Modeling the Effects of Fuel Treatments for the Southern Utah Fuel Management Demonstration Project

Donald Long[1], Kevin Ryan[1], Rick Stratton[1], Ed Mathews[1], Joe Scott[1], Maureen Mislivets[1], Melanie Miller[1], and Sharon Hood[1]

Abstract—*An integrated multi-scale analysis strategy using output from a variety of fire behavior and effects models has been developed for the Southern Utah Fuel Treatment Demonstration Project. Broader-scale analyses at the sub-basin or sub-regional scale will employ the models FIREHARM and LANDSUM across the entire study area. Sub-watershed and landscape level analyses will primarily use the FARSITE, FlammMap, and spatial versions of NEXUS and FOFEM on selected landscapes. Stand and polygon level analyses will be simulated using the Fire and Fuel Extension to the Southern Utah variant of the Forest Vegetation Simulator (FFE-FVS) and non-spatial versions of FOFEM and NEXUS for representative fuel and vegetation conditions in the study area.*

Background

Many areas throughout the United States are facing the triple threat of increasing fire intensity, increasing residential growth in areas prone to wildland fire, and increasing suppression costs and losses. In addition, substantial changes have and are occurring in the way we plan and implement management on the National Forests and Grasslands relative to use of wildland fire, prescribed fire, and mechanical fuel management. Past emphasis in fire management has been on wildfire suppression and prescribed fire in support of other resources such as hazard reduction and site preparation in harvested areas and wildlife habitat improvement. Allowing lightning fires to burn in wilderness areas to restore natural process has also been occurring for better than 30 years. It is only in the last five or six years that fire management has employed prescribed burning and mechanical fuel treatments to reduce unnatural fuel build-up in non-wilderness areas.

The 1995 Federal Wildland Fire Management Policy Review (USDA and USDI 1995) contributed to the development of a new federal fire policy that directs agencies to balance fire suppression capability and the use of fire to regulate fuels and sustain healthy ecosystems. The review directed fire managers to objectively evaluate and compare fuel treatment options including prescribed fire, thinning and other mechanical methods of fuel treatment, and increased utilization of biomass. Following the Cerro Grande Fire of 2000, Secretary of the Interior Bruce Babbitt and Secretary of Agriculture Dan Glickman directed the Interagency Federal Wildland Fire Policy Review Working Group to review the 1995 Federal Wildland Fire Management Policy and Program Review.

[1]Fire Sciences Lab, Rocky Mountain Research Station, USDA Forest Service, Missoula, MT.

The General Accounting Office (GAO) report of 1999 (General Accounting Office 1999) emphasized the need for the Forest Service to develop a cohesive strategy to address catastrophic wildfire threats. This report describes the extent and seriousness of problems related to the health of National Forests in the Interior West, the status of efforts by the Department of Agriculture's Forest Service to address the most serious of these problems, and barriers to successfully addressing these problems and options for overcoming them. The Forest Service responded with a document presenting a potential strategy for addressing fire management issues in fire adapted ecosystems (USDA FS 2000). This cohesive strategy establishes a framework that restores and maintains ecosystem health in fire-adapted ecosystems for priority areas across the Interior West.

In the 1998 appropriation, Congress, with the support of the Administration, provided a more flexible funding authority to support the aggressive use of fire and mechanical fuels treatments, with the goals of reducing the occurrence of uncharacteristically severe wildland fires and improving ecosystem health. In granting this new funding authority, Congress expressed a concern that "both the Forest Service and the Department of Interior lack consistent and credible information about the fuels management situation and workload, including information about fuel loads, conditions, risk, flammability potential, fire regimes, locations, effects on other resources, and priorities for treatment in the context of the values to be protected." This resulted in the creation of the Joint Fire Science Program, a concerted effort toward addressing the "fuels problem" and providing a scientific basis for implementing fuels management activities with a focus on activities that will lead to development and application of tools for managers. Development of methods for fuel characterization, mapping, and assessment must include examination of both available and needed fuel models. In turn, development of tools for managers requires an assessment of the role of information system technology.

