FINAL REPORT: JOINT FIRE SCIENCE PROGRAM: 04.2-1-84

Project Title: Translating SPLATs from a theoretical to a real world landscape: The implications of fuel management strategies for Sagehen Creek Basin, Tahoe National Forest

Project Location: Sagehen Experimental Forest, Tahoe National Forest, near Truckee, California.

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INTRODUCTION

Nearly a century of fire management in the Sierra has had the unintended consequence of placing millions of hectares of forest at risk of catastrophic fire (Biswell 1989, van Wagtendonk 1998). This regional assessment of fire hazard and fuel loads is reflected in the Sierra Nevada Forest Plan Amendment (SNFPA 2004), in which modifying wildland fire behavior is a management priority. An innovative aspect of this plan is an explicit landscape planning approach epitomized by an emphasis on fireshed assessments.

Firesheds are large landscapes (several to many thousands of acres) delineated by fire regime, condition class, fire history, fire hazard, and potential wildland fire behavior. Fireshed assessment is an interdisciplinary and collaborative process to change fuels and vegetation at the landscape scale. Within the context of the Sierra Nevada Forest Plan Amendment, these changes include the strategic placement of treatment (SPLAT) areas across the landscape to interrupt potential wildland fire spread, to reduce the extent and severity of these fires, and to improve the continuity and distribution of old forests across landscapes (Bahro and Barber 2004).

The SPLAT approach is based on the theory (Finney 2001) that disconnected fuel treatment patches that overlap in the direction of the head fire spread reduce the overall rate and intensity of the fire in a forested landscape. Simulations have shown that with as little as 30% of the area in these strategically placed area treatments (i.e., SPLATs), fire risk can be decreased for the entire landscape. Despite the sound conceptual underpinning of landscape planning with strategic fuel treatments, there is uncertainty regarding their efficacy in modifying fire behavior.

Thus the primary goal of this administrative study was to evaluate SPLAT-based fuel management planning for a specific landscape – Sagehen Creek Basin, TNF (Fig.1). Our approach was to build field-parameterized versions of the fire behavior models, FlamMap and FARSITE, and then use them to construct and to test alternative SPLAT designs. We built these models in an iterative fashion allowing for an exchange of expertise and shared learning between the UC Berkeley team and the USFS Truckee Ranger District interdisciplinary team. Our hope is that the specific lessons learned during this intensive study of one landscape will help guide planning for other management units in the Tahoe National Forest and other forest in the Sierra Nevada.

