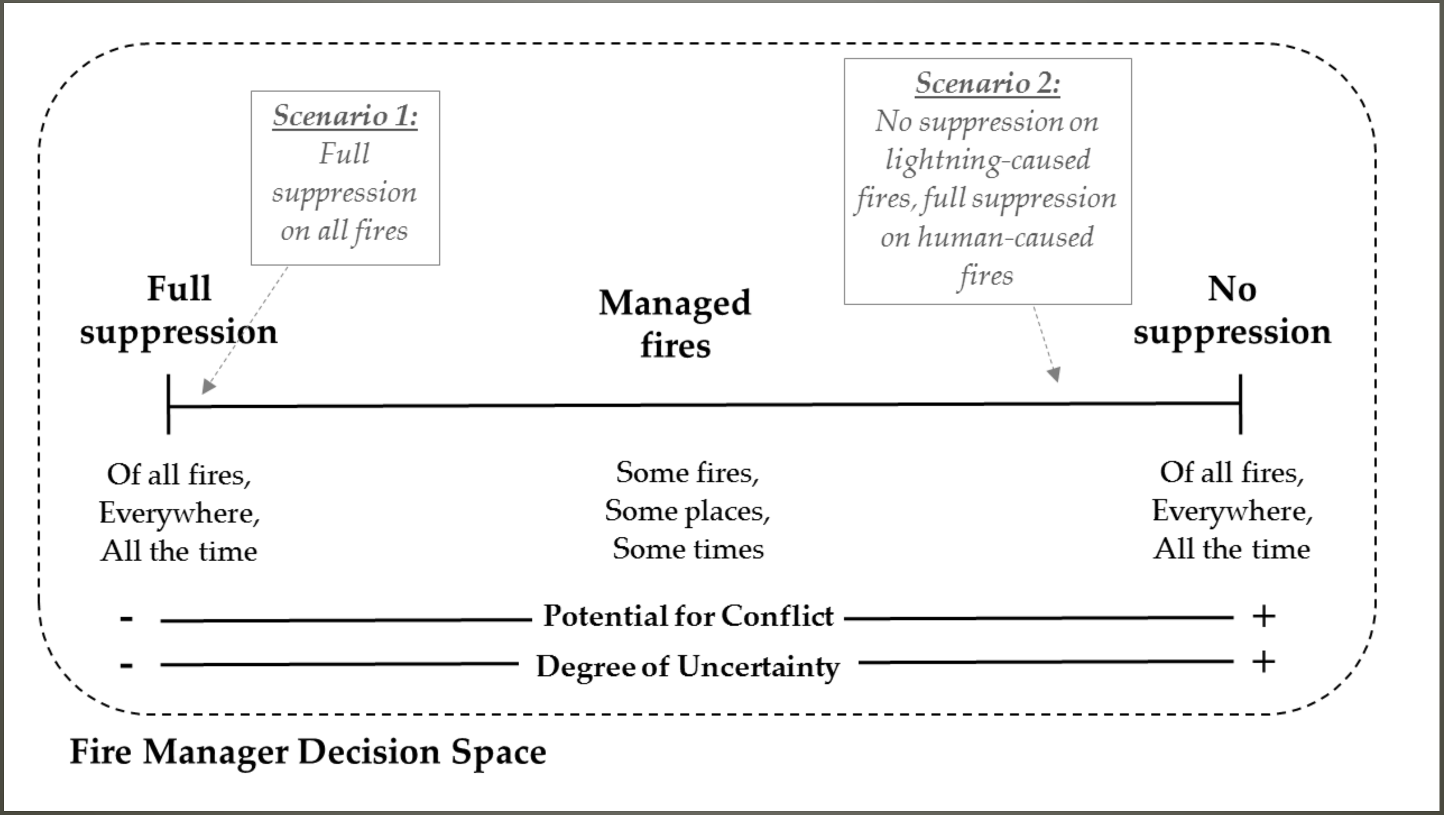
- Fire modeling and risk assessment can help with some of the challenges
  - Identify probability that fire will affect values at risk
    - Benefit
    - Loss
  - Can be used during incidents
  - Now applying it also in a pre-fire planning context



During incidents (FSPro) → firefighting tactics

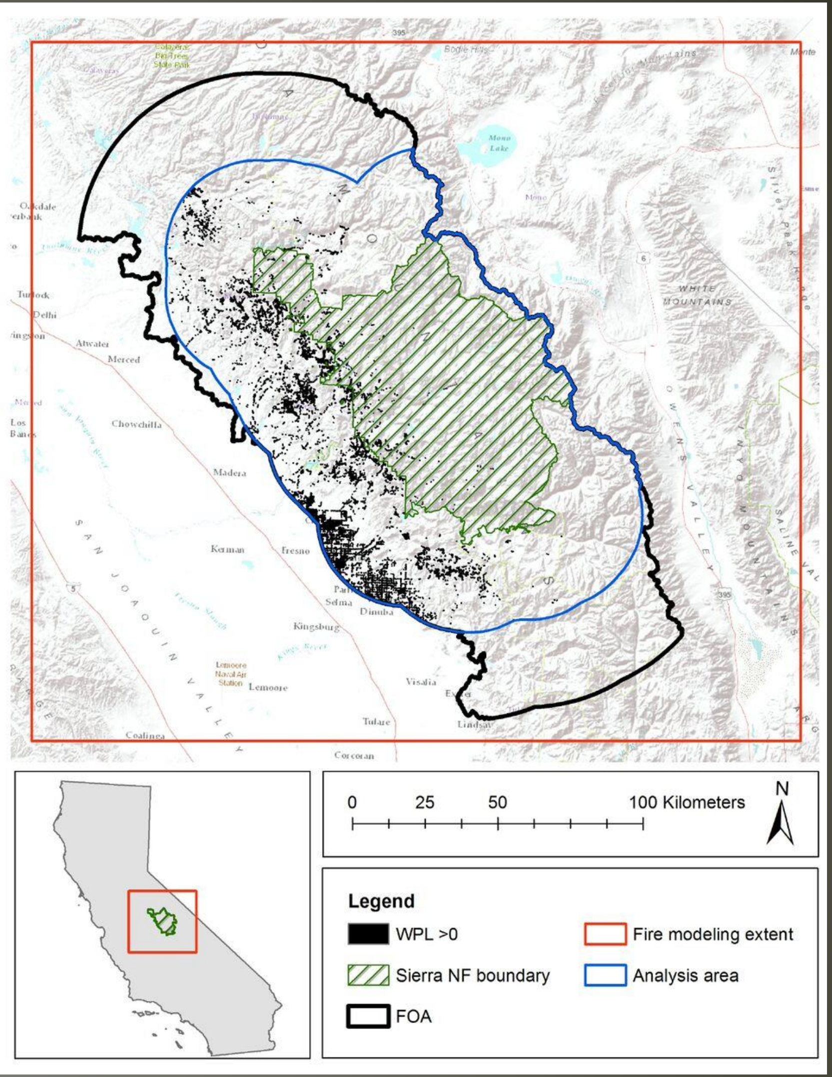
FIRE MODELING AND RISK ASSESSMENT

- *Critical gap is ability to understand and project how alternative response policies/strategies would lead to different outcomes on the landscape*



STUDY DESIGN

- Case study landscape: Sierra National Forest, California
  - Part of broader Southern Sierra Risk Assessment
  - Well-studied area
    - fuel treatment opportunities and backlog (North et al)
    - fuel treatment opportunities (Scott et al.)
    - spatial response planning (Thompson et al.)