Southern Utah Fuel Management Demonstration Project

The Southern Utah Fuels Management Demonstration Project is one such project funded by the Joint Fire Sciences Program. It will creatively link current technology in a consistent and comprehensive manner to allow comparisons of alternatives for fuel management for roughly 13 million acres of Southern Utah and 2 million acres of Northern Arizona. The databases and models will be used to support the planning and implementation of an integrated, interagency landscape level fuel management program for the region. Our goal in this respect is to improve the fuel management program in Southern Utah and a portion of Northern Arizona by establishing an interagency demonstration area. This area is undergoing rapid change in land use, which places some urgency on the need for this approach to fuel management.

The demonstration area (figure 1) includes contiguous state and federal lands within the administrative boundaries of the BLM, Forest Service, state of Utah, and the National Park Service, roughly encompassing the southern 15 percent of Utah (table 1). Several agencies have intermixed land ownership and a history of good interagency cooperation on management issues.

Southern Utah is at the ecological crossroads for much of the Western United States. It contains steep environmental gradients. This allows us to study a

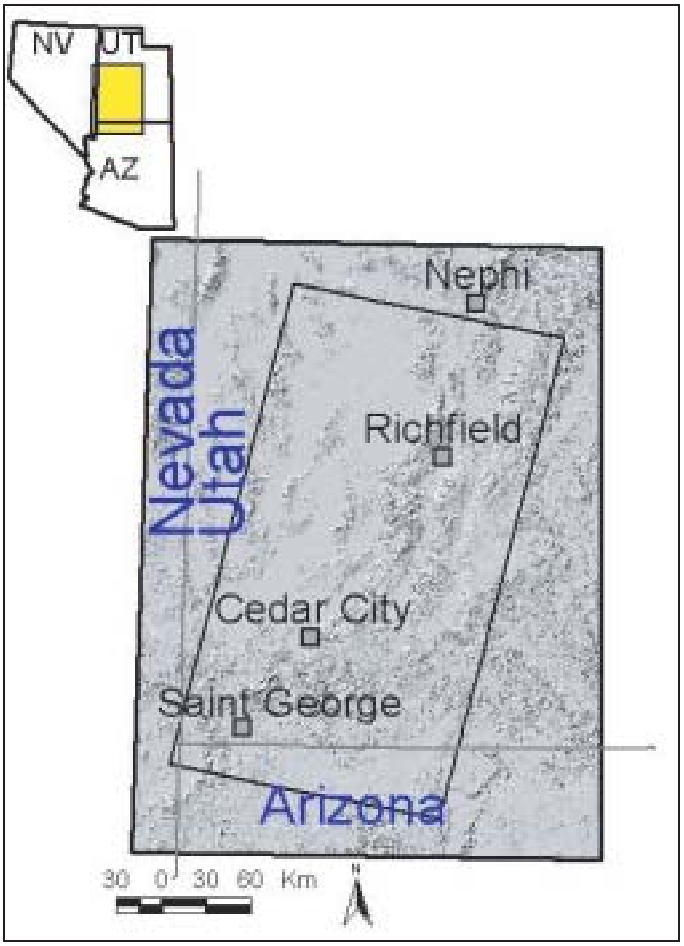

Figure 1—Southern Utah Fuel Management Demonstratioin Area location.

broad range of fuel and fire regimes associated with vegetation types representative of the High Plateaus of Utah, the Great Basin, the Colorado Plateau, and the Mohave Desert. Previous mapping efforts (Homer et al. 1997) identified 29 vegetation types in the demonstration area (table 2), including various associations of pinyon-juniper, ponderosa pine, sagebrush-grass, aspen, spruce-fir, mountain shrubs, and desert shrubs. These vegetation types are similar in species composition, stand structure, and ecologic function, so they have similar fire regimes to vegetation types found on hundreds of millions of acres in the 11 western states. Thus fuel treatment guidelines developed in the project have wide potential applicability.