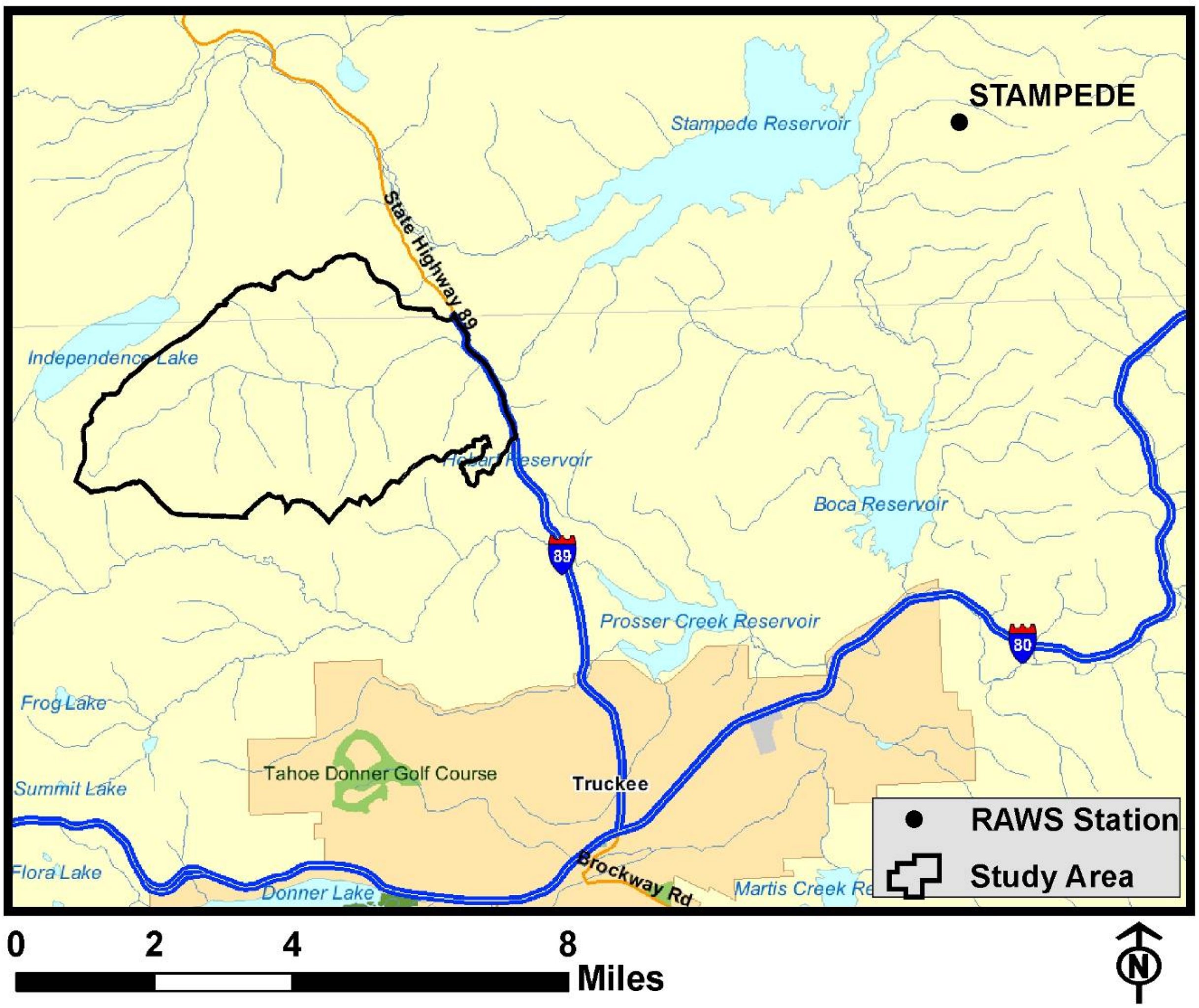

Figure 1. Location of Sagehen Creek Basin, Tahoe National Forest. The project area is approximately 8,000 acres in area. It includes the UC Berkeley Sagehen Creek Field Station. For more information, go to http://sagehen.ucnrs.org/.

METHODS

We relied on fire simulation models (FlamMap/FARSITE) to evaluate the performance of SPLATs in modifying fire behavior. Thus it was essential to build fire models from the best available data using integration and interpolation approaches that are well-vetted and validated when possible. We used three primary data sources: a remote automated weather station (RAWS) located near Stampede Reservoir (Fig. 1); a nested grid of 523 vegetation and fuel inventory plots (Fig. 2); and results derived from a light detection and ranging (LiDAR) flight of the Basin (Fig. 3). These three data sources were used to develop necessary weather input files and landscape files for the FlamMap/FARSITE models. Our final fire model was the culmination of four major revisions that incorporated feedback and advice from both local (Truckee Ranger District) and regional (Pacific Southwest Region Fireshed Assessment Team) experts.

