Assessing the Impacts of Drought and Wildfire on the Colorado Front Range

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1 Background

In recent years, the size, frequency, and severity of wildfires have increased dramatically across the drought-prone Western U.S.

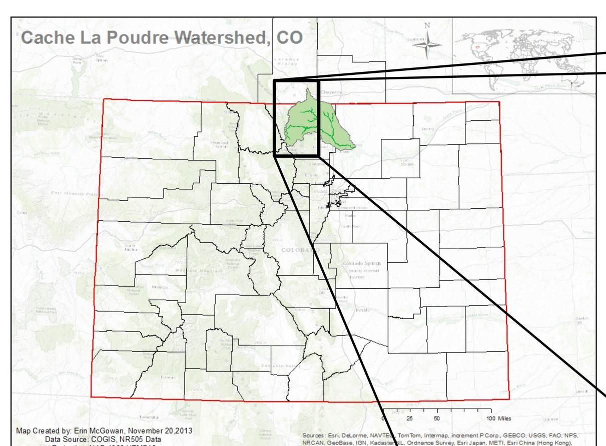
•Wildfires have been shown to increase basin sedimentation rates by 25 times or more, damaging vital water resources infrastructure.

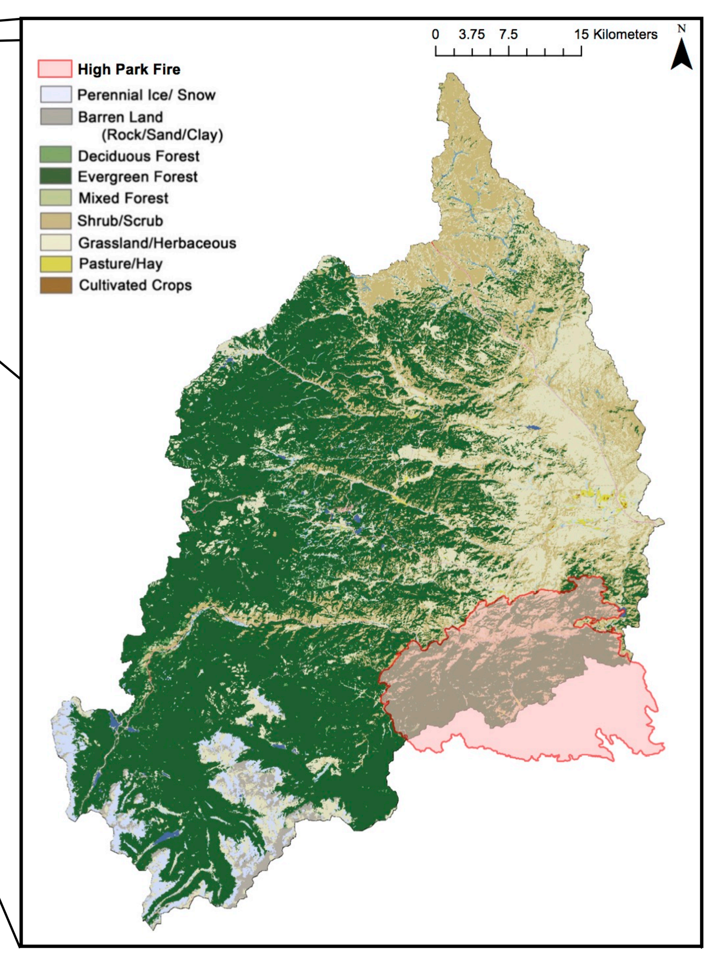
•Many previous studies document wildfire disturbance at either the hillslope or contiental scales, and thus overlook the interaction of local-scale processes across entire watersheds following a fire.

•Previous modeling attempts have often been poorly constrained by ground observations and do not accurately quantify alterations to parameters such as soil erodibility, overland flow depth, and mobilization from the post-fire ash layer.

We simulate wildfire using a high-resolution (30-m or finer) hydrologic model by altering soil and land cover data informed by experimental results obtained from testing field samples. We construct meteorological forcing data from spatially interpolated ground-based observations to produce a first-of-its-kind streamflow and erosional response prediction tool.