- North, Malcolm, et al. 2015. *Constraints on mechanized treatment significantly limit mechanical fuels reduction extent in the Sierra Nevada.* Journal of Forestry 113(1):40-48.
- Scott, Joe H., et al. 2016. *Examining alternative fuel management strategies and the relative contribution of National Forest System land to wildfire risk to adjacent homes—A pilot assessment on the Sierra National Forest, California, USA.* Forest Ecology and Management 362: 29-37.
- Thompson, Matthew P., et al. 2016. *Application of wildfire risk assessment results to wildfire response planning in the Southern Sierra Nevada, California, USA*. Forests 7, 64.

STUDY DESIGN: LARGE FIRE SIMULATOR = FSIM

INPUTS

Spatial Fuels Data (Static Condition: LandFire)

Fire Weather: Time Series Analysis

Large Fire Occurrence (Historical Records)

MODEL COMPONENTS

Fire Behavior (Spread Rate, Fireline Intensity)

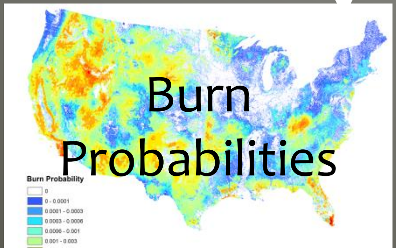
Large Fire Ignition

Fire Growth Model (Minimum Travel Time Algorithm)

Fire Suppression

OUTPUTS

Fire Sizes, Dates, Durations, Locations



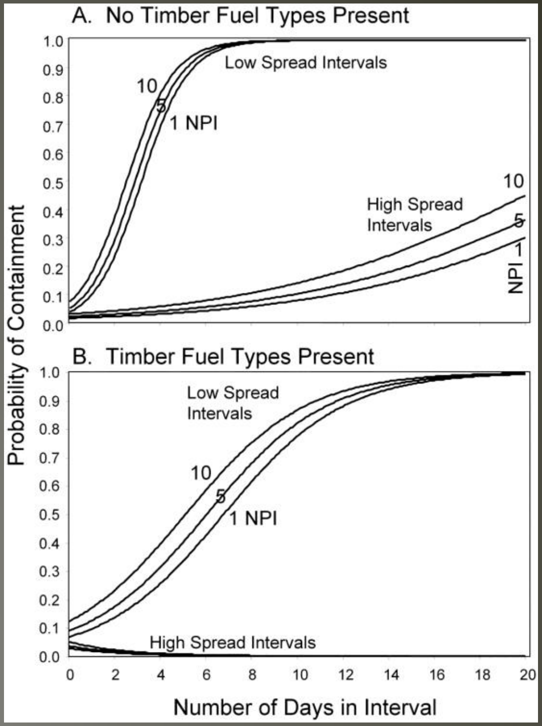
Intensity probabilities

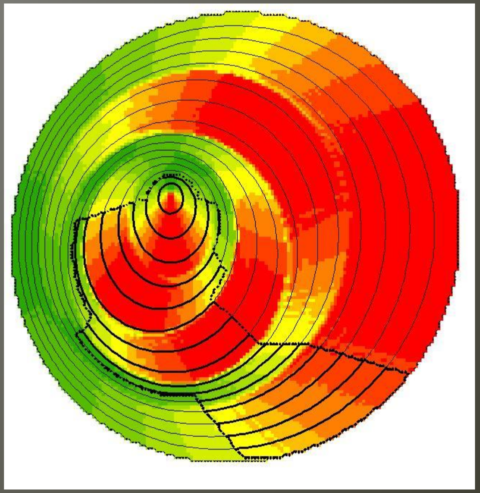
Fire Perimeters

Finney, Mark A., Charles W. McHugh, Isaac C. Grenfell, Karin L. Riley, and Karen C. Short. 2011. A simulation of probabilistic wildfire risk components for the continental United States. Stochastic Environmental Research and Risk Assessment 25:973-1000.

FIRE SUPPRESSION IN FSIM

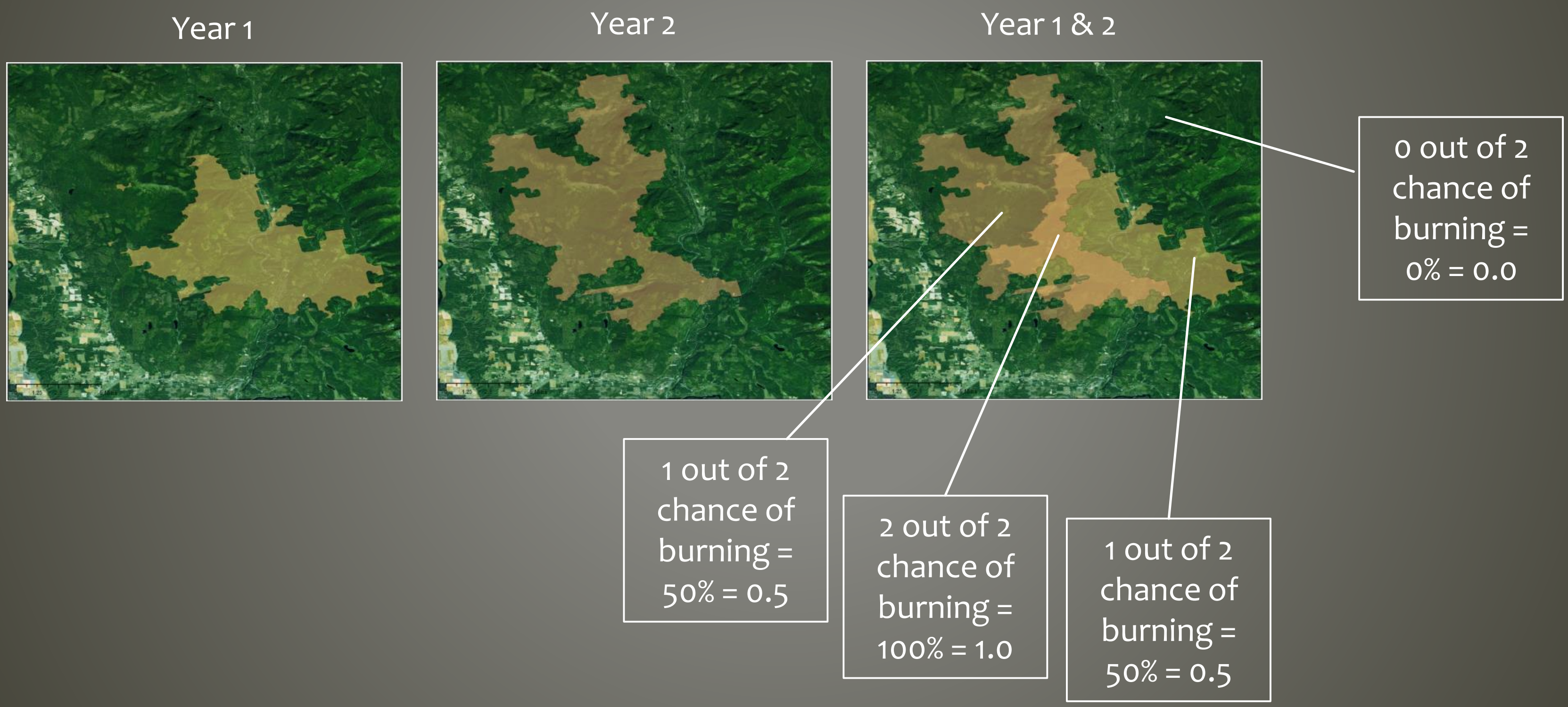
- *Three options:*
  - *Fire suppression on:*
    - *Determines fire duration based on probability of containment. Fire growth is unrestricted until containment.*
  - *Fire suppression plus perimeter trimming:*
    - *The fire's perimeter is successively contained, beginning with the area where fire intensity is lowest. While the suppression algorithm determines the duration, perimeter trimming restricts the spatial extent.*
    - *Trimming parameter can be adjusted to affect the rate of containment. (Alpha~2.4 in Western US)*
  - *No suppression:*
    - *Fires are extinguished by a period of wet or cool days (below 70th percentile ERC). Number of days is set by user; we chose 5.*





