OptFuels: Optimizing Placement of Fuel Treatments over Time at Landscape Scales

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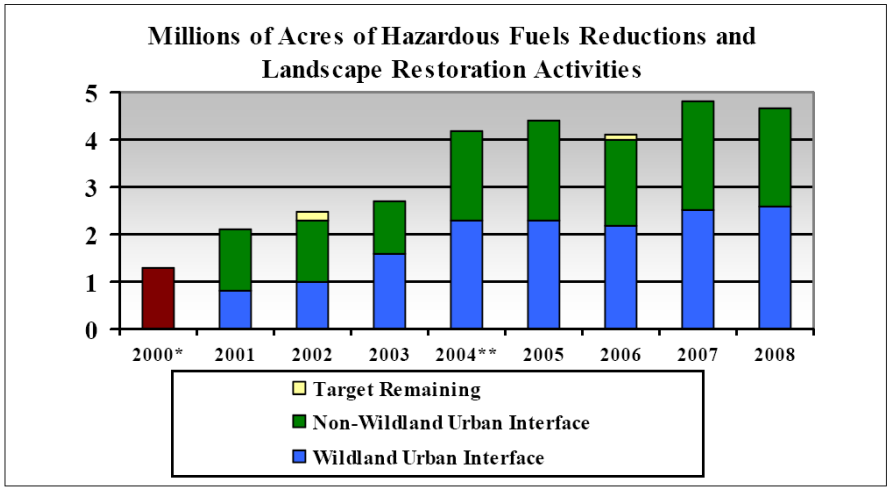
Background

- Over 8 million acres have burned every year between 2004 and 2007 (National Interagency Fire Center 2009)
- USDA Forest Service and DOI spent over $1.8 billion in each year on wildfire suppression in five of the past 8 years
- In 1991, the Forest Service spent 13% of its total budget on wildland fire management. In 2008, 45% of the agency's budget went to fighting fire

Background

- Fuel treatments have been used to alter fire behavior and reduce the potential fire intensity levels across a landscape
- From 2001 through 2008, FS and DOI have treated over 29 million acres of federal lands under the Healthy Forest Initiative (HFI) and the National Fire Plan.

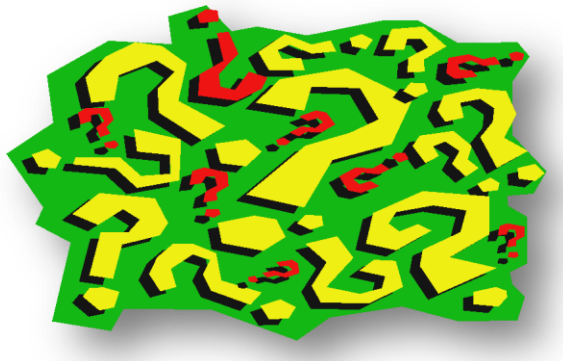


* FY 2000 is used as a baseline for reporting, as the NFP was implemented in FY 2001. Treatment location was not included in reporting prior to FY 2001.
** Acres treated under landscape restoration activities were not reported prior to FY 2004.

(from Healthy Forest Report for FY 2008 written by Healthy Forests and Rangelands)

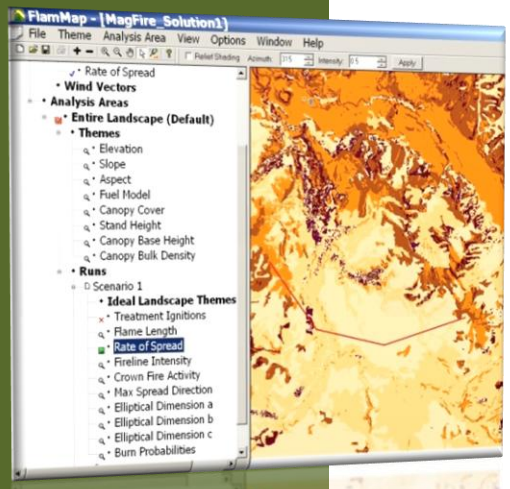
Background

- No tools exist to help land managers establish priorities for **where, when, and how** to apply **new** and **maintenance** fuel treatments



Background

- No tools exist to help land managers establish priorities for where, when, and how to apply new and maintenance fuel treatments
- Tools available for land managers
  - FARSITE (Finney 1998) and FlamMap (Finney 2006)



Background

- Treatment Optimization Model (Finney 2007)

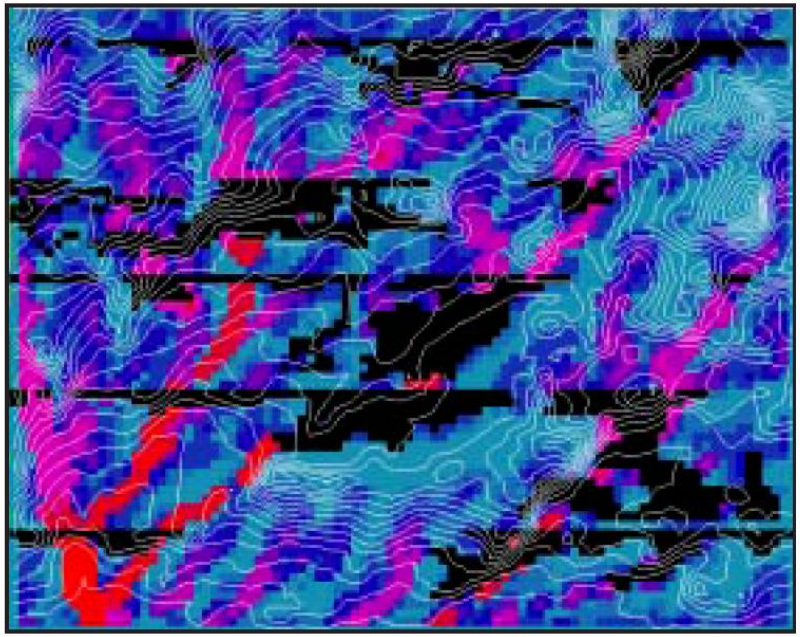


Figure 2—Routes resulting in the most burned area can be identified using graph theory (Finney 2002). These routes reflect the greatest opportunities for disrupting the simulated fire growth using fuel management. Red indicates high influence and blue little or none. Heuristic algorithms can then optimize fuel treatment locations (shown in black) that result in efficient reductions in fire spread rate per unit area treated. The treatments shown in black reduce fire spread rate by 40% with less than 16% of the area treated because treatments are located to block the fastest and most influential routes.

(Source: Finney 2003. Landscape Planning. USDA Forest Service Proceedings RMRS-P-29)

Background

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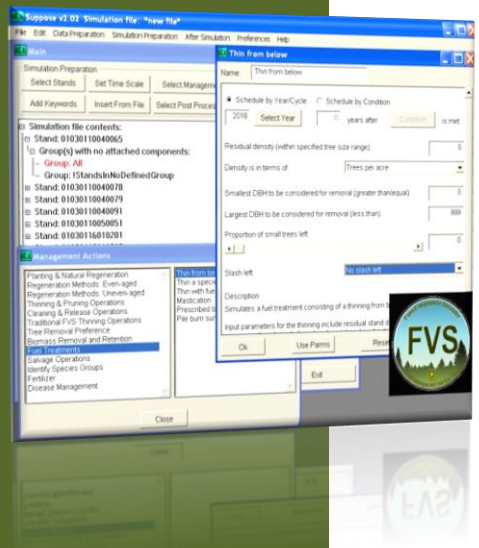
  - Treatment Optimization Model (Finney 2007)
  - FVS-FFE (Reinhardt and Crookston 2003)



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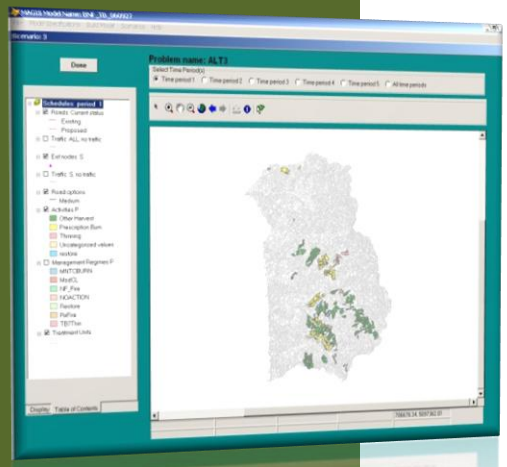
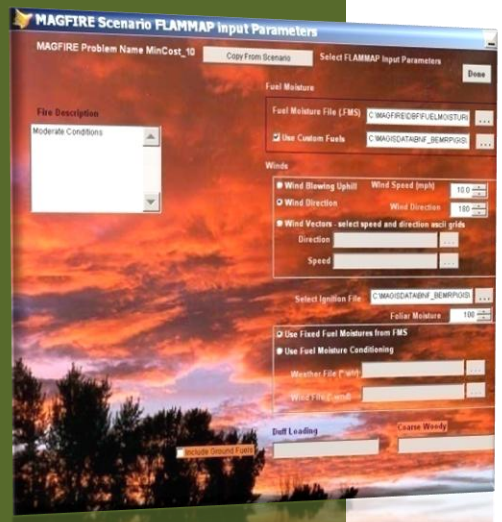
  - MAGIS (Zuuring et al. 1995, Chung et al. 2005)