2 Study Domain and Data





- **The Cache La Poudre (CLP) Basin is located near Ft. Collins, Colorado.**
- **This was the site of the High Park Wildfire in June 2012, which burned over 87,000 acres of land and destroyed 259 buildings.**

Figure 1.

Fig. 1: The Cache La Poudre basin in Colorado and Wyoming, the site of the historic 2012 High Park Wildfire in June 2012.

3 Pilot Study – Erosion Algorithm Ensemble

This work builds on a study (Stewart, et al. 2017) performed in the same area that evaluated the performance of sediment models under a physically-based framework.

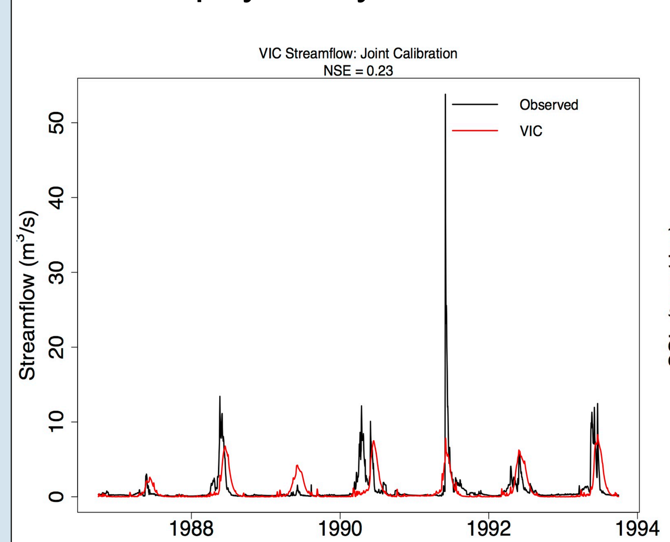


Figure 2.

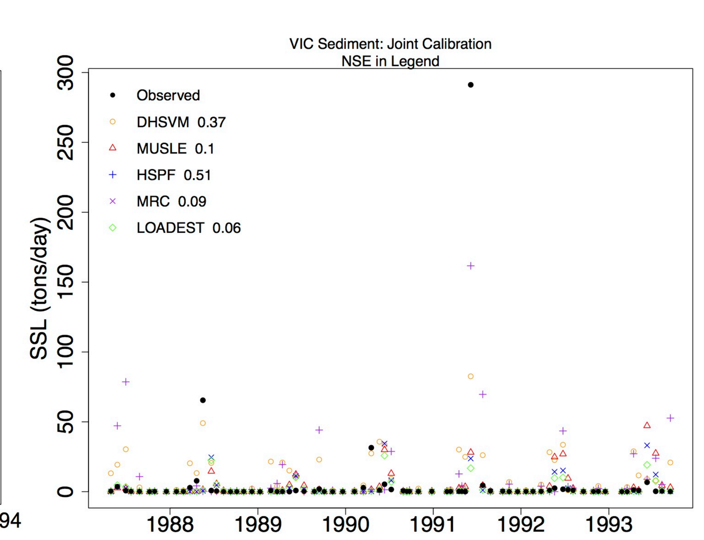


Figure 3.

Five separate hillslope algorithms were implemented in VIC and compared to observational data obtained in the basin.

Fig. 2: Comparison of modeled streamflow against observed streamflow. Fig. 3: Comparison of suspended sediment loading (SSL) response from 5 hillslope erosion algorithms implemented in VIC to observed SSL.

Key scientific questions of this study:

•How can wildfire disturbance be simulated and used to predict and prepare for streamflow and erosional effects that occur immediately following an event?

•How much improvement is seen in modeling accuracy by capturing local-scale processes constrained by remotely sensed and in-situ ground observations?

•In a drying West, what effects will future drought events have on the security and availability of water resources?

4 Variable Infiltration Capacity (VIC) Model Overview

The Variable Infiltration Capacity Model is a mesoscale semi-distributed hydrologic model.

- It operates on a 6km x 6km grid resolution.
- It is upgraded with an ensemble of 5 hillslope erosion algorithms.