Finney, Mark, Isaac C. Grenfell, and Charles W. McHugh. 2009. Modeling containment of large wildfires using generalized linear mixed-model analysis. Forest Science 55(3): 249-255.

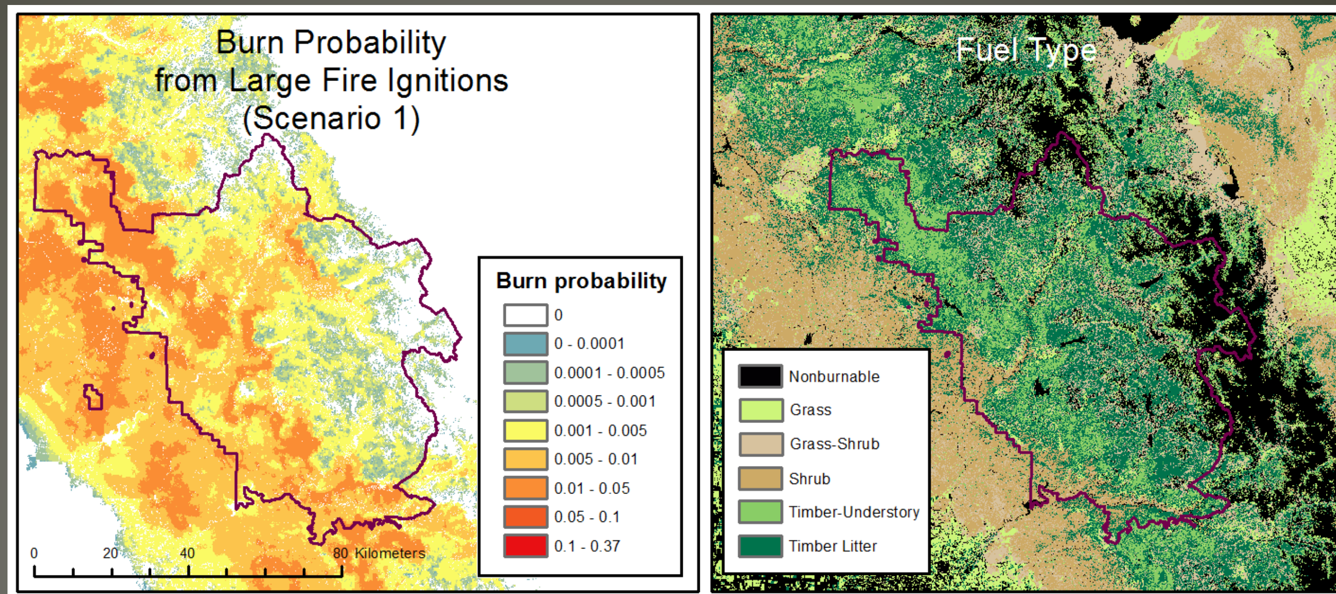
ANNUAL BURN PROBABILITY IN FSIM

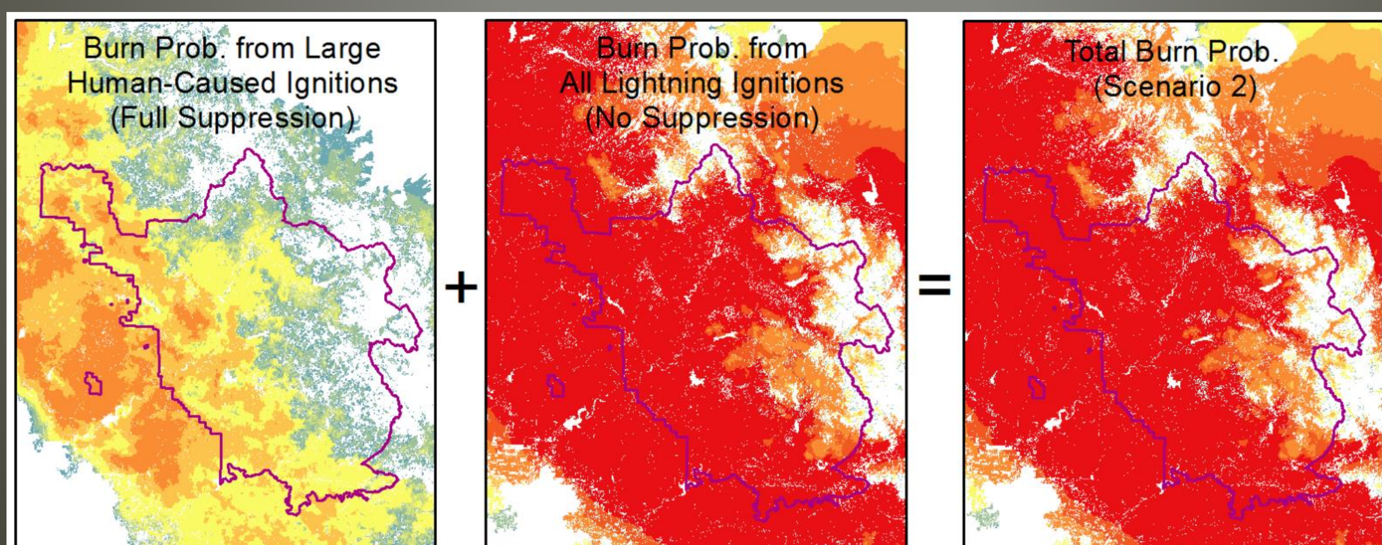


RESULTS

Mean bp = 0.0048 (Observed = 0.0053)