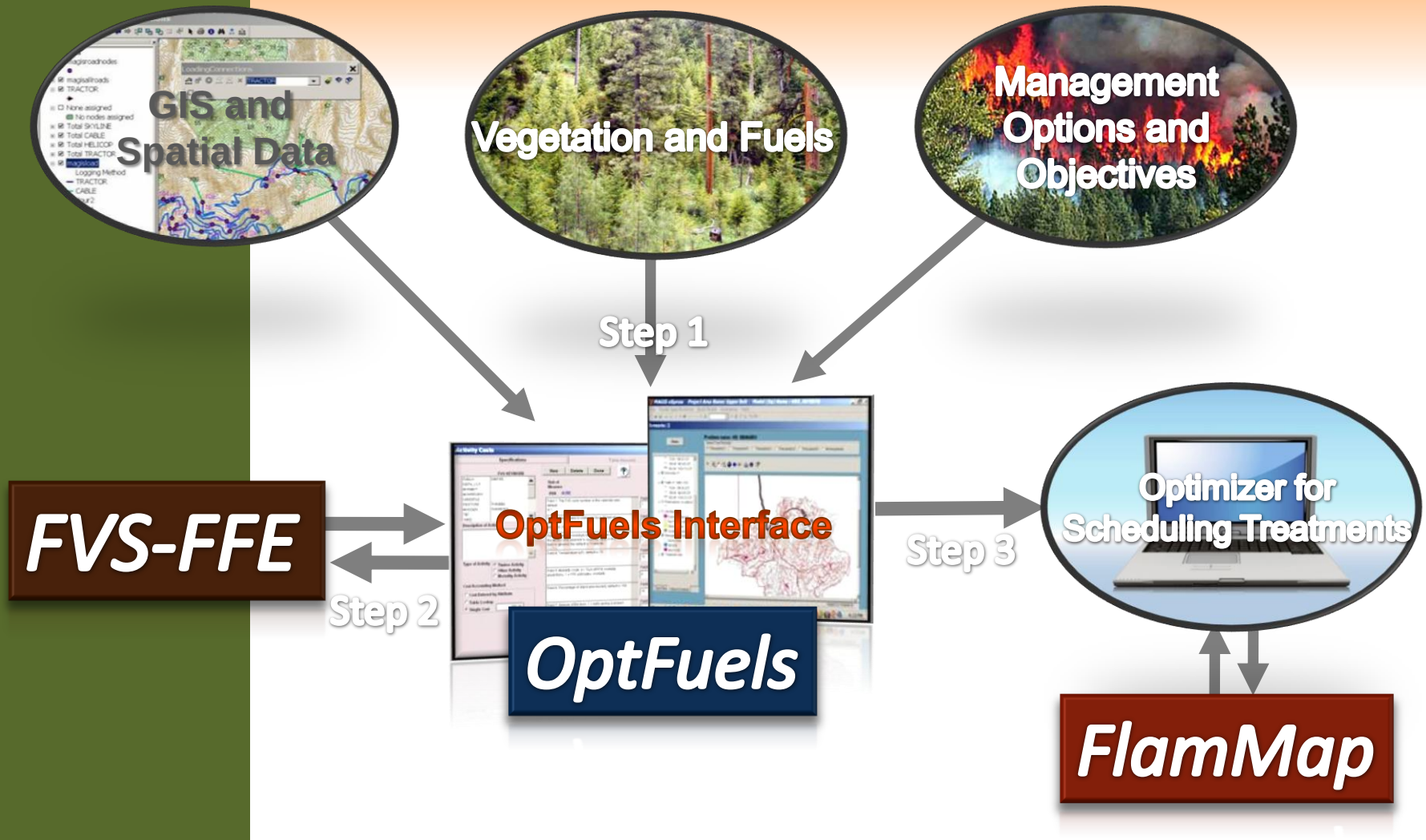
Objective

- Integrate existing fire behavior (FlamMap), vegetation simulation (FVS-FFE), and land management planning (MAGIS) tools into one decision support system that supports long-term fuel management decisions in order to
  - optimize **spatial and temporal** location of fuel treatments in a way that landscape-level fuel management effects are maximized and maintained over time,
  - while satisfying given budget and operational constraints.



OptFuels

System Components



Management Objectives Component

- Objective for driving treatment placement and scheduling
  - Minimize expected loss to wildland fire over time

$$Minimize \sum_{t \in T} \sum_{c \in C} \sum_{f \in F} Loss_{f,c,t} \times Y_{f,c,t} \times P_{c,t}$$

Where

f is an index of flame length category,
c is an index of grid cells,
t is a time period,
$\boldsymbol{Loss_{f,c,t}}$ is an expected loss value of grid cell *c* at flame length category ***f*** in time period ***t***,
$\boldsymbol{Y_{f,c,t}}$ is a binary variable indicating the flame length category of cell ***c*** in period ***t***, and
$\boldsymbol{P_{c,t}}$ is a probability of cell c being burn by given fire scenarios (fire ignition locations and durations) in time period ***t***.

Management Objectives Component

- OptFuels Objective Function

$$Minimize \sum_{t \in T} \sum_{c \in C} \sum_{f \in F} Loss_{f,c,t} \times Y_{f,c,t} \times P_{c,t}$$

Relative Loss Values ($Loss_{f,c,t}$)

	Low	Med.	High	Very High
FS, roadless	0	10	20	30
FS, accessible	0	60	70	80
FS, WUI	50	150	250	480
Right-of-way	0	0	800	800
State and Private	10	30	50	80

Management Objectives Component

- OptFuels Objective Function

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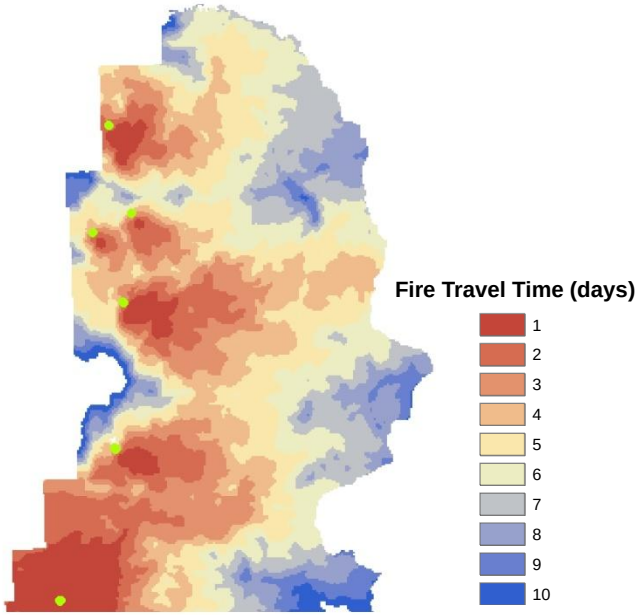


Burn Probability ($P_{c,t}$)

Time step	Probability
1 day	0.9
2 days	0.7
3 days	0.5
4 days	0.3
5 days	0.2
6 days	0.1
7 days	0.1
8 days	0.0
9 days	0.0
10 days	0.0

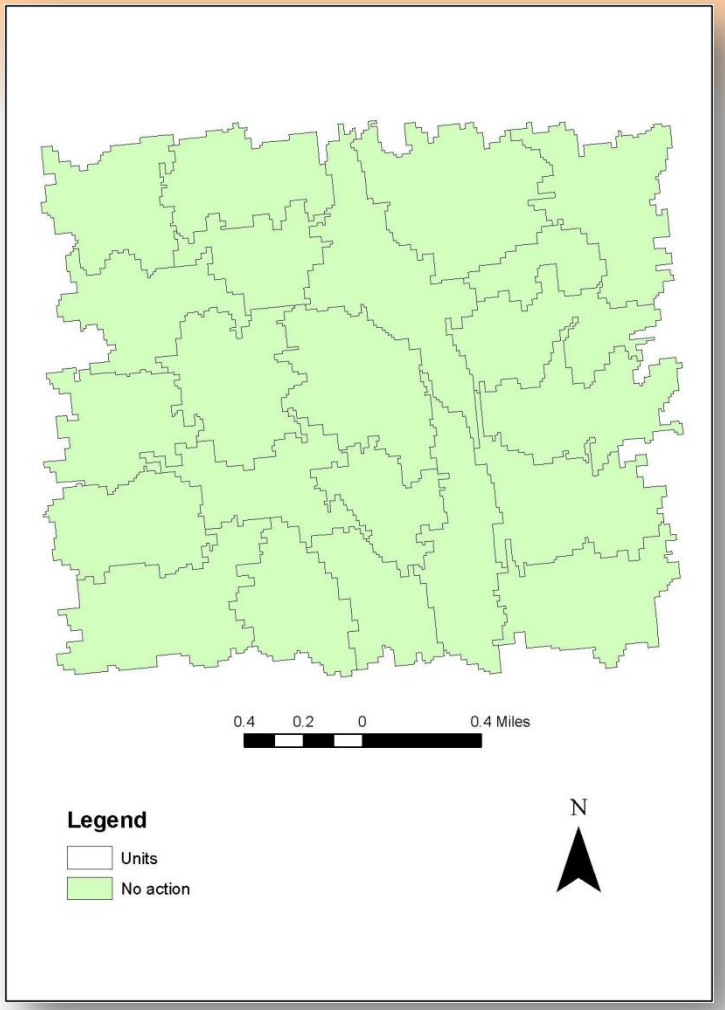
Management Objectives Component

- Potential Constraints
  - Limited budget
  - Limited treatment options and acres by zones (treatment exclusion, treatment priority, treatment type)
  - Quantity and value of products produced by treatments
  - Road access for treatments

