Estimating Expected Fire Suppression Cost Savings due to Vegetation Management on Pinyon Pine and Juniper Invaded Sagebrush Rangelands[1][2]

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1. Background and Motivation

Wildfire suppression costs in the United States have increased steadily over the last decades (Stephens and Ruth 2005, Calkin et al. 2005, Gebert et al 2007, Westerling et al. 2006, GAO 2007), with related expenditures by the U.S. Forest Service and Bureau of Land Management exceeding a billion dollars per year in four out of the seven years leading up to 2006 (Gebert et al 2008). Pre-fire vegetation management on public lands is recognized as an important tool for reducing expected wildfire suppression costs (GAO 2007). Using data from wildfire suppression costs across the US, Lankoande and Yoder (2006) estimate that each dollar spent on fire suppression reduces damage by 12 cents; while each dollar spent in pre-fire preparedness yields a return of \$3.76 in fire suppression cost reduction. Information of this type is necessary for cost-effective public lands management. However, to date there is no similar information about the economic returns from fuels treatments on Great Basin rangelands. This research brief describes one part of an economic study being conducted through the SageSTEP project (McIver et al 2010; Rollins, Kobayashi and Taylor 2010) that estimates the economic benefits of pre-fire fuels treatment on sagebrush rangelands.

The economic benefit of pre-fire treatment is measureable as a positive difference in the expected net present value of outcomes with and without treatment. A full accounting of benefits would require valuation of the changes in all ecosystem goods and services that are affected by treatment. These include changes in wildlife habitat, forage for domestic livestock, recreation, erosion control, and air and water quality as well as treatment costs and wildfire suppression costs. While other components of the SageSTEP economic research are investigating these values, for the purposes of this study we focus solely on differences in wildfire suppression costs and treatment costs.

In many areas in the Great Basin, pinyon pine and juniper (PJ) trees have encroached from higher elevations into lower lands, crowding out native sagebrush plant systems. Fires fueled by PJ stands burn hotter and longer, with longer flame-lengths, than would otherwise occur on these lands. Post-fire restoration is extremely expensive and unlikely to succeed on lands where most of the perennial native grasses and shrubs have been crowded out by dense PJ. Thus, post-fire, the dominant vegetation in these areas consists of cheatgrass and other annual invasive grasses.

Fuels treatments, and vegetation management in general, can be applied at a variety of stages: in early stages of a PJ invasion (Phase I), later stages (Phases II and III), or as post-fire rehabilitation after formerly PJ-invaded areas have become dominated by cheatgrass. Treatments can also be applied to

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[1] Prepared for the Pinyon-Juniper Restoration and Utilization Summit, Hosted by the Nevada Pinyon-Juniper Partnership, North Las Vegas, NV, December 8 & 9, 2010.

[2] This is Contribution Number 56 of the Sagebrush Steppe Treatment Evaluation Project (SageSTEP), funded by the U.S. Joint Fire Science Program. We acknowledge the USFS Rocky Mountain Research Station for making data and support information available to us. We thank Malieka Landis for her research assistance.

mimic natural fire-cycle regimes in areas of relatively healthy sagebrush and perennial grasslands with some cheatgrass and little PJ.

Two policy questions we ask in this study are: what are the economic benefits from pre-fire fuels treatment of sagebrush rangelands that are prone to PJ encroachment and how would a decision-maker faced with a limited budget and a region that contains a patchwork of rangelands in various health stages decide which areas to give higher priority for treatment? We answer these questions using a statistical method and a simulation model to estimate fire suppression costs that can be avoided by the use of preemptive fuels treatments.

The connection between fire suppression costs and pre-fire vegetation treatment comes from the effect of vegetation on wildfire behavior, as wildfires burn differently depending on fuel types and loadings (and other conditions such as weather and topography). Firefighting professionals classify vegetation as fuel types according to fuel models described in the National Fire Danger Rating System of 1978 (Anderson 1982). Table 1 lists the four fuel models that are relevant for the system we study. The healthiest state of the system (perennial grasses, sagebrush and traces of invasive annual grasses) corresponds to fuel model T. An initial invasion of PJ and annual grasses into the system is represented by fuel model C. Over time the PJ canopy closes in and outcompetes perennial grasses and other native sagebrush-related plants while annual grasses continue to spread (fuel model F). In this state, wildfires are harder to ignite but burn extremely hot and can alter the nitrogen in the soil to result in annual grass domination post fire, with extremely low success rates for post-fire rehabilitation (fuel model A).