SCENARIO 1



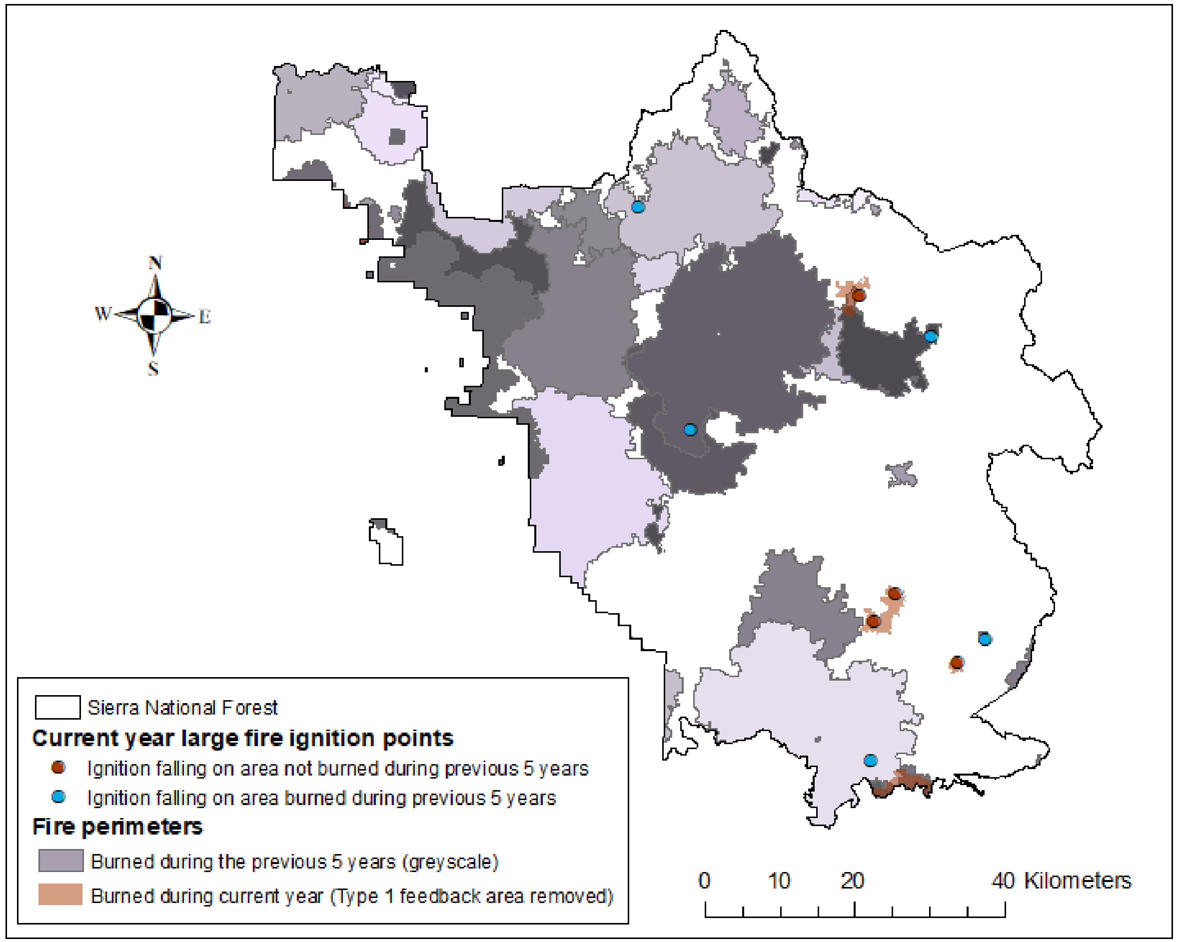


SCENARIO 2

Mean bp = 0.1751

FEEDBACKS IN AREA BURNED

- *Future fire ignition and spread limited in recently burned areas (Parks et al)*
- *Type 1 feedbacks: a future fire that wouldn't have ignited because it fell on a recently burned area*
- *Type 2 feedbacks: a future fire wouldn't have been able to spread into a recently burned area*
- *Method: assume feedbacks last 5 or 10 years. Sample 6 or 11 years of fires from Fsim randomly. (5000 random draws)*



- Parks, S A.; Miller, C.; Holsinger, L.M.; Baggett, S.; Bird, B.J. Wildland fire limits subsequent fire occurrence, *Int. J. Wildland Fire* **2016**, 25, 182-190.
- Parks, S.A.; Holsinger, L.M.; Miller, C.; Nelson, C.R. Wildland fire as a self-regulating mechanism: the role of previous burns and weather in limiting fire progression. *Ecol. Appl.* **2015**, 25(6), 1478-1492.

EFFECT OF FEEDBACKS ON BURNED AREA DURING FIVE- AND TEN-YEAR PERIODS

			Scenario 1		Scenario 2	
			Nonburnable= 5 years	Nonburnable= 10 years	Nonburnable= 5 years	Nonburnable= 10 years
Without feedbacks	area burned (ha)	Min.	0	0	0	0
		1st Q.	0	0	6,287	6,833
		Median	571	529	39,153	41,793
		Mean	2,457	2,367	119,663	122,686
		3rd Q.	2,466	2,378	162,439	164,937
		Max.	78,402	78,402	3,271,611	3,271,611
Type 1	% of cases affected		7	12	91	94
	avoided area burned (ha)	Median	539	467	8,919	5,493
		Mean	89	174	67,163	83,540
	avoided area burned (proportion) *	Min.	0	0	0	0
		1st Q.	0	0	45	66
		Median	0	0	71	83
		Mean	3	7	64	78
		3rd Q.	0	0	90	96
		95th Perc.	20	57	100	100
		Max.	100	100	100	100
Type 2	% of cases affected		27	37	94	95
	avoided area burned (ha)	Median	0	0	30,345	39,892
		Mean	148	289	100,476	117,185
	avoided area burned (proportion) *	Min.	-10	-7	0	0
		1st Q.	0	0	72	96
		Median	0	0	93	99
		Mean	5	10	81	95
		3rd Q.	1	8	100	100
		95th Perc.	34	65	100	100
		Max.	100	100	100	100

CONCLUSIONS

- *Alternative fire suppression policies have the potential to impact burn probabilities and fire sizes*
- *While implementing a no suppression policy on lightning fires is likely to increase burn probability by more than an order of magnitude in the short term, feedbacks would soon begin to act as a self-limitation in area burned*
- *Thus, there is an opportunity for managed fires to act as fuel treatments, in some locations, especially those where fire can produce benefit on the landscape*

CAN WE SAVE MONEY ON WILDFIRE SUPPRESSION BY INVESTING IN FUEL TREATMENTS AND PRESCRIBED FIRE INSTEAD?