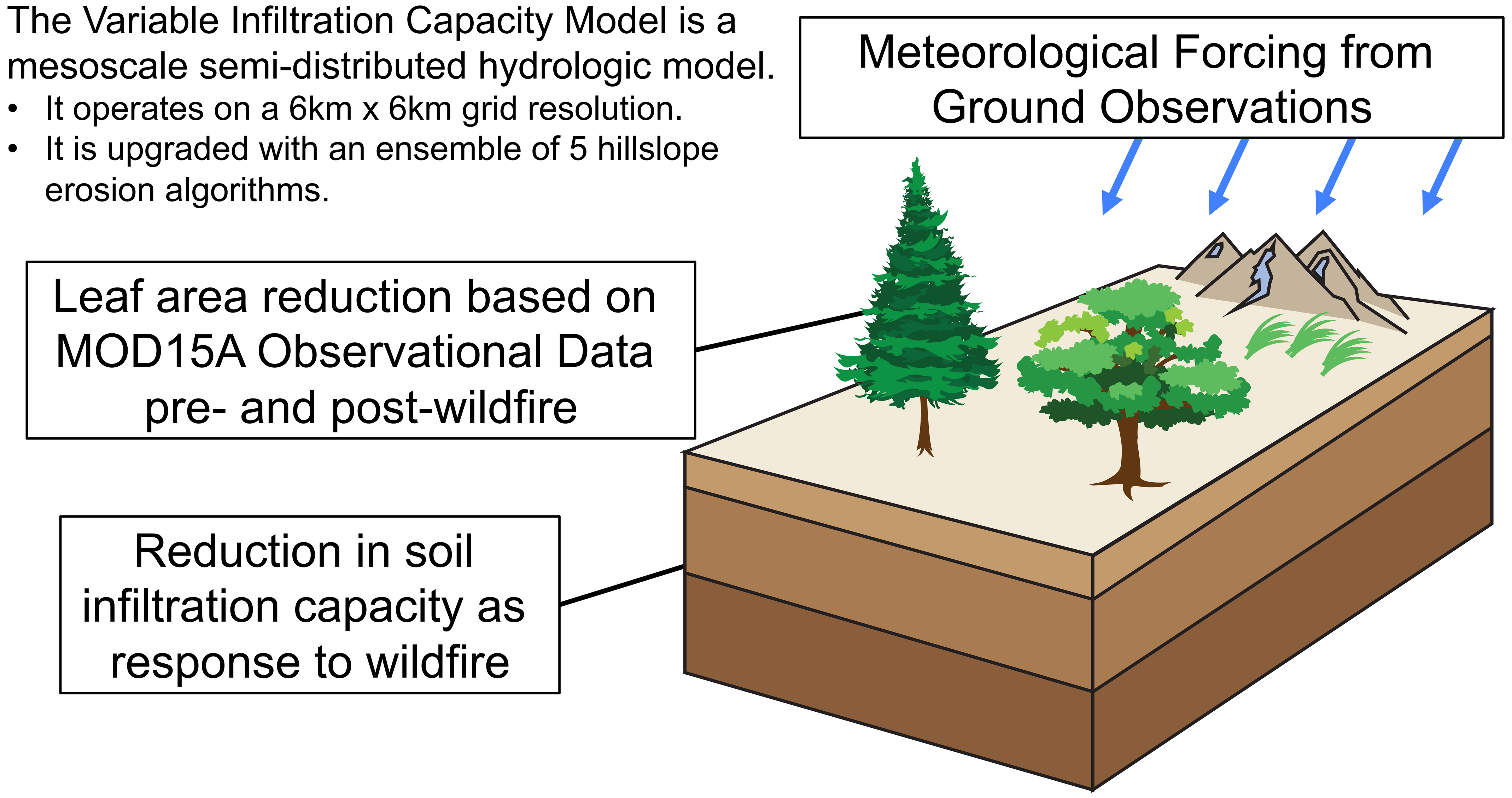