Table 1—Percent composition of land ownership in Southern Utah study area.

Agency	Percent of study area
Bureau of Land Management	49
Forest Service	23
Private	19
State Lands	7
Bureau of Indian Affairs	1
National Park Service	1

Table 2—Percent composition of major vegetation types in Southern Utah study area from Utah and Arizona combined GAP Analysis cover type databases (Homer et al. 1997).

Cover type	Percent of study area
Pinyon-Juniper	28.4
Salt Desert Scrub	16.7
Sagebrush	11.4
Sagebrush-Grass	6.7
Grassland	5.6
Agriculture	4.0
Spruce-Fir	3.5
Blackbrush	3.2
Aspen	3.0
Oak	3
Ponderosa Pine	2.4
Creosote-Bursage	1.6
Mountain Shrub	1.6
Dry Meadow	1.5
Mountain Fir	1.4
Ponderosa Pine/Shrub	1.3
Barren	1.2
Desert Grassland	1.2
Water	.7
Alpine	.3
Greasewood	.3
Lowland Riparian	.3
Urban	.3
Mountain Riparian	.2
Aspen/Conifer	.1
Mountain Fir/Mountain Shrub	.1
Pickleweed Barrens	.1
Spruce Fir-Mountain Shrub	.1
Wet Meadow	.1
Wetland	.1

Project Objectives

This project has three main objectives. First is to develop Geographic Information System (GIS) data layers of fuel, vegetation, weather, and terrain inputs necessary to conduct fire behavior and fire effects analysis across the entire study area. We will use a number of computer models to accomplish this including FARSITE (Fire Area Simulator) (Finney 1998), FlamMap (Finney in progress), NEXUS (Scott 1999), FOFEM (First Order Fire Effects Model) (Reinhardt et al. 1997), LANDSUM (Keane et al. 1997a), a Southern Utah variant of the Fire and Fuel Extension to the Forest Vegetation Simulator (FFE-FVS) (Reinhardt and Ryan 1998), and FIREHARM (Keane in progress). In addition, we will develop criteria for landscape features and map those that deserve important consideration in fire management decisions including infrastructure features and other natural and cultural resource values such as municipal watersheds and wildland urban interface areas (WUI). The second objective is to apply and test these models on the various fuel types and weather conditions across the study area. This objective will facilitate review and validation of model inputs and outputs. The third objective is to demonstrate the use of these models and data at a variety of scales in order to aid in the implementation of fuel treatment activities within the study area. This includes the development of fuel treatment guidelines for the various vegetation types.

Current Efforts

Recently, a number of federal land management agencies have invested in efforts to produce management strategies using GIS data and fire models to reduce extreme fire effects to communities, and cultural and natural resources, while at the same time increasing the health of ecosystems and decreasing the probability of extreme fire events. An initial attempt at developing such a strategy was the "Development of Coarse-Scale Data for Wildland Fire and Fuel Management" (Schmidt et al. 2002). This effort integrated maps depicting potential natural vegetation, current cover type, historical natural fire regimes, and current fuel condition and identified areas in the continental United States where current fire regimes are significantly different from historic conditions and where fuel conditions are potentially suitable for treatment. In addition, this effort also combined maps depicting housing density, extreme fire behavior, and fire exposure from vegetation to assess potential threat of fire to the wildland-urban interface.

The Utah BLM has used Utah GAP Analysis GIS data, created from LANDSAT-TM data (Homer et al. 1997), to assess state level fire hazard and model fire potential for fire planning and dispatch purposes (Wimmer et al. 2000). When combined with GIS data layers depicting population densities and historical fire occurrence, it identified potential areas with a serious fire threat as well as areas where detailed interagency planning and tactical analyses and treatment may be needed.