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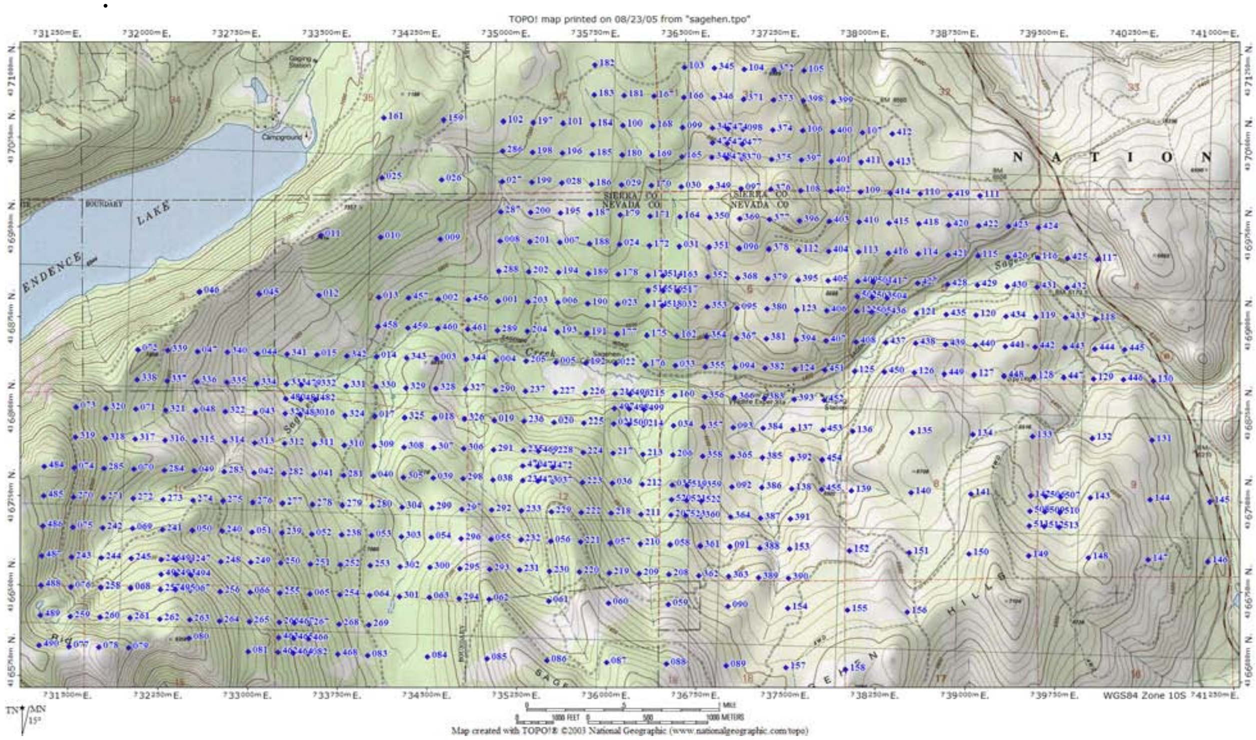

Figure 2. Sagehen plot network. Coarse grid is 500 by 500 m. Outside of plantations, grid is densified to 250 m by 250 m. Nine stands that span the range of forest types in the Basin were sampled with a square grid of 9 plots spaced 125 by 125 m.

We summarized results from our vegetation and fuel plots to provide a spatially-explicit grid of key features. For example, we used tree composition to classify each plot into 11 different vegetation types. Surface fuel loads were summed by size class; herb and shrub cover along with ladder fuel continuity was quantitatively evaluated. This information was used to assign a standard fire behavior fuel model to each plot. Fuel model assignments were extensively revised and vetted based on the input from many experts including fire scientists in the Stephens Lab at Berkeley and USFS fuel officers from Truckee Ranger District, Tahoe National Forest, and the Pacific Southwest Region. Important canopy metrics were derived for each plot based individual tree measurements. These included the determination canopy-sized trees, the height of the canopy, the base of the live tree crown, and crown bulk density. In addition, detailed plot-level assessments of canopy cover were conducted down in a subset of plots to help validate LiDAR-based estimates.

LiDAR remote sensing provided spatially precise and accurate realizations of core topographic information – elevation, slope, and aspect -- that directly influence fire behavior. The validity of these topographic products from LiDAR mapping has been well-established over the last decade. In contrast, the extraction of forest parameters specific to fire modeling is a new application of LiDAR. Thus several applications in this project (e.g., canopy cover and vegetation segmentation) are being used for the first time. In these instances, we have relied on our plot data to inform and bound these metrics. In all cases, we have documented the steps involved in data reduction and synthesis.

Throughout the process, we have worked with the Truckee Ranger District in developing this administrative study. We have relied on their local expertise to correct and improve the fire models. Moreover, they have defined the specific fire scenarios to evaluate and the fire behavior measures to report. Midway through the project, we expanded our collaboration to include the regional fireshed assessment team. This expansion greatly improved both the basic and applied value of this project. This collaboration provided us a better understanding of the fireshed planning process and treatment evaluation employed by the Region. We also greatly benefited from the exchange of ideas regarding the integration of data products into fire models.