OPTIMIZING FUEL TREATMENTS BASED ON RISK REDUCTION AND BUDGET CONSTRAINTS

Karin L. Riley [1], Matthew P. Thompson [1], Jessica Haas [1], and Dan Loeffler [2]

[1] Rocky Mountain Research Station, US Forest Service, Missoula, Montana & Fort Collins, Colorado

[2] University of Montana, Missoula, Montana

WHY USE FUEL TREATMENTS?

- *Restoration of stands where timber harvest and/or fire exclusion have occurred*
- *Reduction of intensity and/or probability of future fires*
- *Safer areas for firefighters to work to control fires*
- *Etc.*

- *Can they be used:*
  - *To reduce risk to highly valued resources?*
  - *To produce savings in preparedness and suppression costs?*

MECHANICAL FUEL TREATMENTS

Treatment = meant to simulate a combination of mechanical and Rx fire to reduce flame length and crown fire potential (after Scott et al 2016)

Canopy cover: only where greater than 35%, mild reductions of 5-20% proportional to cover

Canopy base height: raised to 1.5 times the current level, with a minimum of 2m

Canopy bulk density: reduced by 0.75

Fuel model: changed to reduce intensity and/or rate of spread (grass not treated as it can quickly regrow)

Scott, Joe H., Matthew P. Thompson, and Julie W. Gilbertson-Day. 2016. *Examining alternative fuel management strategies and the relative contribution of National Forest System land to wildfire risk to adjacent homes – A pilot assessment on the Sierra National Forest, California, USA*. Forest Ecology and Management 362: 29-37.

FUEL TREATMENT SCENARIOS

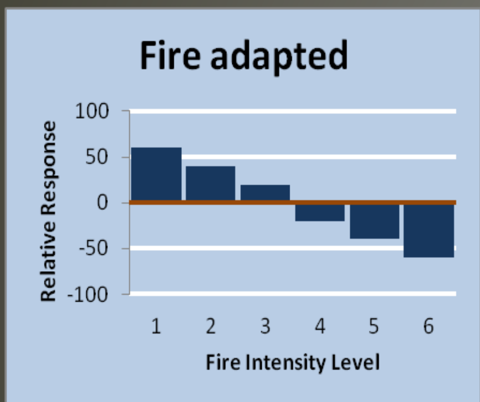
- *treat all feasible pixels*
- *choose places to treat based on risk to highly valued resources at four different budget levels*
  - *$10 million*
  - *$20 million*
  - *$30 million*
  - *$40 million*
- *wildfire as a fuel treatment*

HIGHLY VALUED RESOURCES OF THE SIERRA N.F.

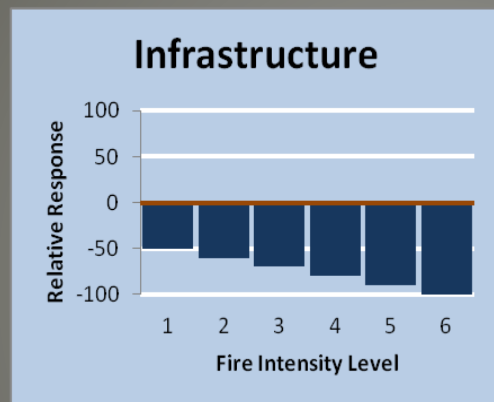
- *Human habitation*
- *Inholdings (private timber companies and state land)*
- *Major infrastructure (e.g. transmission lines)*
- *Recreation-administration infrastructure*
- *Scenic byways*
- *Habitat (sage grouse, owl, fisher, goshawk)*
- *Timber*
- *Watershed*
- *Vegetation condition (is there enough or too little of a certain type of vegetation?)*

WHERE FIRE IS A BENEFIT, OR LOSS

- Conditional Net Value Change = the change in Highly Valued Resources expected if the pixel burns

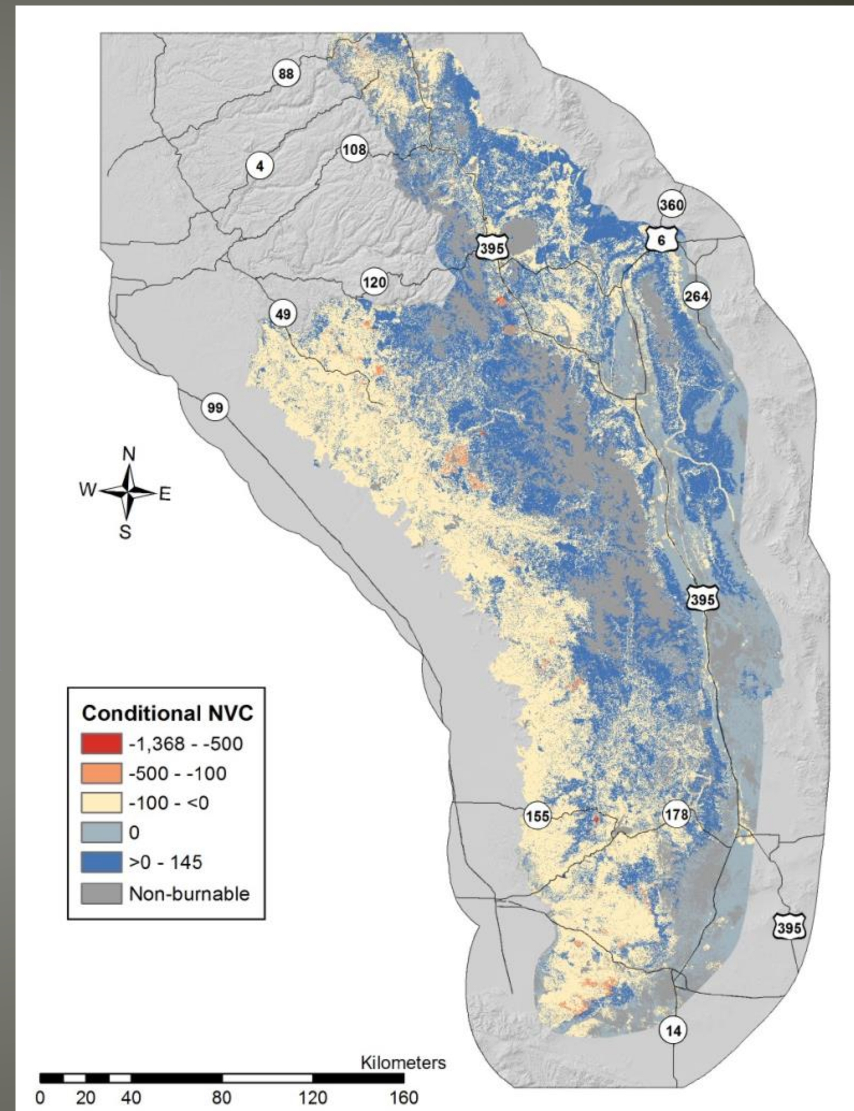


Description:
Strong benefit at low fire intensity decreasing to a strong loss at very high fire intensity.