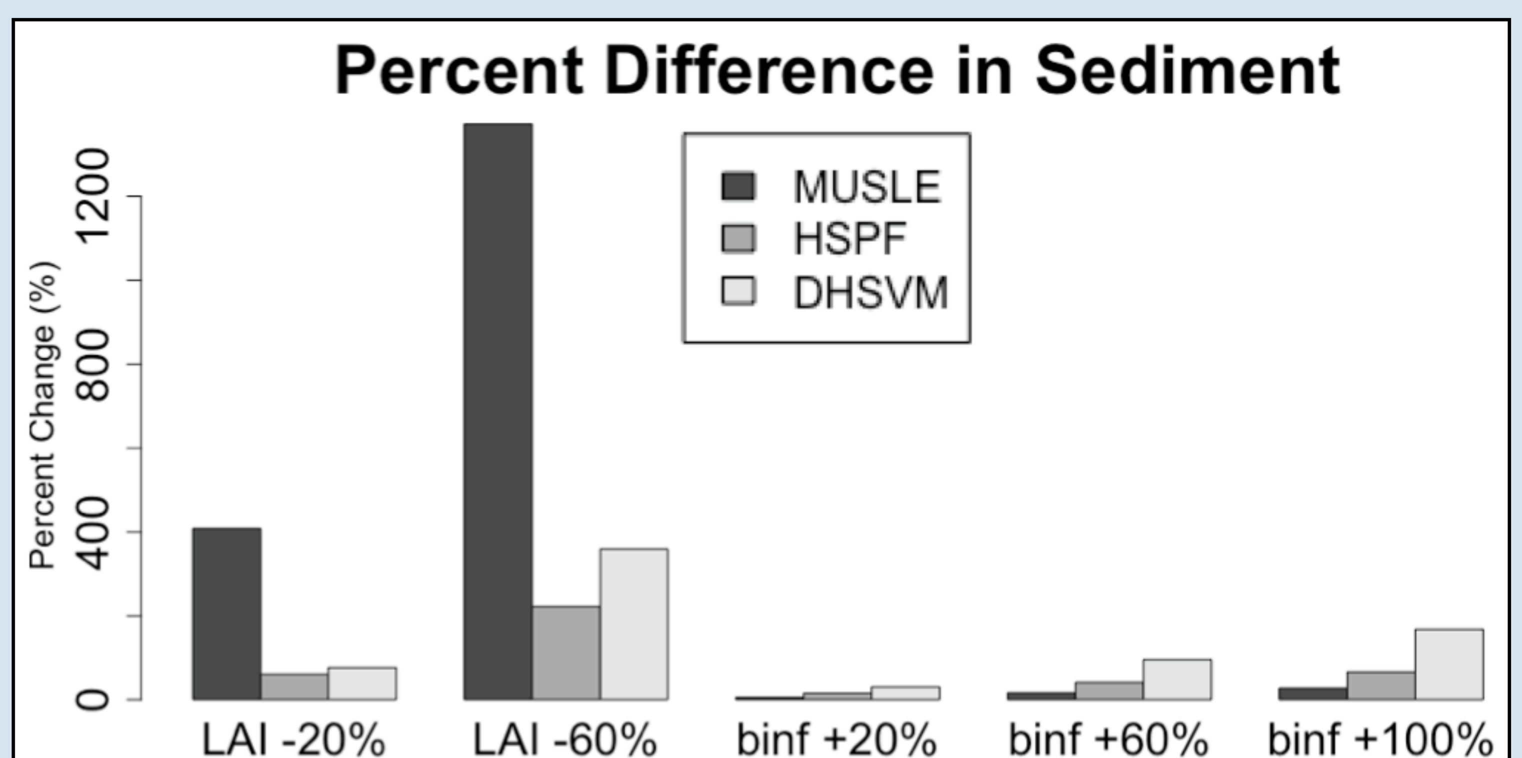