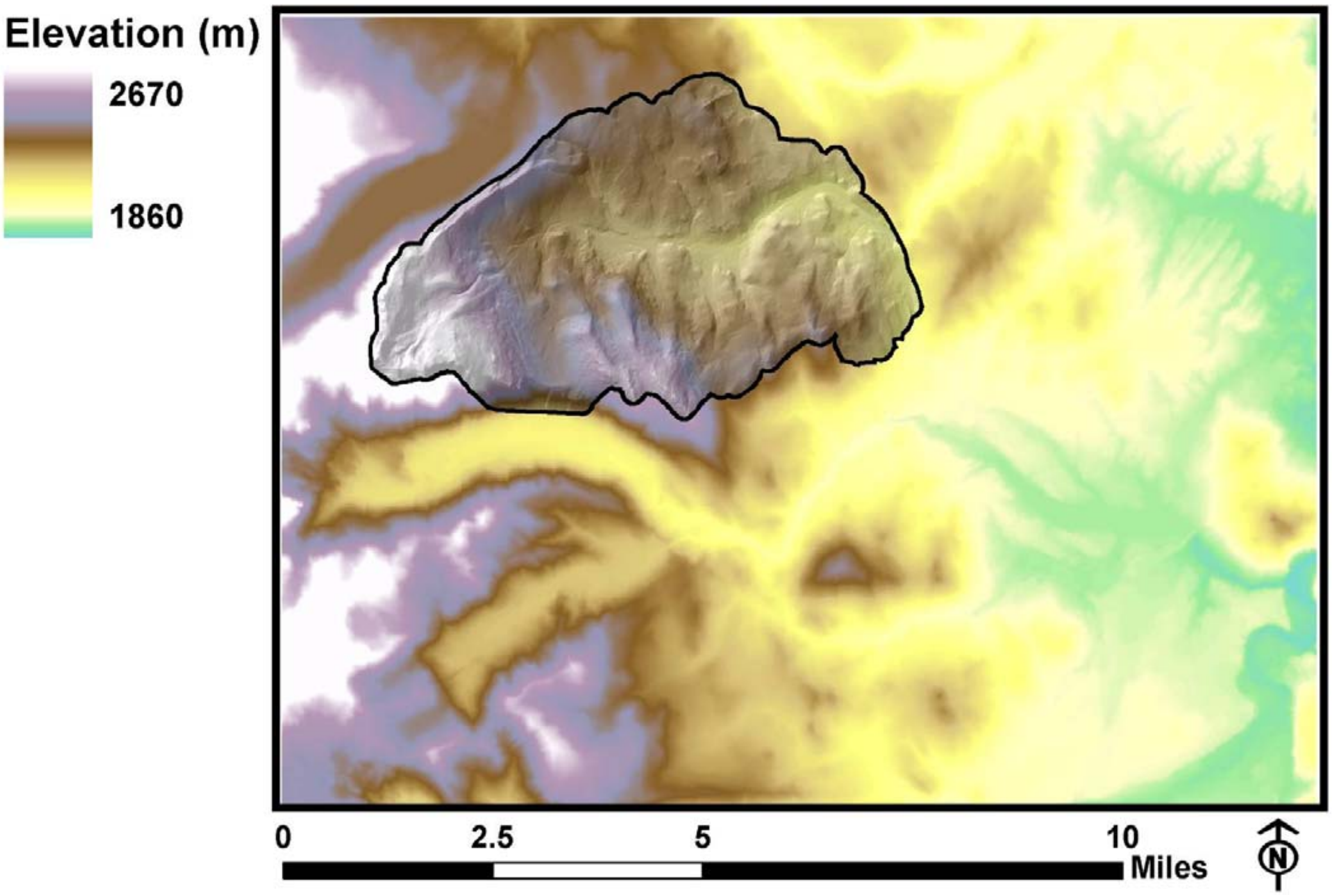

Figure 3. Digital elevation model of Sagehen Creek Basin study area derived from LiDAR (September 2005).

SUMMARY OF FINDINGS TO DATE

“Real-world” SPLAT design seem to work in Sagehen Creek Basin.

Analysis of a preliminary SPLAT design that incorporated many (but not all) of the “real-world” implementation constraints supports the theoretical contention that SPLATs can effectively moderate fire spread rates and fire intensity across the landscape. Extensive FlamMap analysis shows that SPLATs can slow fire spread rates, reduce flame lengths, and decrease crown fire activity. The most compelling evidence to support this contention comes from our “wake analysis” that summarizes the spatial and temporal dimensions of fire spread in the Basin. We reported these results at our February 2007 meeting with the Regional Fuels Planning Team. Model development, FARSITE simulation, and fire wake visualization are summarized in the file: SPLAT_SAGEHEN_WAKES_20070226.ppt.

At the request of the Truckee ID team we developed a wildfire scenario to test the performance of a preliminary SPLAT design. We based our parameterization on the historical Donner Fire where a wildfire started outside the Basin close to Donner Lake and burned for 1.5 days before entering the Basin along its southwest ridge. The fire spread through the Basin on a southwest to northeast trajectory before being contained. We ran the scenario for 95th percentile fire weather conditions.