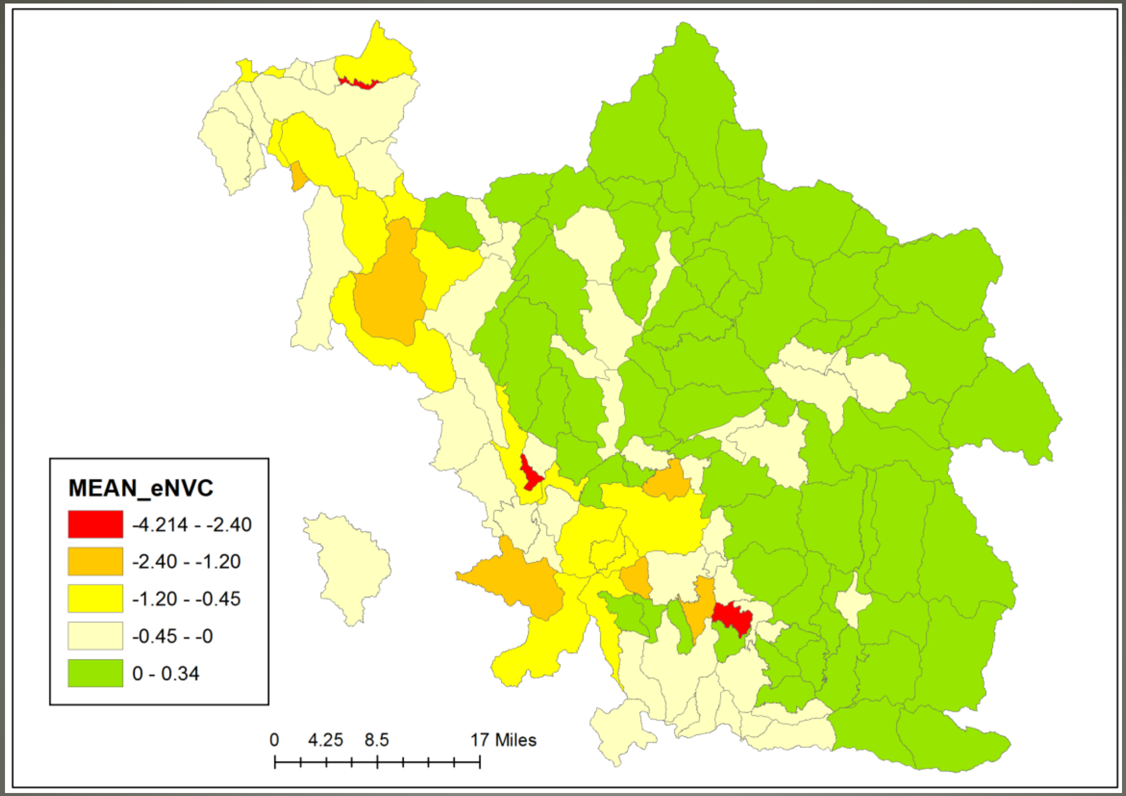


Description:
Moderate to strong loss as fire intensity increases.

$$cNVC = \sum_{i}^{n} FLP_i * RF_i$$



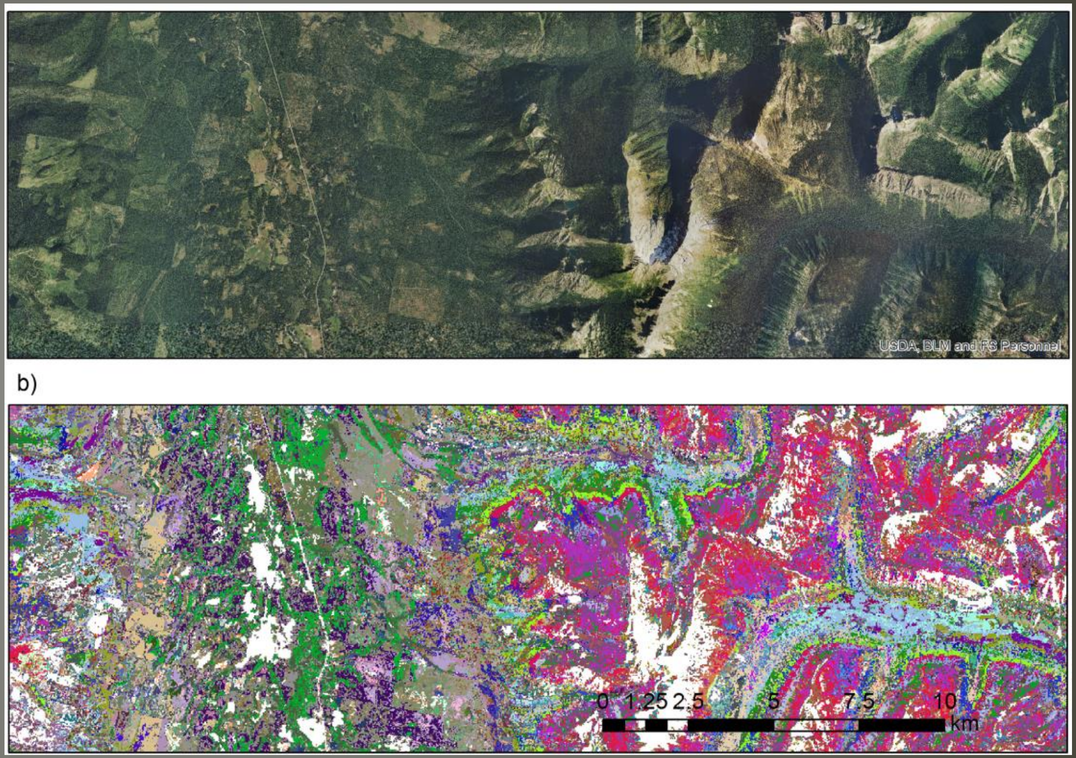
DECIDING WHERE TO TREAT



- Potential Operational Delineations (PODs) are areas within which a fire might be expected to be contained
- We calculated the mean Net Value Change for each POD
- Treatments were optimized based on two factors:
  - Where resources were most negatively affected by fire (eNVC)
  - Timber volume from thinning

CALCULATING TREATMENT COSTS

- *We matched forest inventory plots to each pixel of raster landscape data using random forests. This provided the number, size, and species of trees at each pixel.*
- *Applied a thin-from-below in the Forest Vegetation Simulator (FVS) to determine which trees would be cut*
- *Treatment costs determined by the Fuel Reduction Cost Simulator (FRCS)*



Riley, Karin L., Isaac C. Grenfell, and Mark A. Finney. 2016. Mapping forest vegetation for the western United States using modified random forests imputation of FIA forest plots. Ecosphere 7(10), 1-22.