Optimizer for Scheduling Treatments

Heuristic Solver

- Generating alternative solutions



Optimizer for Scheduling Treatments

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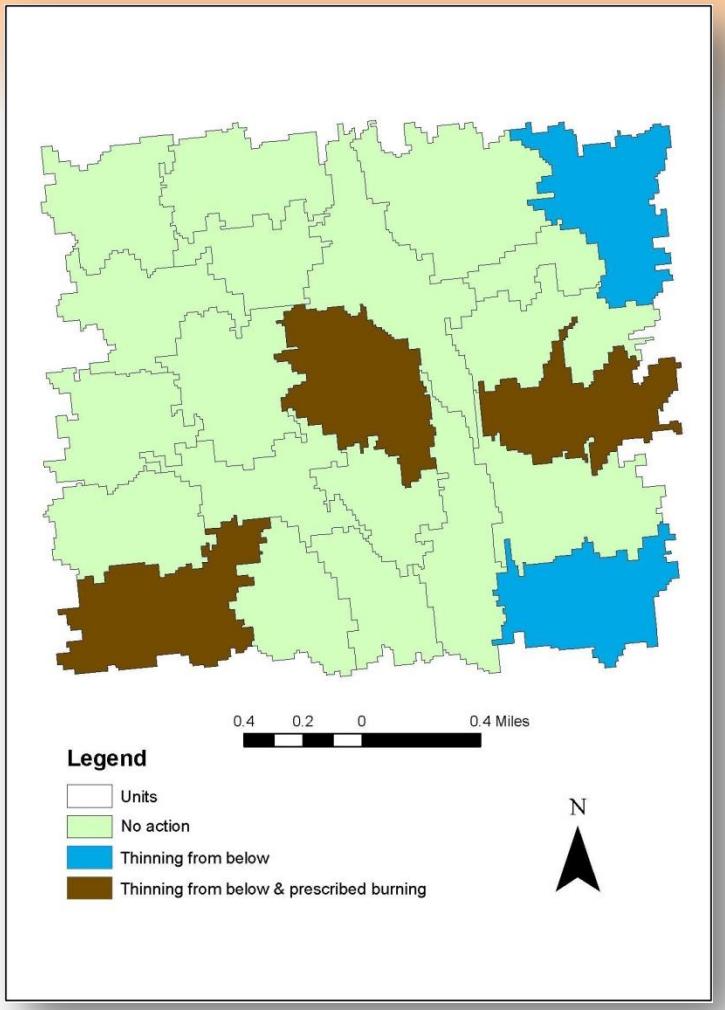
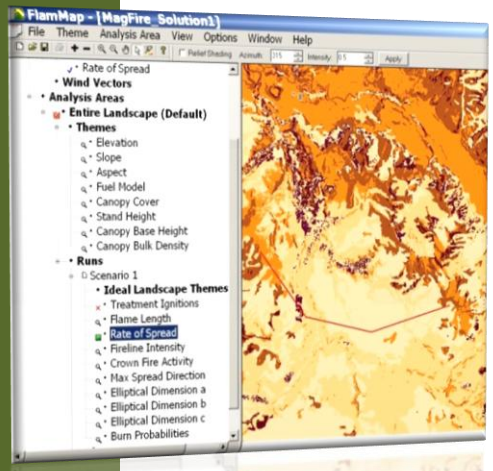