We compared fire spread rates, flame lengths, and crown fire activity for baseline conditions (no SPLATs) and conditions following implementation of a preliminary “real-world” SPLAT design. We summarized SPLAT performance relative to the current baseline (i.e. current forest structure and fuel loadings). During our initial runs, we realized that diurnal fluctuations in key drivers of fire behavior (temperature, humidity, wind speed) made it difficult to isolate the specific spatial impact of the SPLAT treatments. For example, the effect of treatment understandably varied if the fire reached it at 2 pm or 2 am. Thus in our wake analysis, we ran the fire under constant weather conditions. So while the absolute magnitude of fire parameters are exaggerated the **relative differences** between baseline and SPLATs are meaningful measures of the extent of fire behavior modifications. We termed this a wake analysis because our change detection map show clear areas of slowed fire spread rates in the lee of the SPLATs treatment (Fig. 4).

Planning fuel treatments across a forest landscape is a daunting technical and practical challenge.

One of the primary justifications for this administrative study was to learn how to implement SPLATs as part of a fireshed assessment process. Ultimately any management plan will have to meet all the environmental review standards required by federal law and USFS policies. Thus we had to meet legal standards and public scrutiny for justifying the need for SPLAT treatments, namely demonstrating that SPLATs modify fire behavior and improve forest health. This is a high standard particularly when new research methods are being applied.

USFS Districts commonly have multiple land management objectives versus reducing fire hazards and potential fire behavior. In our case forest health and resiliency are the land management objectives. While reducing potential fire behavior and effects and increasing in the resiliency in forested ecosystems do share some common goals they are not completely similar. Quantitative fire behavior models are available to assist in the fire aspect of this project whereas we currently do not have spatial models of how to increase forest health. The result is some compromise in SPLAT arrangement to accommodate the other objectives.