These efforts indicate areas of Southern Utah are at risk and are suitable for fuel treatments. They provide a strategic basis for broad, regional scale programmatic direction, particularly with respect to fire suppression activities, but lack the spatial and thematic resolution required by current state-of-the-art models to prioritize and locate landscape or project-level fuel treatments. Generally, these models require 30 m resolution datasets that describe a wide range of fuel and vegetation attributes such as surface fuel loads, crown fuel, density and height of vegetation, and biophysical site potential. In addition, they do not utilize existing fire behavior and effects models to test the relative efficacy of fuel treatments. Concurrent with these efforts, a number of land management agencies in Utah have initiated numerous site and project level fuel treatment projects utilizing funding provided by the National Fire Plan. However, these efforts are not directly linked to existing strategic and forest level planning efforts and do not integrate these programs within and across multiple temporal and spatial scales.

Multi-Scale Fuel Treatment Analysis

Recently, a multi-scale, integrated planning approach has been identified as a way to link broader scale fuel management plans to more site-specific project level fuel treatment projects (Hann and Bunnell 2001). This approach maximizes efficiency at each scale and can be more successful at achieving objectives not only at the project level but upward to the regional and national scales (Hann and Bunnell 2001). Also, in order to rate the relative effectiveness of fuel treatments at a variety of scales, simulating potential fire behavior and fire effects in a modeling environment will require use of the different models at different scales (Reinhardt et al. 2001). The Southern Utah Fuel Management Demonstration Project will utilize a number of fire behavior and fire effects models at what we feel is the appropriate scale (table 3). This project has worked closely with fire managers within the study area to produce products that will allow them to prioritize, select, and implement fire restoration projects across a number of different spatial and temporal scales. We have sponsored

Table 3—Fire behavior and fire effects models used in the Southern Utah Fuel Management Demonstration Project with corresponding management application and spatial scale of application.

Model	Applications	Scale
LANDSUM	Management strategy comparisons to determine vegetation response and predict successional pathways to reduce future fire intensity, crowning potential and flame length.	Sub-basin/sub-regional
FIREHARM	Management strategy comparisons to assess the probability of extreme fire effects using various weather scenarios.	Sub-basin/sub-regional
FARSITE/ Flammap	Management strategy comparisons under various weather scenarios.	Sub-watershed/landscape
NEXUS	Management strategy comparisons for reducing crown fire risk including thinning, pruning, and other fuel removal.	Stand/polygon and Sub-watershed/landscape
FOFEM	Management strategy comparisons to determine optimum treatment schedules to reduce first-order -impacts on surrounding environments under wildfire and prescribed fire conditions.	Stand/polygon and Sub-watershed/landscape
FFE-FVS	Management strategy comparisons to determine optimum treatment schedules that reduce fire intensity, tree mortality, and surface fuel loading over time.	Stand/polygon

series of workshops attended by local fire managers to help us develop GIS layers, understand vegetation succession, assign fuel attributes to vegetation layers, and design weather scenarios to ensure these products are valid and usable.

The coarsest scale of analysis, across a sub-basin and sub-regional geographic extent, will require the use of a spatially explicit multiple pathway succession model called LANDSUM to assess general trends in vegetation distribution and fire regimes through multi-century time periods. This analysis will primarily determine departure of current fuel and vegetation conditions from historical conditions as well as allow us to simulate potential future conditions under changing climatic regimes. We will initially develop successional pathway models using the Vegetation Dynamics Development Tool (VDDT) (Beukema and Kurz 1998). We will also use LANDSUM to predict the consequences of the treatment versus no treatment of fuel over somewhat shorter time scales such as 10 years, 50 years, and 100 years within portions of the study area. The model will be used to programmatically simulate fuel treatment prescriptions throughout the study area to reduce extreme fire events and maintain healthy ecosystems and communities, mainly surrounding the higher priority areas.

The model FIREHARM will characterize potential fire hazard and fire risk for the entire study area across time periods more appropriate for operational fire management planning by using computed spatial and temporal probabilities of extreme fire events. This will integrate 18 years of daily weather data, from 1980-1996, with fire behavior and fire effects models to compute temporal probabilities of user-specified fire events occurring within the study area for every polygon on the landscape. Values at risk, including communities, natural, and cultural areas of importance in the southern Utah landscape, will be assessed with regards to the fire hazard and risk maps.