Optimizer for Scheduling Treatments

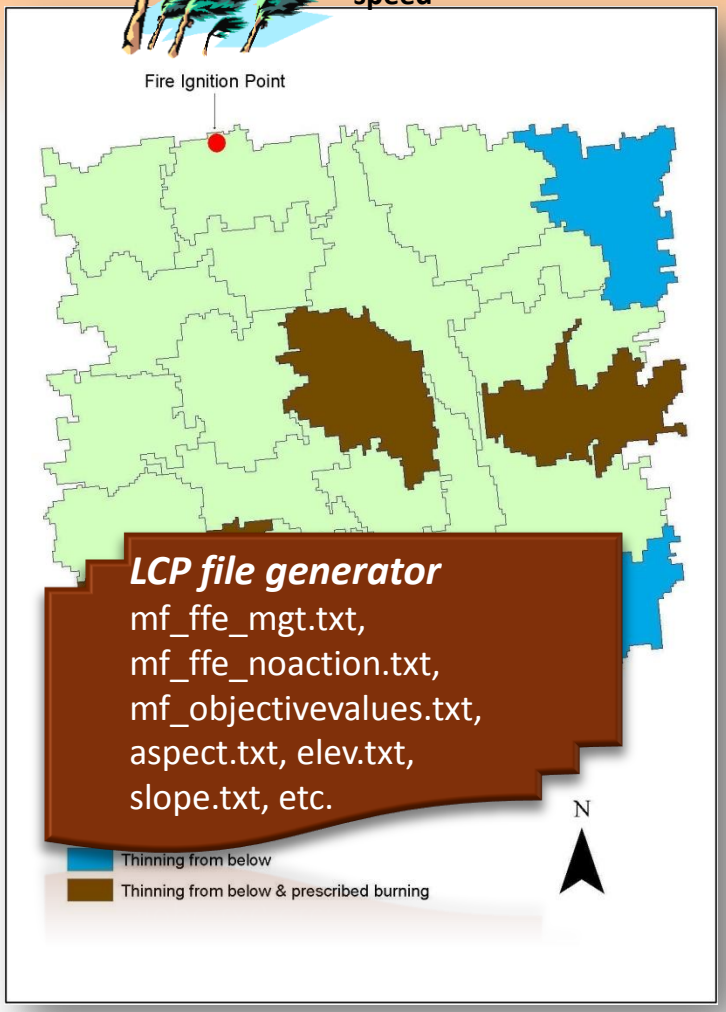
Heuristic Solver

- Evaluating each candidate solution



FlamMap-MTT DLL

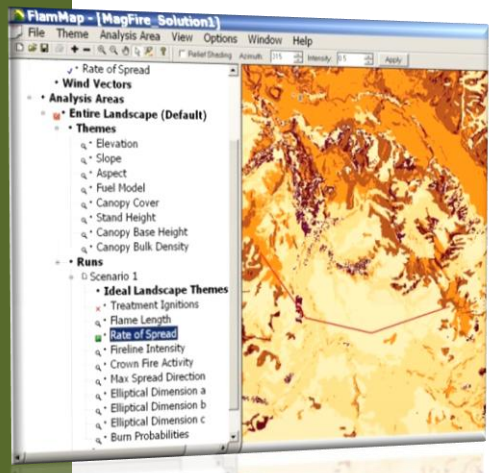
Wind direction & speed



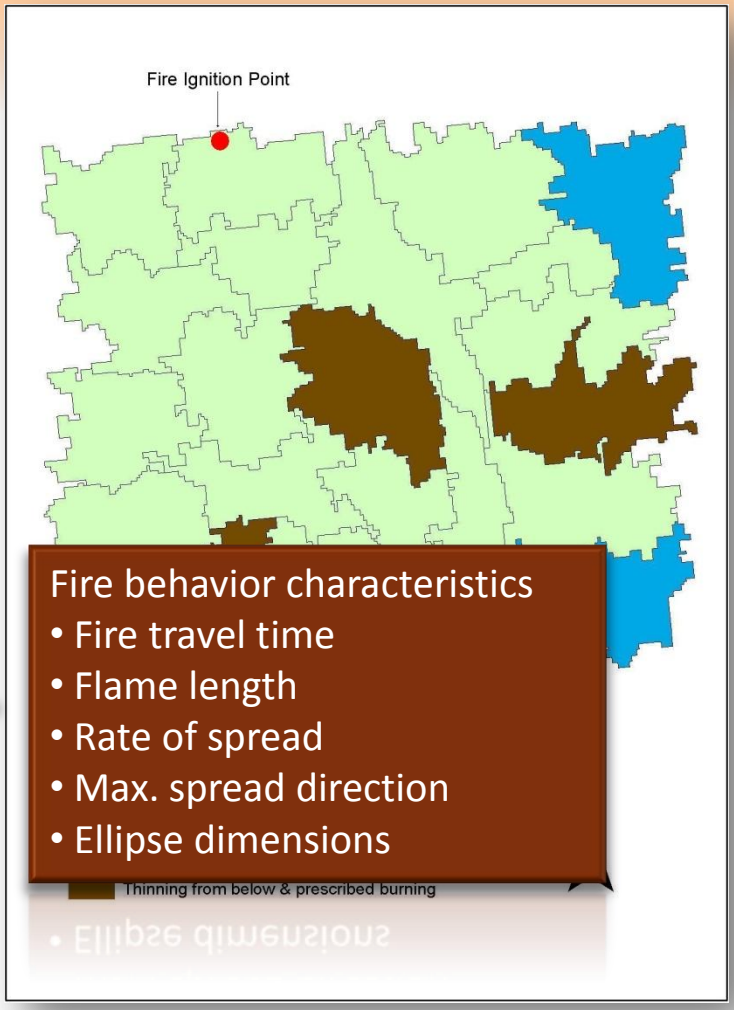
Optimizer for Scheduling Treatments

Heuristic Solver

- Evaluating each candidate solution



FlamMap Outputs



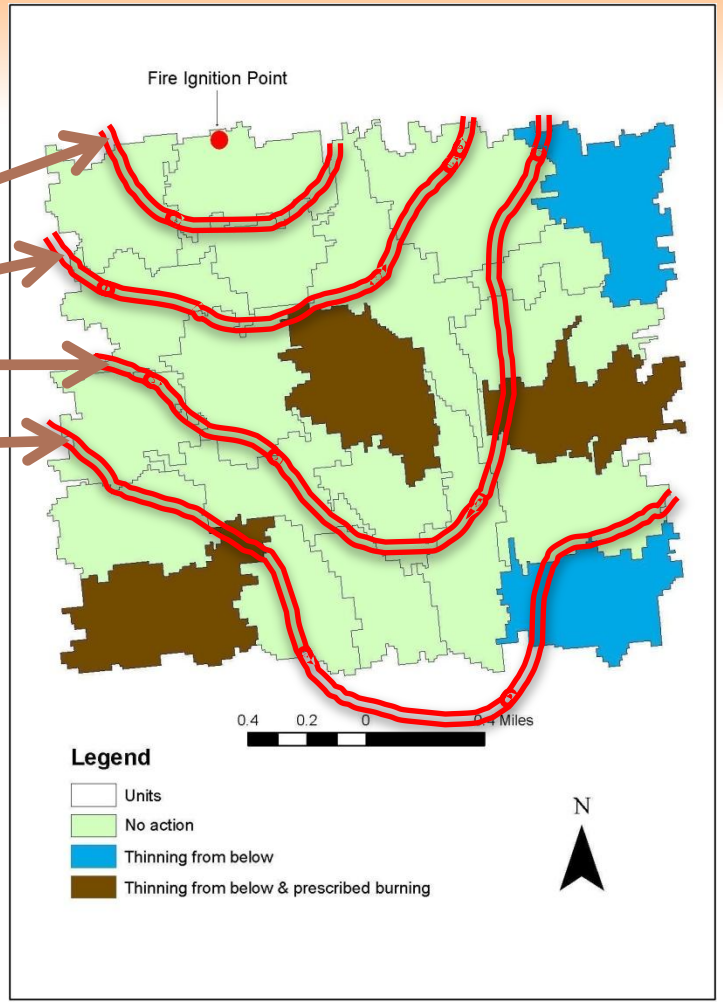
Heuristic Solver

1 day (90%)

2 days (70%)

3 days (50%)

5 days (20%)

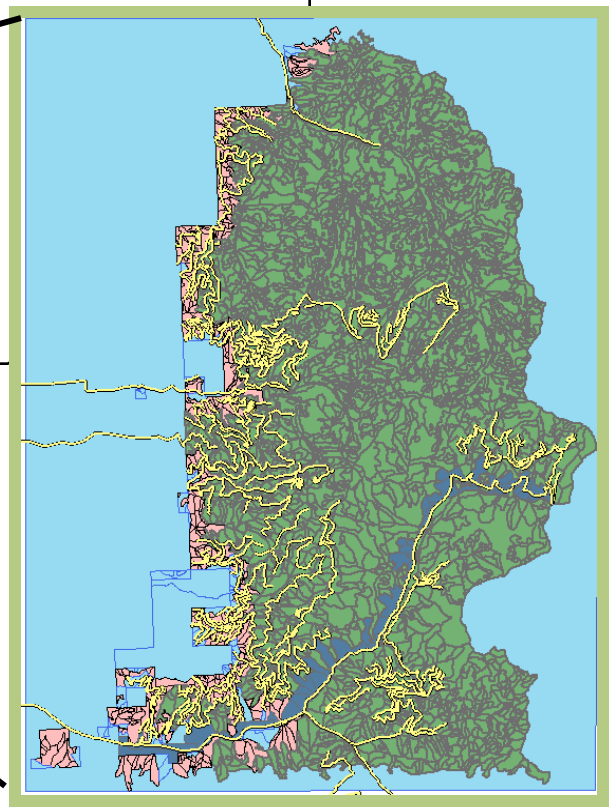


$$\textit{Minimize} \sum_{t \in T} \sum_{c \in C} \sum_{f \in F} Loss_{f,c,t} \times Y_{f,c,t} \times P_{c,t}$$

Application

Montana

Bitterroot National Forest



Willow-Gird analysis area

Application

Study area

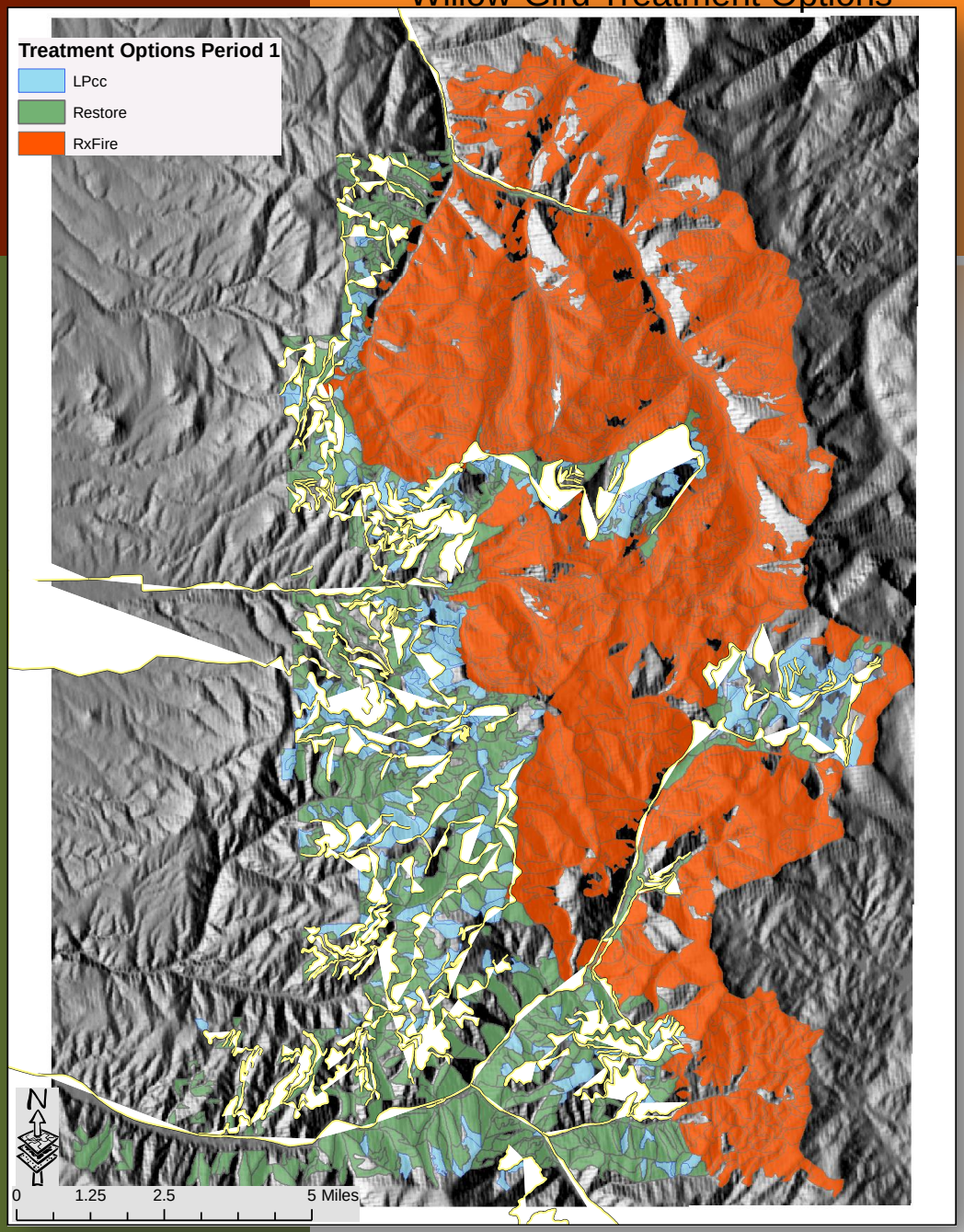
Types	Acres
FS, roadless	52,744
FS, accessible	30,939
FS, WUI	9,817
Right-of-way	3,830
State & Private	6,358
TOTAL	103,688

Relative Loss Values ($Loss_{f,c,t}$)

	Low	Med.	High	Very High
FS, roadless	0	10	20	30
FS, accessible	0	60	70	80
FS, WUI	50	150	250	400
Right-of-way	0	0	800	800
State and private	10	30	50	80

Application

Willow-Gird Treatment Options



Treatments

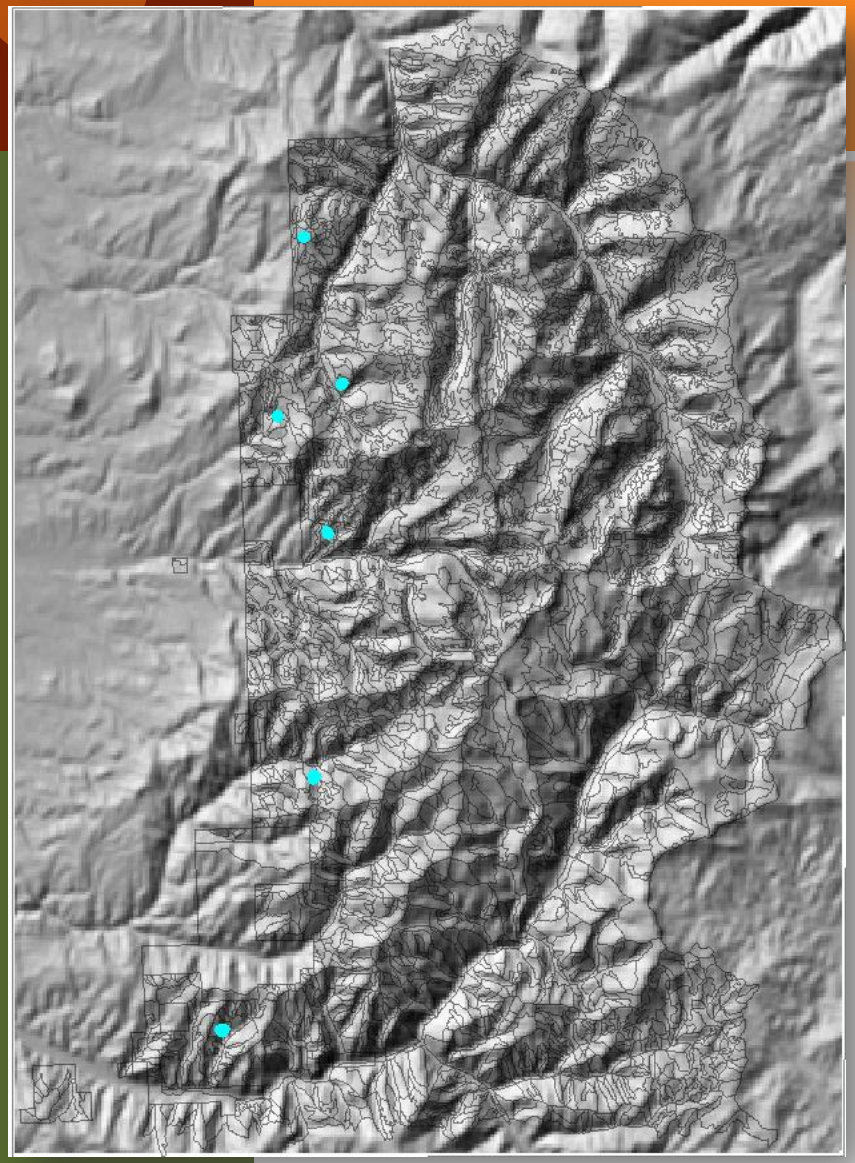
Types	Polygons
LP Clear Cut	309
PP, DF Restoration	807
Prescribed Fire	1319
No action only	775
TOTAL	3,210