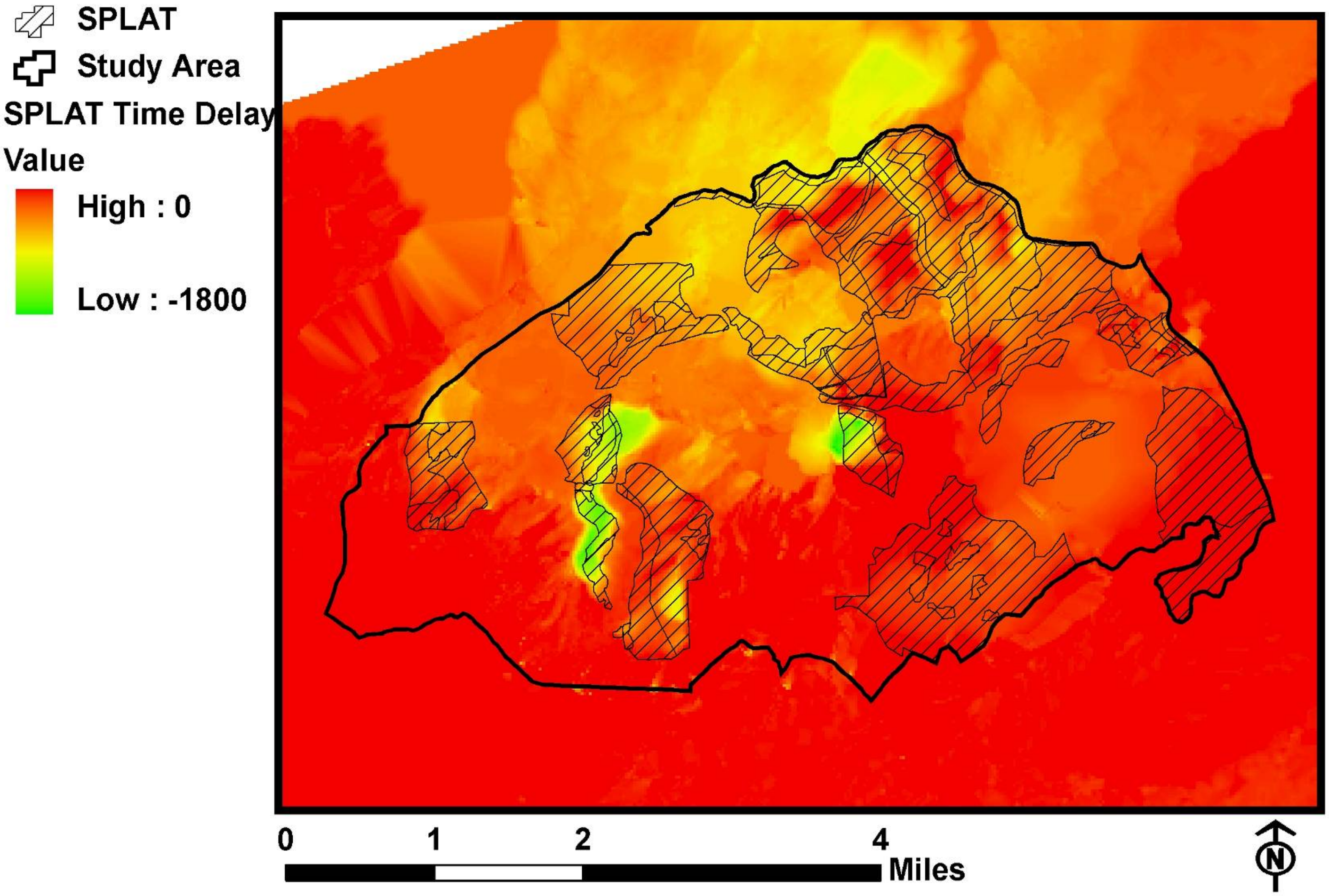

Figure 4. Change detection map showing relative differences in fire spread rates between baseline conditions in Sagehen Creek Basin and conditions in the Basin following SPLATs implementation. Time units are in minutes but note that absolute values are exaggerated by specification of simulation (see text). Fire spreads from the southwest to the northeast (bottom left to top right in map).

Another challenge is that the use of fire planning tools, like FlamMap and FARSITE, requires sophisticated GIS support. The user-base is very well-versed in the concepts and is experienced in analyzing the impact of fuel modifications on the stand level. But fireshed assessment is explicitly a landscape level process. Even within the University community, the skills to integrate multiple GIS layers, to model many specific and different treatments on the landscape, and then to summarize the impacts on fire behavior are rare.

FlamMap is a powerful and potentially useful planning tool for fireshed assessment.

We have demonstrated the value of FlamMap as a fireshed planning tool. However, it will take more time and more experience to develop the necessary knowledge-base among users at the USFS District level and the engaged public. In the first pass, it is challenging to interpret and to apply its results. The value of a model that simultaneously evaluates the fire behavior of every pixel in a forest is not immediately apparent. In general, the tools and approaches required for fireshed assessment rely heavily on a landscape perspective.

The integration of approaches from community and landscape ecology can provide robust, continuous estimates of forest canopy parameters important to fire behavior.

Statistical analysis determined that the high resolution field and remotely sensed data were significantly correlated to the LANDFIRE data but not to the initial data used in the fireshed analysis. Use of the 3 different datasets in FLAMMAP resulted in differing potential fire behavior outputs, especially with the initial fireshed data. In other words, the results varied depending on the data used. Clearly our intensive research approach is not a practical solution. Thus a priority in our ongoing work is to complete the sensitivity analysis to determine the most highly leveraged data needs. Our early analyses suggest that there are ways to combine existing information to improve the fireshed data.

The assignment of fire behavior fuel models is a critical step in the performance of fire simulation models. Even in circumstances with detailed quantitative information, the judgment of experts is still essential to obtaining models with realistic fire behavior.

We have not yet been able to develop a purely objective algorithm that reliably assigns fire behavior fuel models. Despite detailed measures of all the relevant fuel parameters, we could not produce a statistical integration of the information that predicted fuel model assignments based on expert opinion (see file: METHOD_Sagehen_fuel_analysis.doc).

Index of supporting documents

Many of the key results and deliverables of this project are summarized in presentation form and in parameterized fire models. Here is a listing of the Deliverables available on-line and on the enclosed DVD. The FTP address for online access is:

http://ecology.cnr.berkeley.edu/battles/download/JFSP

Folder: Models

Contents:

FlamMap_Sagehen_baseline.zip
FARSITE_Sagehen_baseline.zip

1) The compressed file FlamMap_Sagehen_baseline.zip contains two archived files of our FlamMap project. This project contains all the final fire model of baseline conditions in Sagehen Creek Basin.

To explore the FlamMap model, open FlamMap, click on the Extract and Open Archive, and select the file BASE_SAGEHEN.fza This will extract the files necessary to run FlamMap. We have included the results from our baseline analysis (base run).

2) The compressed file: FARSITE_Sagehen_baseline.zip contains our final landscape files necessary to run FARSITE simulations.