CALCULATING FIRE SUPPRESSION COSTS

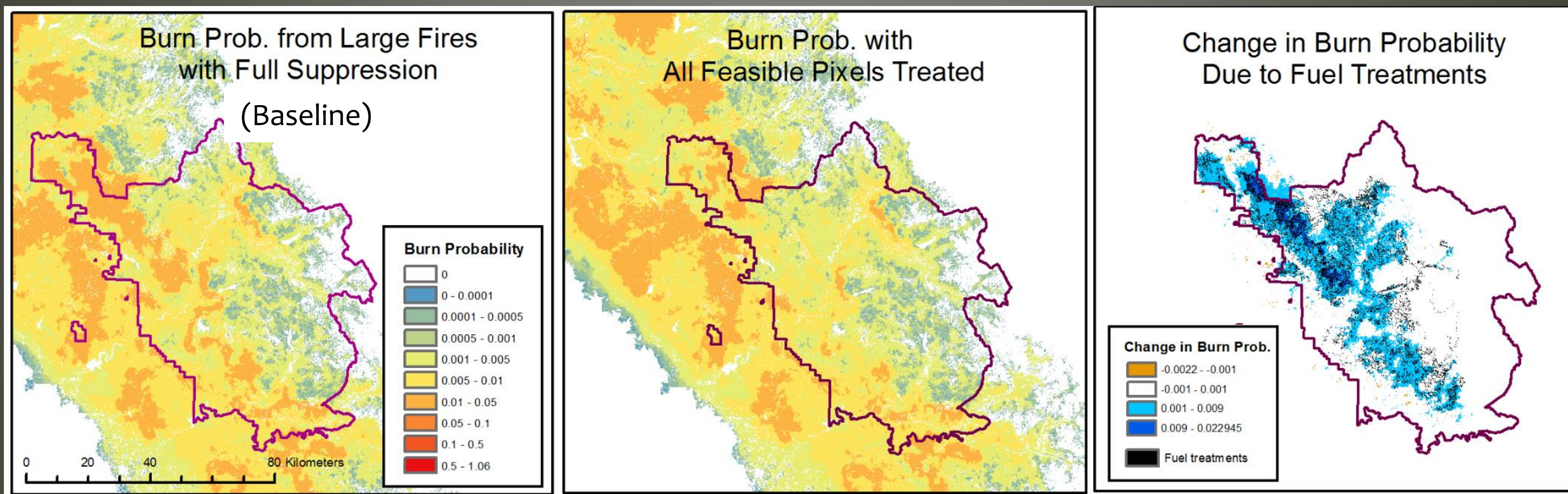
- *Spatial Stratified Cost Index (Hand et al. 2016)*
- *Regression equations built on 406 fires that occurred on USFS land between 2006-2011 that were larger than 300 acres*
- *Predictors:*
  - *final fire size*
  - *Aspect*
  - *Elevation*
  - *Proportion of fire in different slope categories*
  - *proportion of fire in different fuels categories (grass, brush, timber, and slash),*
  - *proportion of fire in different land management categories (Wilderness, roadless, other specially designated)*
  - *Proportion of fire in different land ownership categories (USFS, DOI)*
  - *Housing value within 5, 10, and 20 miles*
  - *Energy Release Component maximum and standard deviation (related to fuel dryness)*
  - *USFS geographic region*

Michael S. Hand, Matthew P. Thompson, and David E. Calkin. 2016. Examining heterogeneity and wildfire management expenditures using spatially and temporally descriptive data. Journal of Forest Economics 22: 80-102.