Two time periods with a 10 year interval

Two management scenarios

- Scenario#1: Treat up to 10% of the total area in each period
- Scenario#2: Treat up to 20% and 15% of the total area in the first and second periods, respectively

Application



- Fire Scenario
  - Wind speed: 15 MPH
  - Wind direction: 270°

Burn Probability ($P_{c,t}$)

Time step	Probability
1 day	0.9
2 days	0.7
3 days	0.5
4 days	0.3
5 days	0.2
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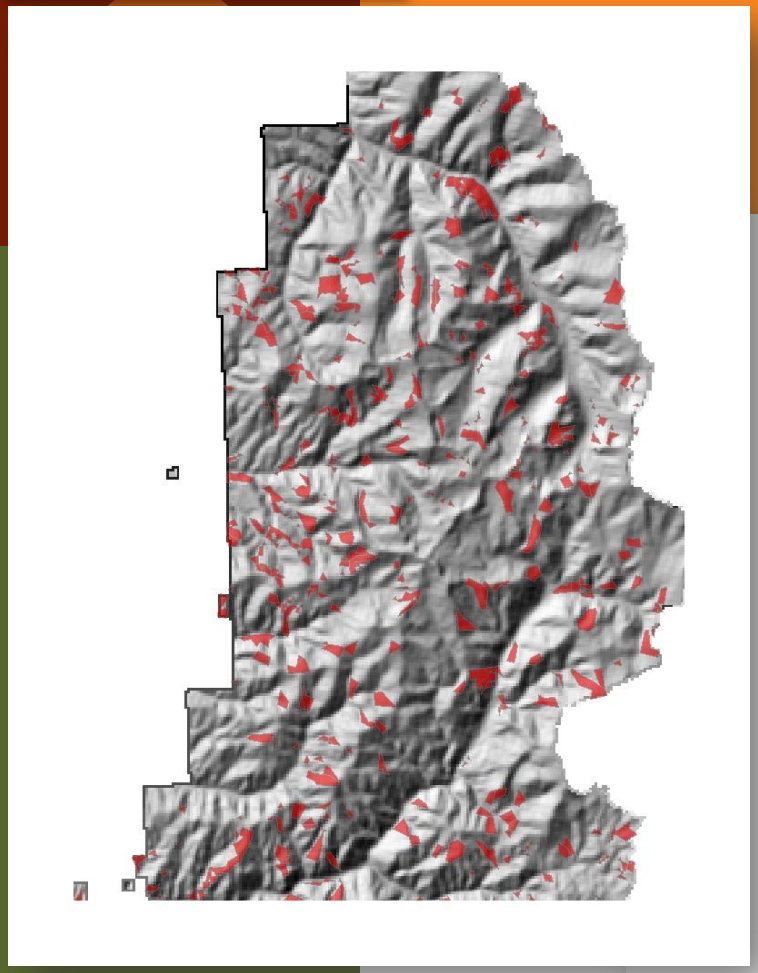
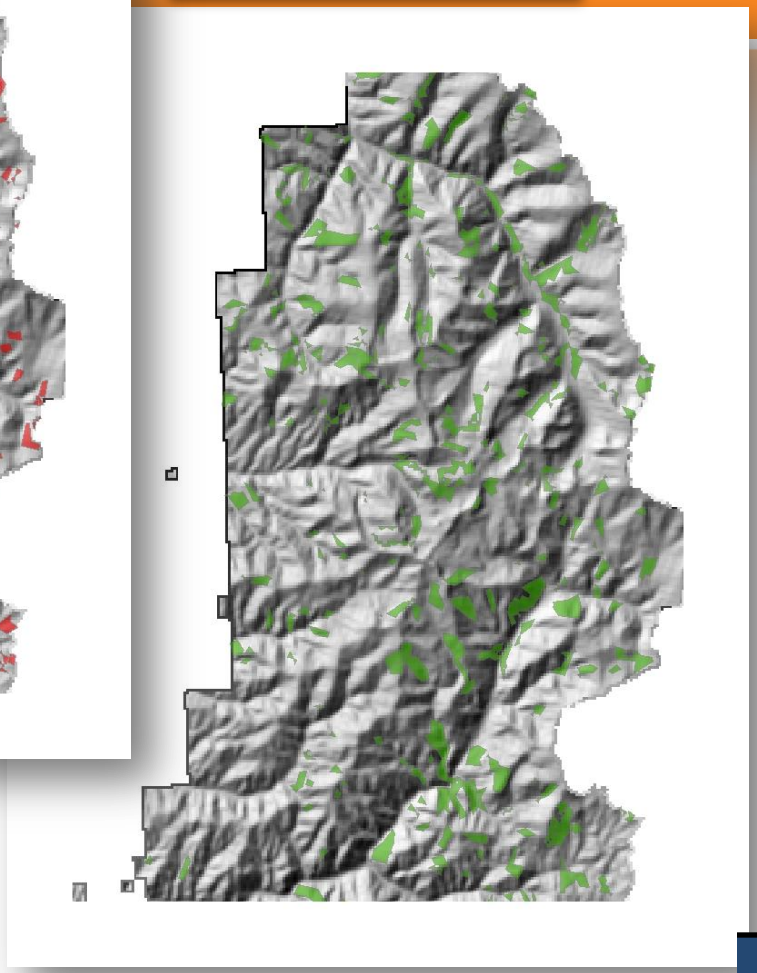
9 days	0.0
10 days	0.0