The middle scale of analysis, at a sub-watershed or landscape geographic extent, will consist mainly of varying the spatial pattern of fuel and vegetation on the landscape in order to test ways of reducing the intensity and severity of wildfires and protecting values at risk. The spatial pattern of fuel treatments has an important effect on disrupting fire growth across a landscape. Work by Finney (2000) indicates that one effective means to reduce the intensity and severity of wildfires is to treat fuel in such a way as to minimize the area burned by a head fire. We will work with local fire managers to identify areas on the landscape where they have planned or implemented fuel treatment projects and use these areas for intensive modeling. We will use FARSITE and FlamMap to game the portions of these sub-watersheds and landscapes in order to determine the size, shape, and configuration of fuel treatments necessary to form an effective barrier to the development of large fires or to the spread of large fires into sensitive areas identified as having high values at risk. The FARSITE model is a state of the art model for predicting the spread and intensity of fires across a landscape. It is designed to model continuous fire behavior through time using spatial data representing elevation, slope, aspect, surface fuel model, canopy cover, crown base height, crown bulk density, and stand height. FlamMap predicts fire behavior without the use of a fire spread algorithm and produces maps of surface and crown fire behavior characteristics using FARSITE input data layers for a given set of weather and / or fuel moisture data inputs for all points across the landscape simultaneously. Fuel treatment strategies will include a method for linking or modifying the landscape with respect to low spread rate landscape polygons identified through the use of FARSITE and FlamMap.

In addition, NEXUS will be used to determine the effect of combinations of thinning, pruning, and fuel removal on likelihood of surface fire vs. crown fire and FOFEM will be used to evaluate changes in fire effects (fuel consumption, smoke, tree mortality, soil heating, and mineral soil exposure) with wildfire vs. prescribed fire conditions for these selected landscape as well. The NEXUS model calculates instantaneous changes in fire behavior, as well as transitions from surface fire to torching to crown fire with varying harvest, pruning, and fuel treatment options. We are also developing a spatial variant of NEXUS that will allow retrieval of data from GIS databases, and will produce output in a format suitable for inclusion in GIS for spatial analysis and mapping.

Stand or polygon level analysis will consist of individual non-spatial model simulations of the full range of fuel and vegetation conditions identified within the study area. The Fire and Fuel Extension to the Southern Utah variant of the Forest Vegetation Simulator will be used to model forest and woodland fuel and vegetation types. Simulation runs will summarize fuel conditions and associated fire behavior and effects resulting from a variety of potential fuel treatment strategies. NEXUS will be used to determine the effect of combinations of thinning, pruning, and fuel removal on likelihood of surface fire vs. crown fire. Simulation runs using FOFEM will be used to summarize fuel conditions and associated fire behavior and effects resulting from a variety of potential fuel treatment in non-forested and non-woodland vegetation types. We will calculate first order fire effects such as fuel consumption, smoke production, and tree mortality using the FOFEM, including the use of a “batch” mode programmed to run for multiple stands at the landscape level. We will analyze stand or polygon scale treatment effects on long term fuel and fire dynamics with varying treatments to determine optimum treatment schedules the FFE-FVS model. We will be using a new regional variant that addresses species that occur in Southern Utah and the Intermountain West.

Summary

The Southern Utah Fuel Management Demonstration Project is a Joint Fire Sciences project that creatively links a number of fire behavior and fire effects models to allow comparison of fuel management strategies for roughly 13 million acres of Southern Utah and 2 million acres of Northern Arizona. The databases and models will be used to support the planning and implementation of an integrated, interagency landscape level fuel management program for the region. A multi-scale analysis strategy using output from a variety of fire behavior and effects models will be developed. Broader-scale analyses at the sub-basin or sub-regional scale will employ the models FIREHARM and LANDSUM across the entire study area. Sub-watershed and landscape level analyses will primarily use the FARSITE, FlammMap, and spatial versions of NEXUS and FOFEM on selected landscapes. Stand and polygon level analyses will be simulated using the Fire and Fuel Extension to the Southern Utah variant of the Forest Vegetation Simulator (FFE-FVS) and non-spatial versions of FOFEM and NEXUS for representative fuel and vegetation conditions in the study area.