Folder: SPLAT

Contents:

SPLAT_SAGEHEN_INIT_20060524.ppt
SPLAT_SAGEHEN_FMOD_20061029.ppt
SPLAT_SAGEHEN_WAKES_200702026.ppt
SPLAT_SAGEHEN_FBASE_20071014.ppt

This folder contains the results and summaries from our four full revisions/iterations of fire models. Since we presented these results for discussion among groups, we organized the results as Powerpoint presentations. All the files start with "SPLATS_SAGEHEN" and then are followed by a short descriptor and more importantly a date. Exploring these files along the dateline is the best way to investigate the shared learning among the teams. The content of these files are all noted under DELIVERABLES.

Folder: Methods

Contents:

METHOD_Sagehen_canopy_cover_analysis.ppt
METHOD_Sagehen_field_protocols.doc
METHOD_Sagehen_fuel_analysis.doc

These files summarize technical reports that documented field methods and addressed key methodological questions.

Folder: Presentations

Contents:

TALK_Sagehen_aug06_fin.ppt
TALK_Sagehen_50th.ppt
POSTER_SPLAT_Sagehen.ppt

These files provide examples of presentations of the study given to both public and scientific audiences.

Folder: Information

Contents:

INFO_LiDAR.ppt
INFO_FARSITE_INPUTS.ppt

These files are examples of the informational presentations we created to explain some of the technical aspects of fire modeling and promote shared learning among the teams.

DELIVERABLES

(Note: In general, our timeline was delayed by approximately a year. The major reason was the initial delay in the project start date. The proposal was written assuming a June 1, 2004 start, yet funding did not begin until August 1, 2004. Thus we lost most of our first year field season. We did not complete the core field data necessary to build the fire models until October 2005).

Proposed	**Accomplished/Status**
November 15, 2004. Deliver methodology (with critique) for relascope sampling of surface fuels with the TNF (corresponds with peer-reviewed journal submission).	◦ Compared results and efficiency of point relascope sampling (Gove et al. 1999) of coarse woody debris to results from line intersect sampling. ◦ Discussed results with fuel officers from TNF. Internal report: METHOD_fuel_analysis.doc ◦ Hosted a field trip to Sagehen Basin (May 25, 2006) to review different methodologies for assessing forest fuels in order to consistently assign fire behavior fuel models. ◦ Teams agreed that Sagehen analysis should use “standard” fuel models as described in Scott and Burgan 2005. ◦ Tabled journal submission – none of the surface fuel characteristics were sufficient to reliably assign fuel model. Re-evaluating approach.
May 15, 2005. Provide preliminary field-parameterized FlamMap and FARSITE models to TNF collaborators.	◦ Results from initial FlamMap analysis was presented to district interdisciplinary team (ID team) during a 2-day on-site workshop (May 24-25, 2006). ◦ Results summarized in presentation file: SPLAT_SAGEHEN_INIT_20060524.ppt ◦ Documented and discussed questions and concerns raised by ID team members. ◦ Provided background on value/use of LiDAR (remote sensing) in developing forest fire models. ◦ Results summarized in presentation file: SPLAT_SAGEHEN_INIT_20060524.ppt ◦ Delivered initial FlamMap/FARSITE project files to GIS analyst on Truckee ID team (May 24, 2006).

Proposed	**Accomplished/Status**
January 15, 2006. Deliver field-parameterized version of FlamMap and FARSITE models to TNF.	◦ Results from revised FlamMap analysis was presented to district interdisciplinary team (ID team) during workshop at Truckee office on Oct 29, 2006. ◦ Major change in this version was the complete revision of how we assigned fire behavior fuel models. ◦ Results summarized in presentation file: SPLAT_SAGEHEN_FMOD_20061029.ppt ◦ Berkeley and Truckee teams agreed that modeled fire behavior of baseline runs in Sagehen Creek Basin fit with expert opinion of how fires burn in forests like Sagehen. ◦ Truckee ID team requested FARSITE analysis of specific fire scenarios in order to evaluate performance of planned SPLAT design. Fire scenarios defined by Truckee ID fuel officer. ◦ Delivered modified FlamMap/FARSITE project files to GIS analyst on Truckee ID team (Oct 29, 2006).
November 15, 2005. Deliver methodology (with critique) for estimating forest structure and canopy fuel loads (corresponds with peer-reviewed journal submission).	◦ During 5-month period (Oct 06 – Feb 07), conducted an extensive review/data exchange/methodologies for parameterizing the fire model of Sagehen Creek Basin. At the request of the District, we worked with the Regional Fuels Planning Specialist (Berni Bahro) and his team. ◦ Culminated in meeting at the regional office in Sacramento between regional fireshed assessment team, Truckee Ranger District, and UC Berkeley on Feb. 26, 2007. Evaluated performance of initial SPLAT design at Sagehen Creek Basin in modifying behavior of fire that started outside the Basin (southwest) and moves through the Basin on northeast trajectory (prevailing wind direction) during 95th percentile fire weather conditions. ◦ Results summarized in presentation file: SPLAT_SAGEHEN_WAKES_20070226.ppt ◦ All raw data files, interpolation routines, statistical analyses, GIS layers, and FlamMap/FARSITE project files were shared with Regional Fuels Planning Team and Truckee Ranger District. ◦ Journal submission in preparation.