Application

Scenario #1 – 1st period



Scenario #1 – 2nd period

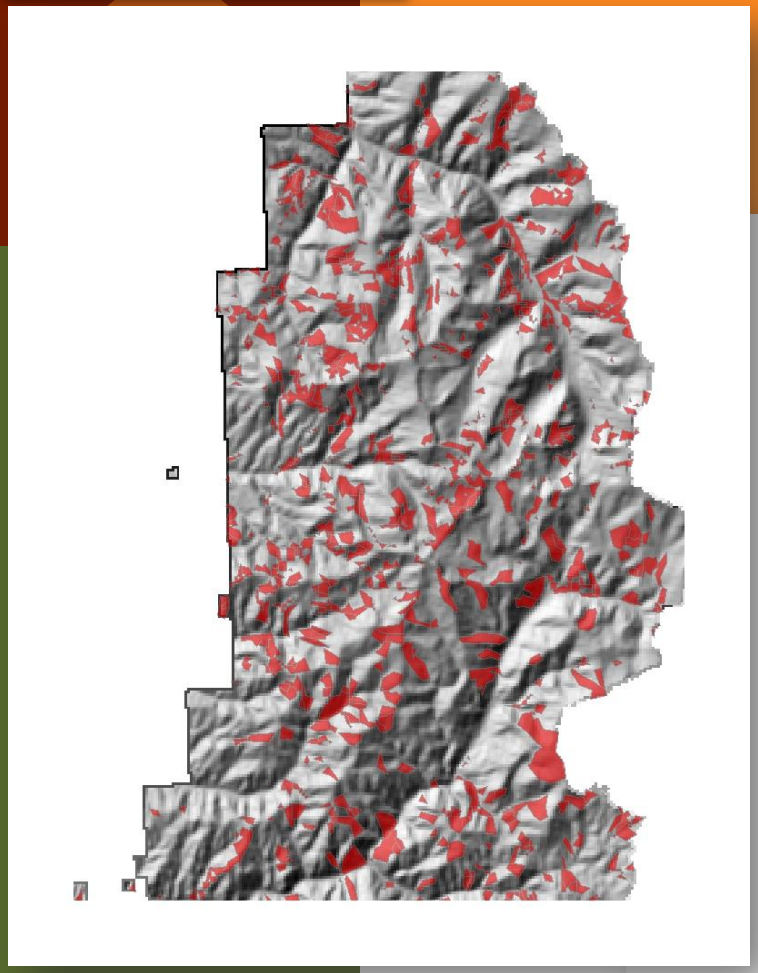


Upper limit: 10% of total area

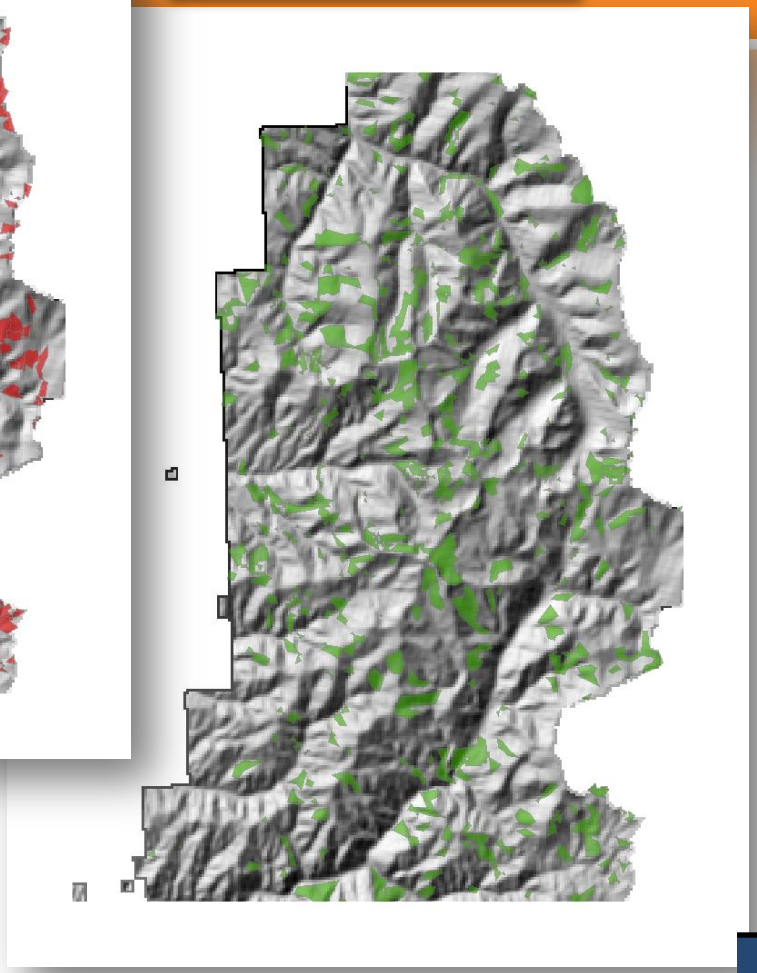
Period	Acres	Polygons
1	9,968	371
2	9,822	307

Application

Scenario #2 – 1st period



Scenario #2 – 2nd period



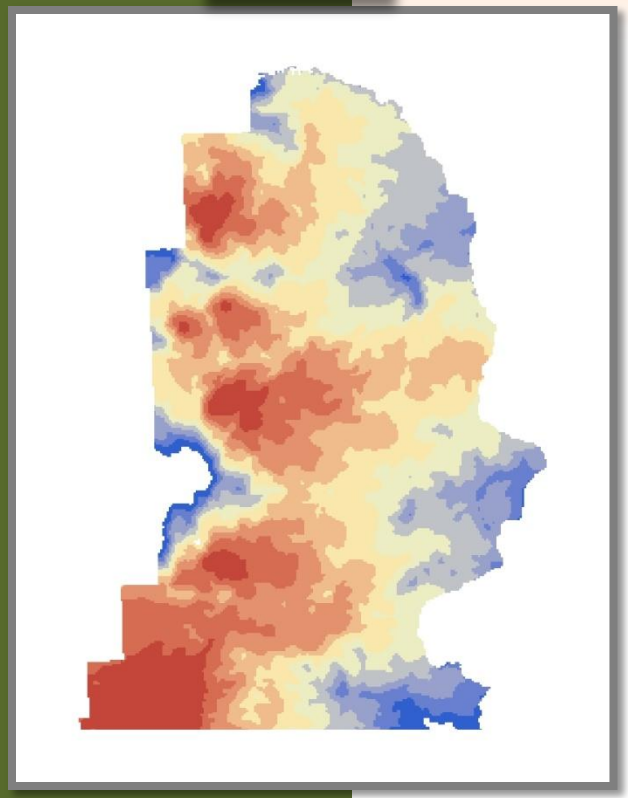
Upper limit: 20% and 15 % of total area

Period	Acres	Polygons
1	19,970	639
2	14,384	508

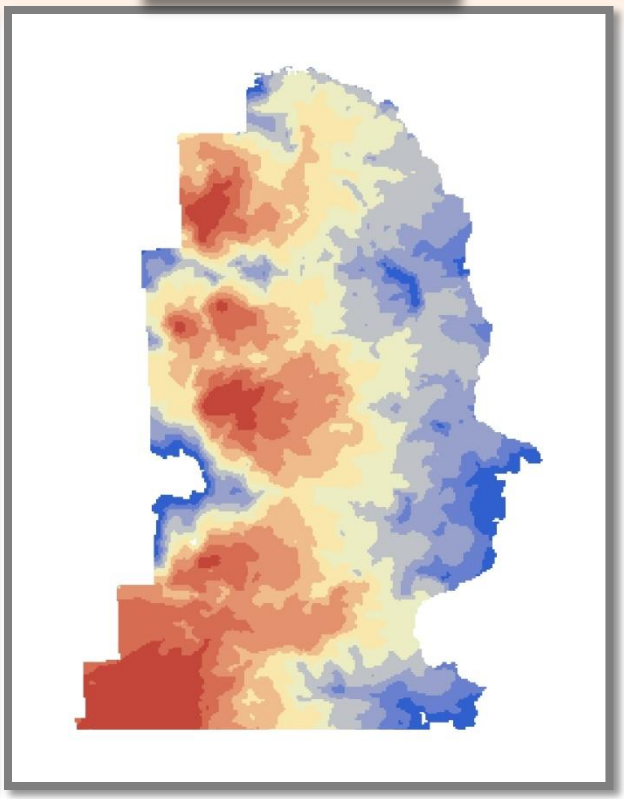
Application

1st Period

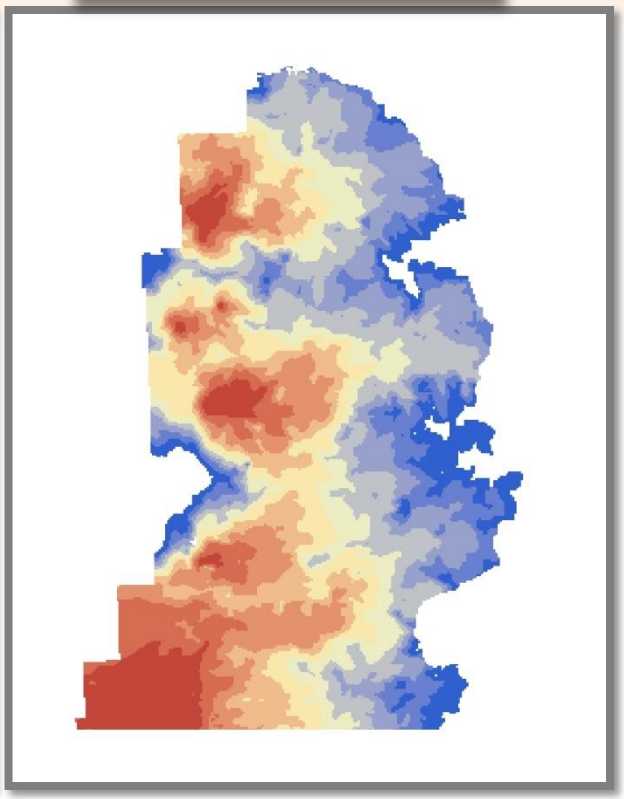
No action



Scenario #1 (10%)



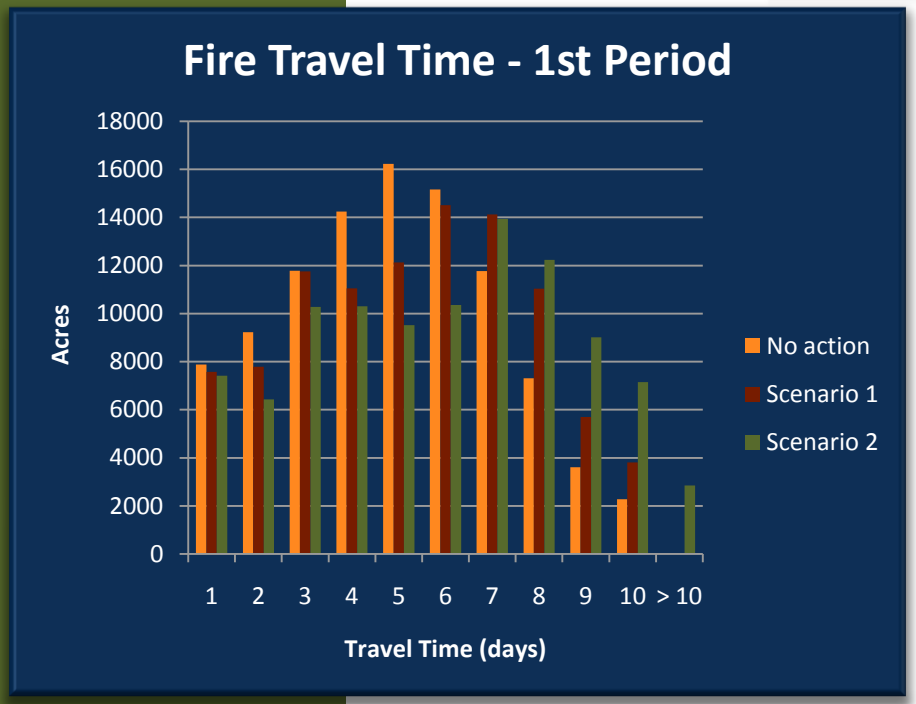
Scenario #2 (20 and 15%)