References

Beukema, S.J.; Kurz, W.A. 1998. Vegetation dynamics development tool user's guide. Version 3.0. Prepared by ESSA Technologies Ltd., Vancouver, BC. 102 pp. Pp 309-324.

Finney, Mark A. [In progress]. FlamMap. Rocky Mountain Research Station, Fire Sciences Lab, Missoula, MT.

Finney, Mark A. 2000. Design of regular landscape fuel treatment patterns for modifying fire growth and behavior. Forest Science. 47(2): 219-228.

Finney, Mark A. 1998. FARSITE: Fire Area Simulator - model development and evaluation. Res. Pap. RMRS-RP-4. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p.

Hann, Wendel J.; Bunnell, David L. 2001. Multi-scale land and fire planning. International Journal of Wildland Fire. 10: 389-403.

Homer, C.G., Ramsey, R.D., Edwards, T.C., Falconer, A. 1997. Landscape cover-type modelling using multi-scene thematic mapper mosaic. Phototgrammetric Engineering and Remote Sensing. 63: 59-67.

Keane, Robert E. [In progress]. Fire harm. Rocky Mountain Research Station, Fire Sciences Lab, Missoula, MT.

Keane, Robert E.; Long, D.G.; Basford, D.; Levesque, B.A. 1997. Simulating vegetation dynamics across multiple scales to assess alternative management strategies. In: Integrating spatial information technologies for tomorrow: GIS '97 conference proceedings; 1997 February 17-20; Fort Collins, CO : GIS World: 310-315.

Reinhardt, Elizabeth D., Keane, Robert E.; Brown, James K. 2001. Modeling fire effects. International Journal of Wildland Fire. 10: 373-380.

Reinhardt, Elizabeth D.; Ryan, Kevin C. 1998. Analyzing the effects of management actions including salvage, fuel treatment, and prescribed fire on fuel dynamics and fire potential. In: Pruden, Teresa L.; Brennan, Leonard A., eds. Fire in ecosystem management: shifting the paradigm from suppression to prescription, proceedings of the 20th Tall Timbers fire ecology conference; 1996 May 7-10; Boise, ID. Tallahassee, FL: Tall Timbers Research Station: 206-209.

Reinhardt, E.D.; Keane, R.E.; Brown, J.K. 1997. First Order Fire Effects Model: FOFEM 4.0, user's guide. Gen. Tech. Rep. INT-GTR-344. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 65 p.

Schmidt, Kirsten M.; Menakis, James P.; Hardy, Colin C.; Hann, Wendel J.; Bunnell, David. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Scott, Joe H. 1999. NEXUS: A system for assessing crown fire hazard. Fire Management Notes. 59(2): 20-24.

U.S. General Accounting Office. April 1999. Western National Forests: A cohesive strategy is needed to address catastrophic wildfire threats. Report to the subcommittee on forest and forest health, committee on resources, House of Representatives. GAO / RCED-99-65.

U.S. Department of Agriculture, Forest Service. 2000. Protecting people and sustaining resources in fire-adapted ecosystems: a cohesive strategy. The Forest Service Management response to General Accounting Office Report, GAO / RCED-99-65. 86 p.

U.S. Department of Agriculture, U.S. Department of the Interior. 2000. National fire plan: managing the impact of wildfire on communities and the environment. 35 p.

U.S. Department of Agriculture, U.S. Department of the Interior. 1995. Federal wildland fire management, policy and program review-final report. National Interagency Fire Center: Boise, ID. 45 p.

Wimmer, Sheldon; Shive, John C.; Sheffey, Jack. 2000. Utah statewide fire assessment. Proceedings Crossing the Millennium: Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management. Joint Fire Science Conference and Workshop; Volume 1. Boise, Idaho, 1999 June 15-17. 298 p.