Proposed	Accomplished/Status
March 15, 2006. Complete the sensitivity analysis of FlamMap/FARSITE model to quality/extent of data input.	◦ Berkeley Ph.D. student Nicole Vailant (Stephens lab) is completing this analysis as part of her dissertation. ◦ Three sources of data have been compared 1) high resolution and accuracy data from extensive field plots and remote sensing, 2) data available from LANDFIRE, and 3) initial data used by the USFS Tahoe National Forest for fireshed analysis.
September 15, 2006. Provide report on the 30-yr trajectory of forest dynamics in Sagehen Creek (corresponds with peer-reviewed journal submission	◦ Berkeley Ph.D. student Nicole Vailant (Stephens lab) is completing this analysis as part of her dissertation. ◦We plan on evaluating this trajectory once the final USFS Sagenhen Experimental Forest SPLAT plan is in place. Forest treatments will change over time as natural ecosystem dynamics occur. Initial surface fuel loads will increase, trees will regenerate and die, and the effectiveness of the fuel treatment will decline. The FFE extension of the FVS simulator will be used to assess how the SPLAT treatments will change over time. We have an excellent assessment of pre-treatment data that will be used in this analysis.
March 15, 2006. Deliver vegetation and fuel databases to TNF. Post online and on-site. Include slideshow/poster (Powerpoint) describing SPLAT simulations and visualizations of planned treatment regimes.	◦ Complete vegetation and fuel databases were delivered to Truckee Ranger District in May 2006. ◦ Waiting for final SPLAT plans from Truckee Ranger District to complete simulations and visualizations (pending).
Jan 15, 2007. Deliver preliminary assessment of fuel management and SPLAT plans to TNF.	◦ Evaluated performance of initial SPLAT design at Sagehen Creek Basin in modifying behavior of fire that started outside the Basin (southwest) and moves through the Basin on northeast trajectory (prevailing wind direction) during 95th percentile fire weather conditions. Feb 26, 2007. ◦ Results summarized in presentation file: SPLAT_SAGEHEN_WAKES_20070226.ppt ◦ Waiting for final SPLAT plans to complete assessment (pending).

Proposed	Accomplished/Status
March 15, 2007. Deliver final version of field-parameterized FlamMap/FARSITE model.	◦ Final version of field-parameterized FlamMap/FARSITE model completed on Oct 14, 2007. ◦ Results summarized in presentation file: SPLAT_SAGEHEN_FBASE_20071014.ppt ◦ FlamMap/FARSITE projects with supporting GIS layers can downloaded http://ecology.cnr.berkeley.edu/battles/downloan/JFSP
May 31, 2007. Complete final report on the performance of fuel management strategies for Sagehen Creek Basin.	◦ Final report completed Nov. 16, 2007. ◦ UC Berkeley team committed to completing performance analysis of final SPLAT plan for Sagehen Creek Basin when available.
New items (not initially proposed) being pursued that leverages JFSP-funded research	◦ Evaluation of consistency in terms of spatial scale and magnitude of forest canopy cover. This ongoing study compares results from various approaches to measuring canopy cover including: detailed field measurements, hemispherical photographs, 2 kinds of simple digital photographs, USFS GIS layers, and LiDAR extracted values. ◦ Validation of LiDAR approximation of live tree biomass designed for similar forest types in the Tahoe National Forest. ◦ Development of detailed fire history for white fir/mixed conifer forest types in Sagehen Creek Basin ◦ Refinements in application of object-based image analysis (from remote sensing products such as LiDAR and satellite photographs) to define robust vegetation classification.

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