Fig. 4: Variable Infiltration Capacity Model Typical Cell Schematic.

5 Preliminary Sensitivity Analysis

An initial sensitivity analysis was conducted by varying Leaf Area Index (LAI) and the Variable Infltration Curve parameter, binf (which affects the ratio of runoff in the model) by a set of arbitrary percentages. These results are shown in Figure 4 below.



	LAI -20%	LAI -60%	binf +20%	binf +60%	binf +100%
MUSLE	408	1371	5	16	27
HSPF	61	222	15	40	66
DHSVM	77	359	30	96	168

This initial sensitivity analysis shows that:

- Decreasing LAI affects post-fire sedimentation **more strongly** than increasing the curve parameter by the same percentage amount.
- The Modified Universal Soil Loss Equation (MUSLE) is most sensitive to this change.

Fig. 5: Sensitivity analysis of sediment response to adjustments in LAI and the variable capacity curve parameter, binf. LAI creates a relatively large increase in model sediment response as it is decreased.

6 Next Steps

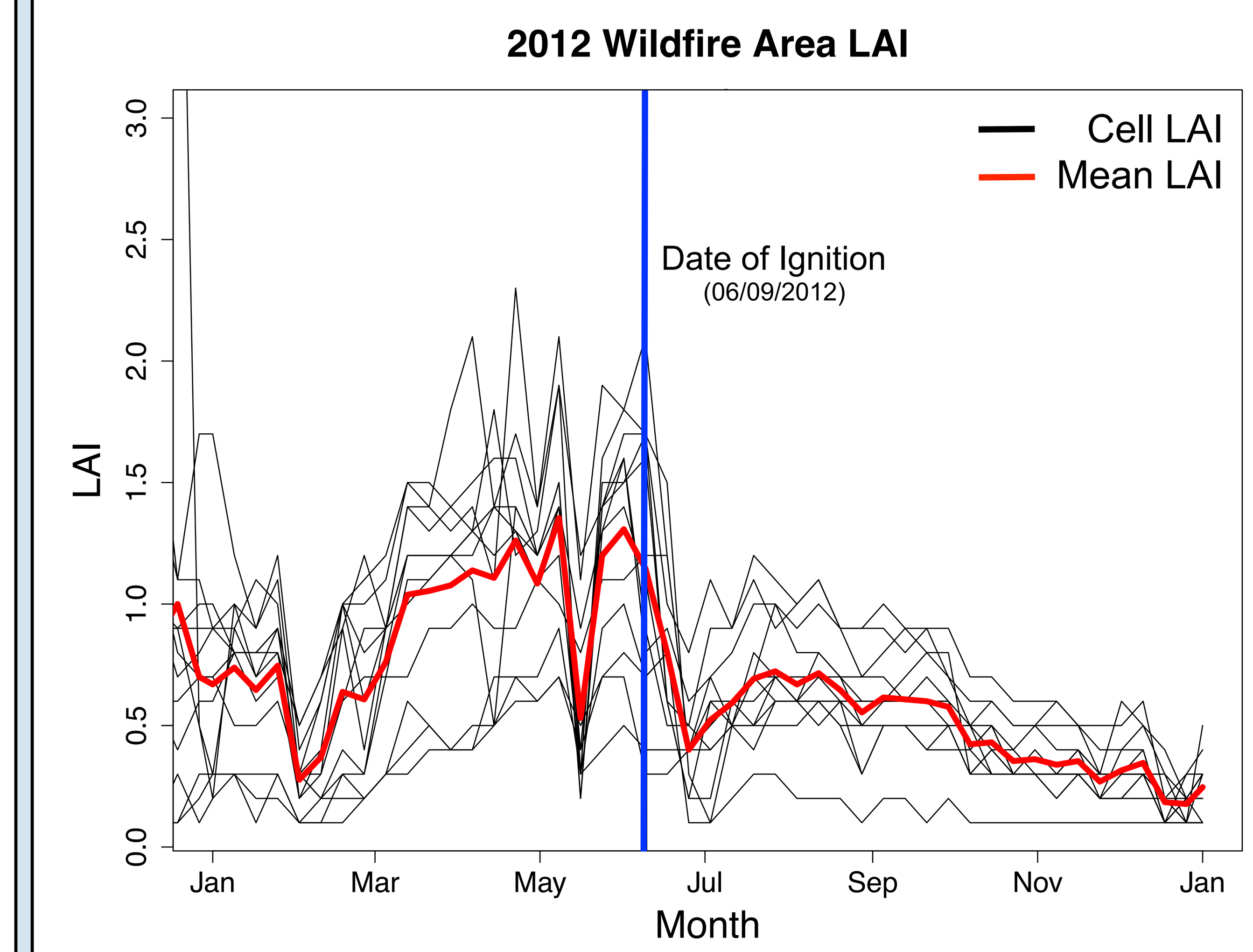


Fig. 6: MODIS-produced LAI for the wildfire extent area in 2012. The red line is the average of all grid cells, represented in black.

MODIS LAI data for the burned area from 2000-2017 were analyzed. Pre- and post-wildfire values were compared to obtain a percent reduction in LAI informed by satellite measurements (Figure 5). Results show:

- Immediate pre-fire LAI (from data obtained 06/01/2012) = **1.31**
- Immediate post-fire LAI (from data obtained 07/03/2012*)= **0.52**

suggesting a reduction in LAI of approximately **60%** due to the wildfire disturbance.

**after containment on 06/30/2012*

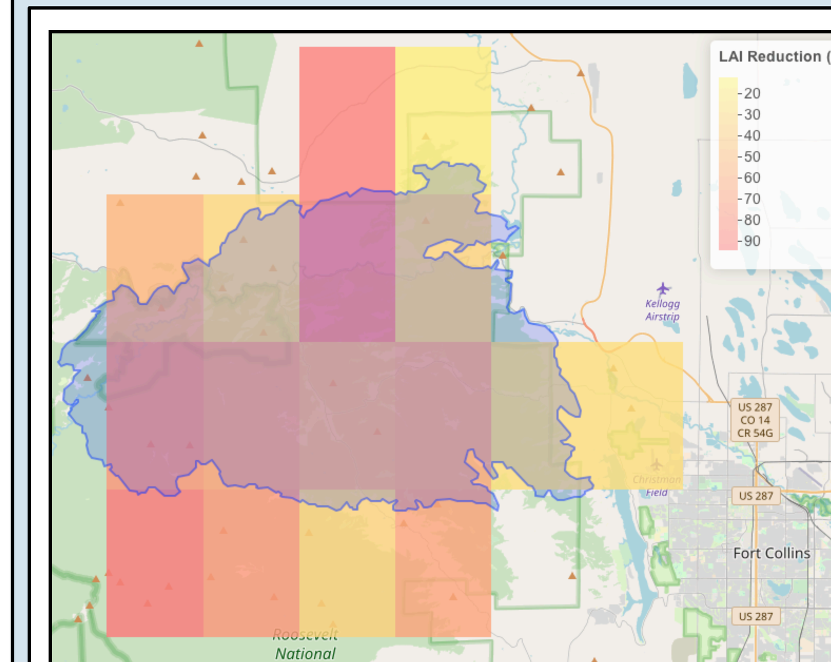


Fig. 7: Reduction in LAI due to High Park Wildfire.

- LAI data will be combined with burn severity information from the fire to develop a relationship between the two.
- This will be reprojected onto the model grid so LAI can be modified uniquely by grid cell.

7 Open Questions

- Does modification of LAI and soil disturbance adequately capture wildfire? Are there other processes that can be incorporated?
- For what wildfires or regions do data for post-wildfire sedimentation exist?

References: Westerling, A.L. et al., Science 313, 940-943 (2006)., Benavides-Solorio, J. & MacDonald, H., Hydrol. Process. 15, 2931-2952 (2001)., Moody, J. & Martin, D., IJWF 18, 96-115 (2009)., Benda, L. et al., Forest Ecology and Management 178, 105-119 (2003)., Cuo, L. et al., Hydrol. Process. 22(21), 4205-4213 (2008).

Acknowledgments: This work is supported by the U.S. Environmental Protection Agency, "National Priorities: Systems-Based Strategies to Improve the Nation's Ability to Plan and Respond to Water Scarcity and Drought Due to Climate Change", Grant No. R835865.