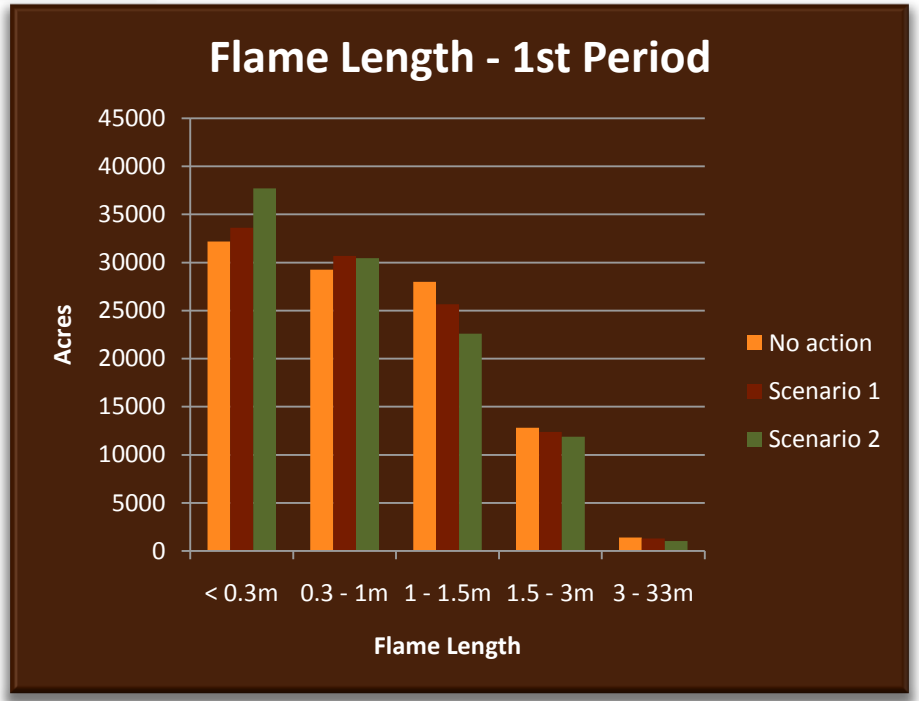


Fire Travel Time (days)

Application

1st Period

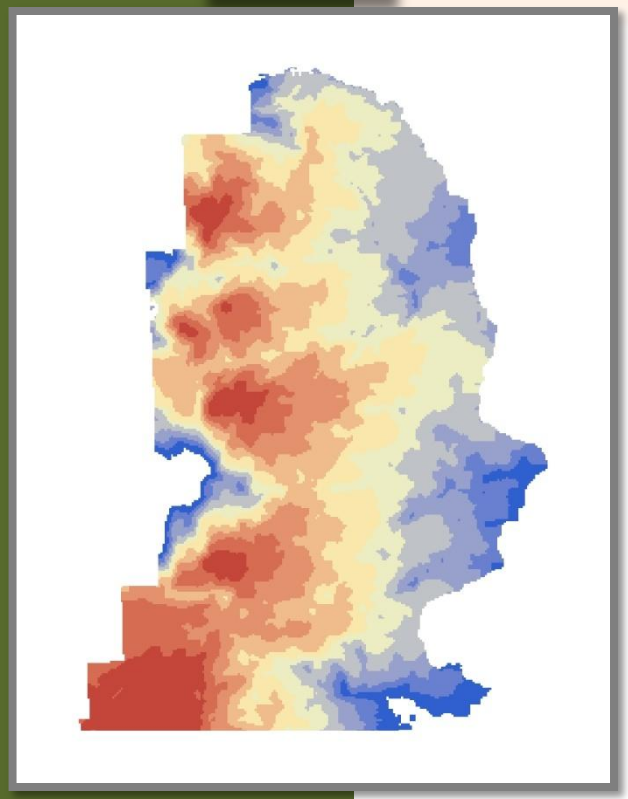




Application

2nd Period

No action



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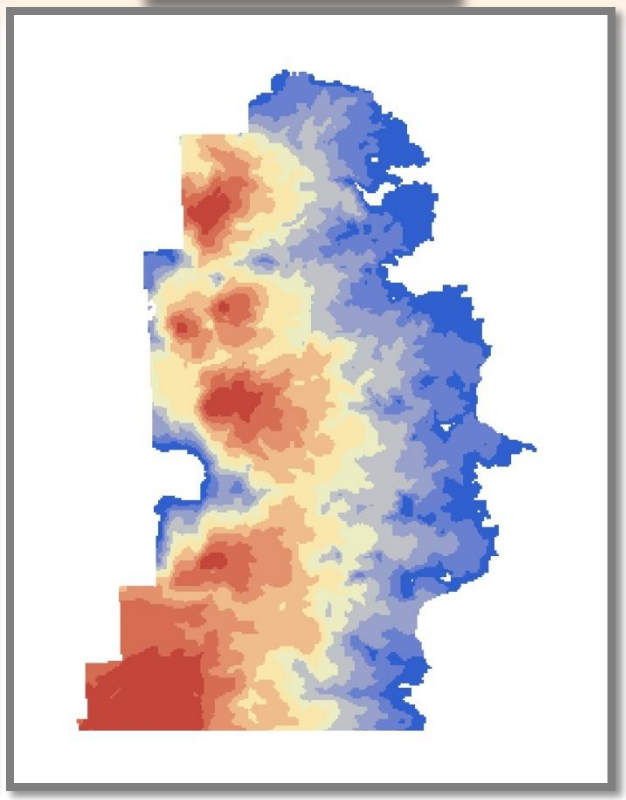
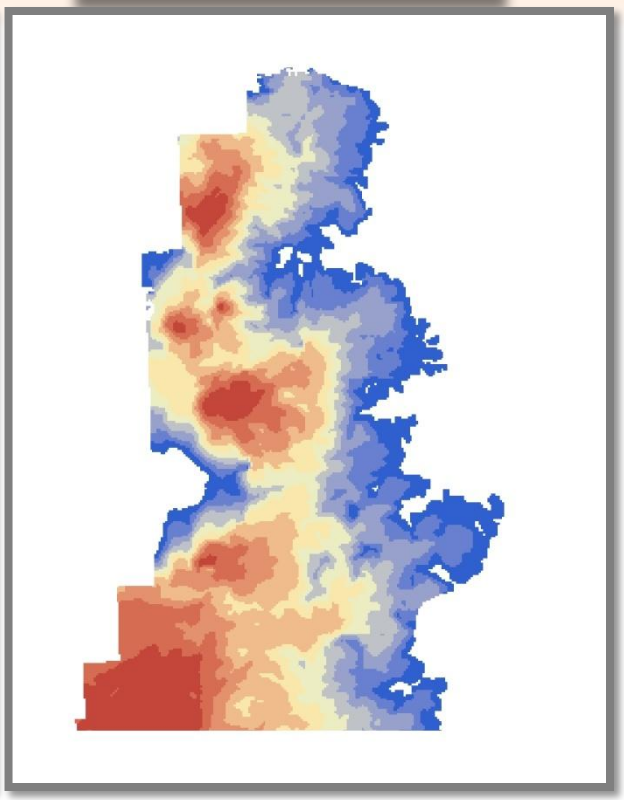


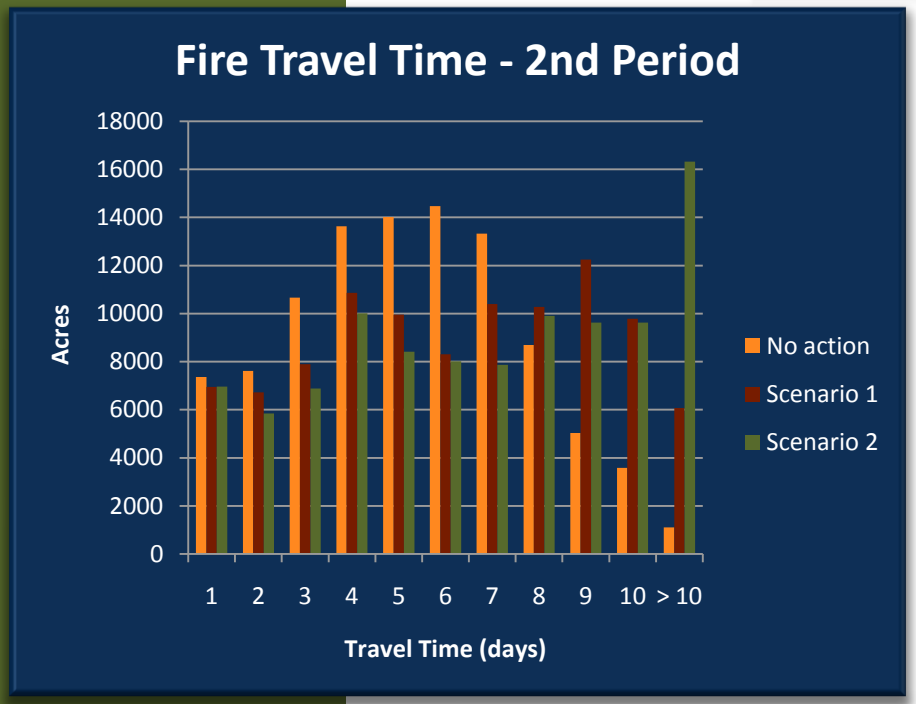
Scenario #2 (20 and 15%)