BURN PROBABILITY RESULTS

Mean=0.0048

Mean=0.0036



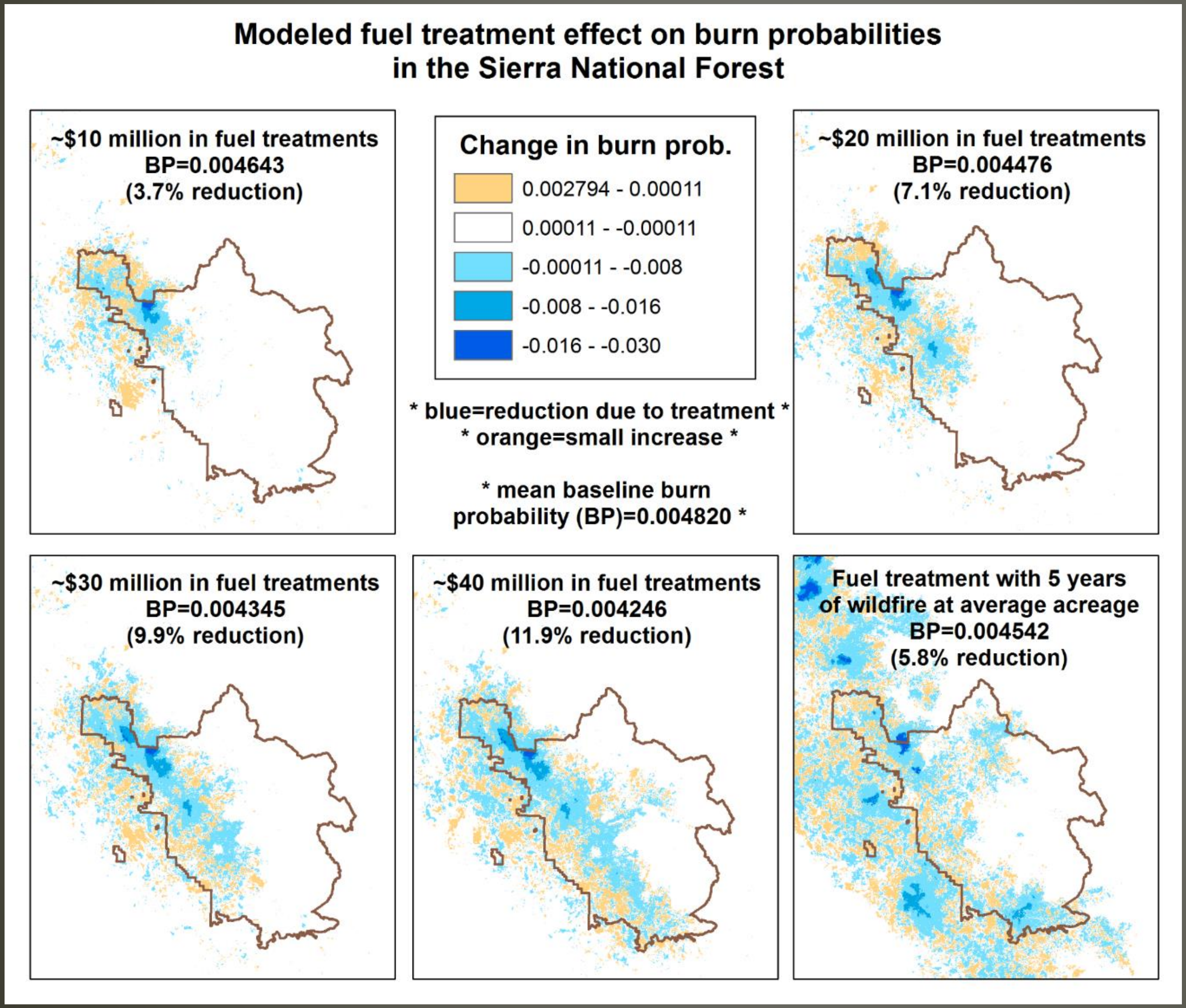
Median fire size=992 acres

Median fire size=880 acres

Reduction of:

- 25% in burn probability
- 11% in median fire size

BURN PROBABILITY RESULTS



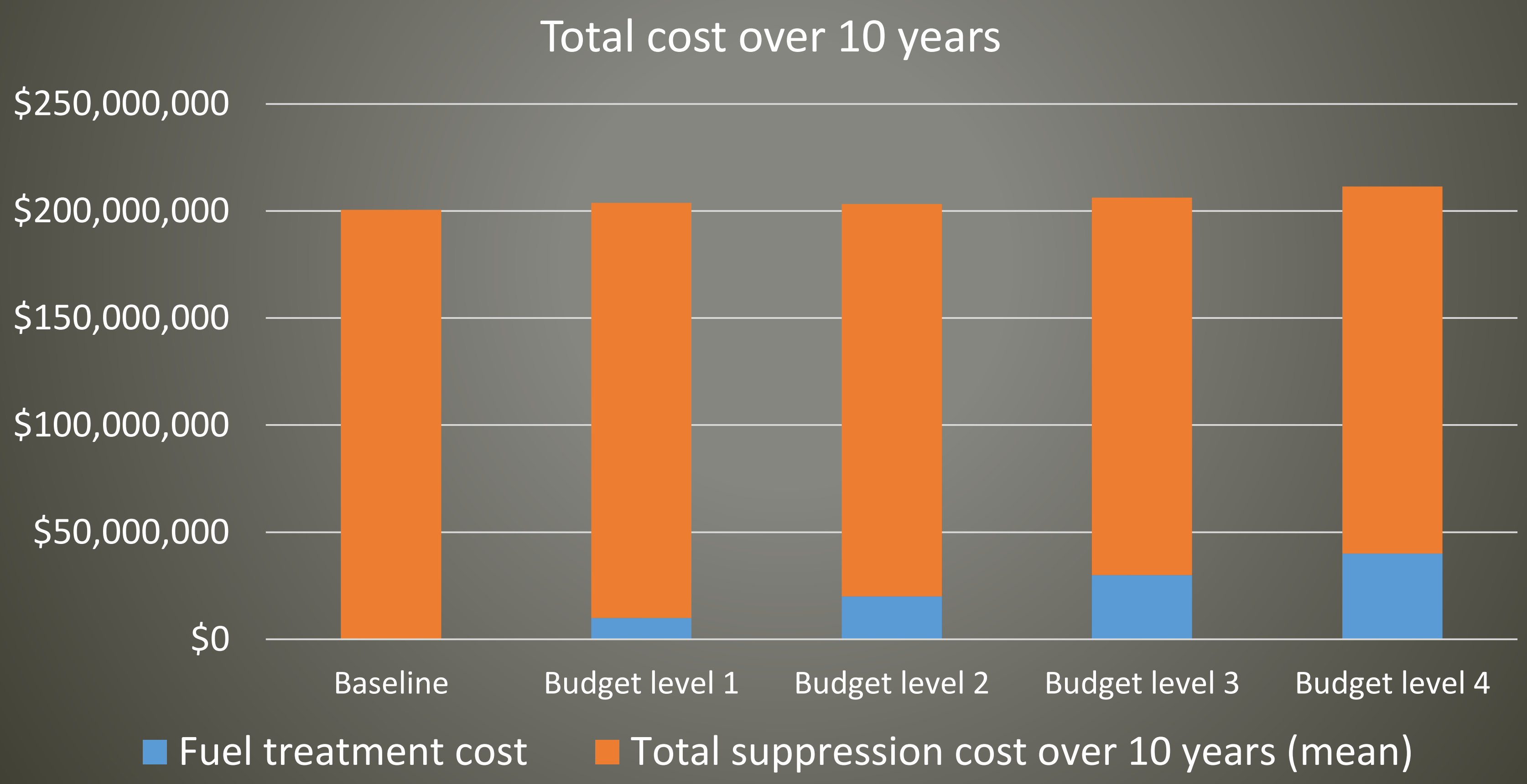
Fuel treatments can reduce risk from wildfire to highly valued resources

FUEL TREATMENTS CAN REDUCE THE SIZE OF FUTURE WILDFIRE AND PRODUCE SUPPRESSION COST SAVINGS

	Mean large fire size (ac)	Mean number of large fires/year	Mean acres burned/year	Mean suppression cost/fire	Total suppression cost/year (mean)	Suppression cost savings if fuel treatments effective for 10 years
Baseline	2619	2.42	6336	$8,290,000	$20,055,460	$0
$10 million in fuel treatments	2543	2.4	6091	$8,090,000	$19,378,085	$6,773,750
$20 million in fuel treatments	2455	2.38	5839	$7,704,000	$18,321,186	$17,342,740
$30 million in fuel treatments	2389	2.36	5644	$7,461,000	$17,630,438	$24,250,220
$40 million in fuel treatments	2338	2.35	5487	$7,304,000	$17,141,156	$29,143,040
Treatment with 5 years of wildfire at average number of acres burned	2529	2.36	5967	$8,061,000	$19,023,096	NA

Investment at $20 million in fuel treatments roughly equivalent to projected suppression cost savings

- *The bulk of substantial investment in fuel treatments can likely be largely if not entirely offset by savings in suppression (shown below) and preparedness costs (not modeled in this analysis)*



CONCLUSIONS

- *The new methodology presented here allows treatment locations to be optimized based on their potential to reduce risk to highly valued resources, making efficient use of limited funding*
- *Strategically located treatments can reduce the probability that highly valued resources will burn, and the likely fire intensity*
- *There is potential for treatments to "pay for themselves" by reducing preparedness and suppression costs*
- *Managed fires likely have potential to "treat" more acres, but the locations of managed fires are based on lightning ignitions and thus are uncertain.*


QUESTIONS?
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