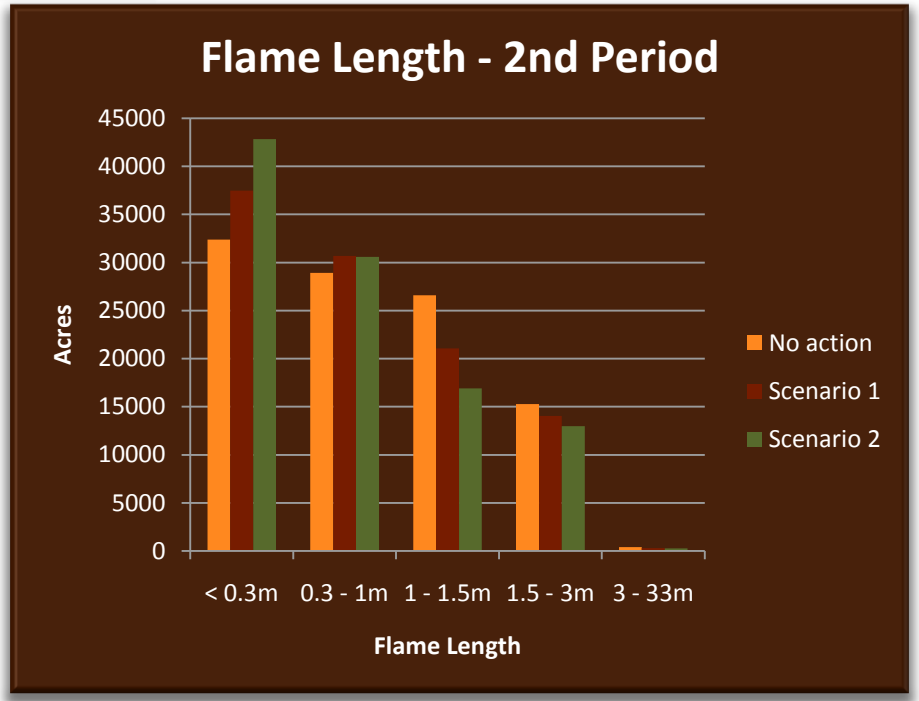


Fire Travel Time (days)

Application

2nd Period





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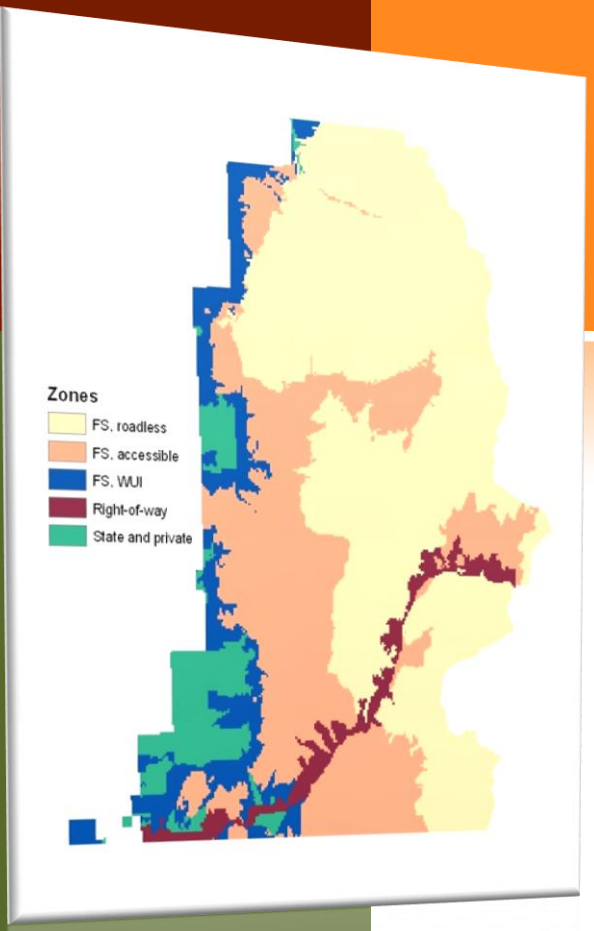
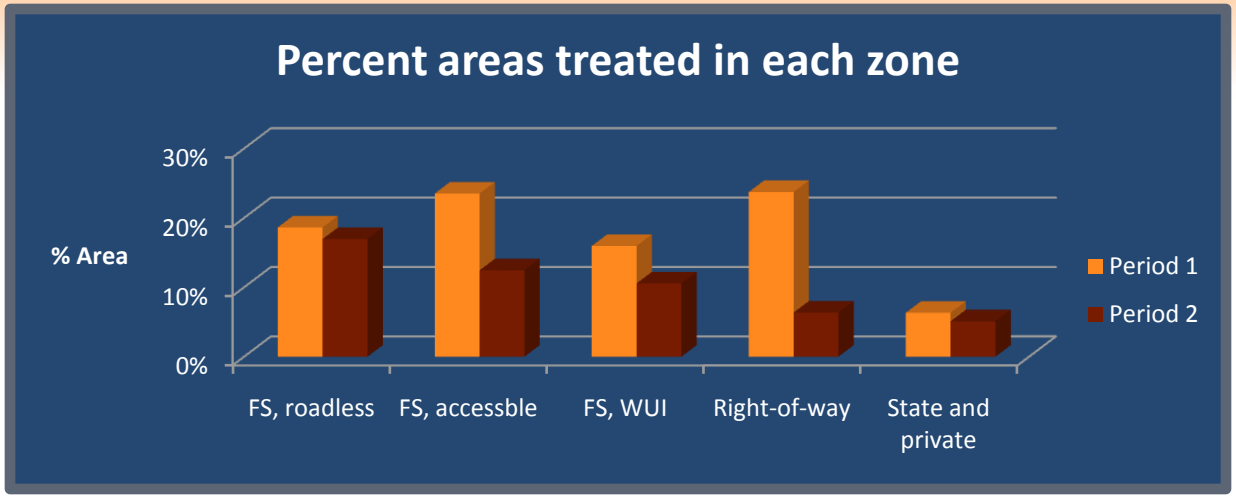
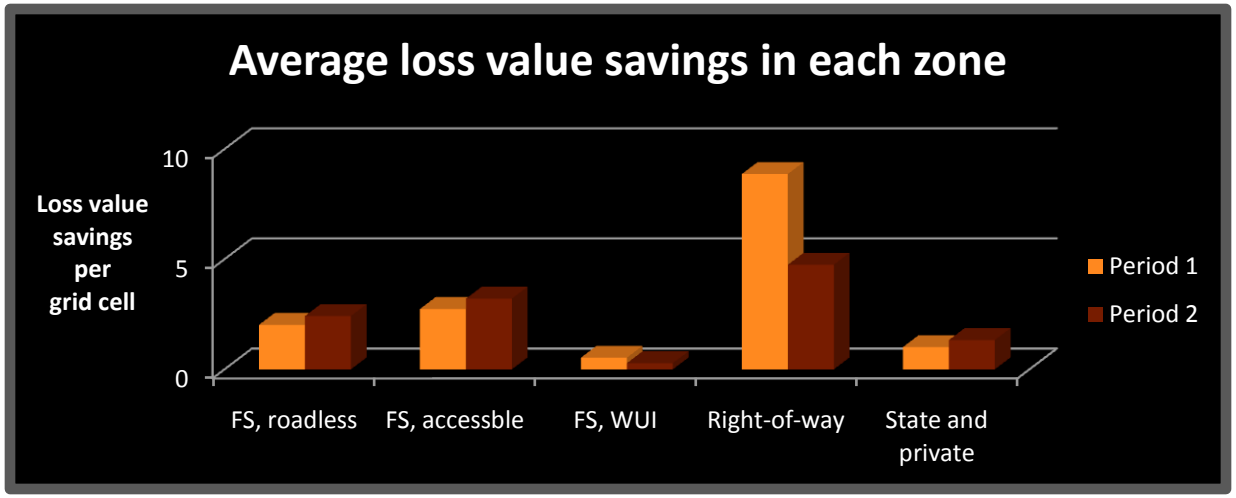






	Lo	Me	Hi
FS, roadless	0	10	20
FS, accessible	0	60	70
FS, WUI	50	150	250
Right-of-way	0	0	800
State	10	30	50

Concluding Remarks

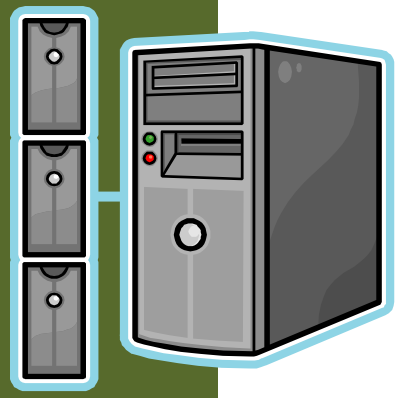
- Development of data transfer interfaces among the OptFuels, FVS-FFE, FlamMap models and the heuristic solver has been completed.
- Extensive testing of the system and applications development have been in progress.

Concluding Remarks

- Highlights of OptFuels
  - Management objective: minimize expected loss value across a landscape
  - Temporal – FVS-FFE
  - Spatial – GIS
  - Constraints – budget, treatment zones, access
  - Work with management units
- Upon completion of the system, OptFuels can be useful for developing fuel treatment schedules that are cost-efficient and practically feasible

Concluding Remarks

- Challenges
  - Lack of spatial data for individual polygons
  - Considerable computation time required
    - OpenMP – multi-processing programming in C
    - Genetic Algorithm
    - Other techniques for solution development
      - Group treatment units
      - Prioritize treatment locations
      - Select treatment units located on major fire paths



Acknowledgement

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- Collaborators
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