Table 1: Fuel Models and Vegetation Types for Great Basin Rangelands

Description of vegetation type	Forest Service Fuel Model
Predominately healthy perennial grass and sagebrush plant community with traces of invasive annual grasses	T
Pinyon pine and junipers with mature sagebrush and invasive annual grasses	C
Closed-canopy pinyon pine and juniper stands with invasive annual grasses	F
Dominated by invasive annual grasses	A

2. Fire Suppression Cost Estimation

In the context of this study, the decision whether to implement pre-fire fuels treatments on given patches of land is a long-run decision. We assume that in the short run, at the time of fighting a wildfire, the firefighting resource manager takes the fuel type as given and tries to minimize the cost of firefighting and the damage due to fire. Maintaining this assumption, we would expect that wildfire suppression cost data reflect the outcome of cost-minimizing effort for each fire given the conditions that the manager cannot control, including fuel types, weather and topography. As a first step towards estimating the benefit of pre-fire vegetation management, we estimated the contribution of each fuel type to overall wildfire suppression costs per fire. We obtained data from the US Forest Service Rocky Mountain Research Service (RMRS) on wildfire suppression costs for 397 wildfires that occurred over the years 1995 to 2007 in the Great Basin[3]. The data include suppression costs, fuel type at the point of

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[3] The RMRS data use the National Interagency Fire Management Integrated Database (NIFMID) and federal government financial accounting records. The Great Basin corresponds to USFS Region 4, which covers Utah, western Wyoming, southern Idaho, Nevada and a small portion of California.

ignition, and other characteristics of the fires that are known to affect fire behavior. In order to isolate the contribution of fuel types in determining the average wildfire suppression cost levels, we conducted a regression analysis of the total suppression cost per wildfire with the explanatory variables including fuel types relevant for areas prone to PJ encroachment.

Table 2 summarizes relevant regression results. Contributions of vegetation (fuel) type to fire suppression cost were estimated relative to fuel model T (healthy sagebrush). The estimated coefficient represents the contribution of each fuel type to the Log of wildfire suppression cost. The last column translates the information in dollar terms. For wildfires under fuel model A, elevation also affected the total cost. The figures in the last column imply that, relative to the healthiest vegetation under fuel model T, a wildfire that started on a land with early stage of PJ encroachment (fuel model C) was on average $1,608 more expensive to fight. At the elevation of 6,000 feet, a fire that started on a cheatgrass dominated land cost $2,710 more.

Table 2. Selected Regression Results of Cost Function Estimation
(Dependent variable = ln(total expenditure), n = 397, R^2 = 0.35)

		Estimated coefficients	**Contribution to fire suppression cost**[a]
Fuel model C	PJ, mature sagebrush with cheatgrass	0.475	$1,608
Fuel model F	Closed-canopy PJ with cheatgrass	0.076	$1,079
Fuel model A	Cheatgrass	-24.812	$2,710
Fuel model A x ln(elevation)	dominated	2.967	(at 6000 feet)

[a] Relative to fuel model T (healthy sagebrush)

3. Wildfire Suppression Cost Saving due to Fuels Treatment

The cost estimates from the regression analysis were used to calculate potential savings on wildfire suppression cost due to fuels treatment applied to land in each of the fuel types. We use a simple simulation model, run over a 200-year period with a discount rate of 4% and a series of assumptions:

- Wildfire will occur with an annual probability that varies according to the vegetation type.
- Without fuels treatment, vegetation type will transition from T to C, to F, and then to A.
- Treatment is applied in year 1 and, if successful, brings land in C, F, and A back to T after a transition period. If the treatment is unsuccessful, land in C and F will convert immediately to A and land in A will remain in A. For land in T, a successful treatment maintains the land in T, while an unsuccessful treatment will have no effect, thus resulting in transition T → C → F → A.
- Following a successful treatment, a subsequent treatment is applied to maintain the land in T. No further treatment is applied following an unsuccessful treatment.

Simulation results are presented in Table 3. Dollar values represent the present-valued sum of expected costs and benefits over a 200-year time horizon, using a 4% discount rate. The first two rows show fire suppression costs on land characterized by each type with and without treatment. Without treatment per-acre fire suppression costs, in thousands of dollars, are lowest for T (healthy sagebrush), followed by A (cheatgrass dominated) and C (mature brush with some PJ). Not surprisingly, fire suppression costs are highest in F, with closed-canopy PJ. The gross cost saving is the difference between the first two rows, and it is largest in F, followed by C, T, and A. It is interpretable as the expected gross return on the investment of a treatment, where the risk is taken into account by the assumed probabilities of success and failure and fire occurrence in a given year. The assumed values for these probabilities are listed in the appendix. Since treatment costs are small compared to fire suppression cost, the order of the cost saving net of treatment cost remains the same. This result suggests under the assumptions and parameters used in the exercise, treatment of areas with heavy PJ first (F), then C, and then T represents the greatest return to management resources invested in terms of avoided wildfire suppression costs. The benefit of treating land in A (that is, post-fire restoration of cheatgrass dominated areas) is minimal.

Table 3. Expected Present-valued Wildfire Suppression Cost over 200 Years on Land with Four Initial Vegetation Types ($000 per acre, in 2004 dollars, using a discount rate of 4%)

	Initial Vegetation Type			
	Fuel model T	Fuel model C	Fuel model F	Fuel model A
	Healthy sagebrush	PJ, mature sagebrush with cheatgrass	Closed-canopy PJ with cheatgrass	Cheatgrass dominated
No treatment	60.428	115.977	238.850	112.881
	(44.40, 76.51)	(77.30, 154.84)	(150.99, 326.79)	(46.2, 179.68)
With treatment	59.437	83.042	168.879	112.797
	(43.80, 75.13)	(51.88, 114.32)	(99.9, 237.93)	(46.23, 179.51)
Gross cost saving due to treatment	0.991	32.935	69.971	0.084
	(0.6, 1.39)	(25.42, 40.51)	(51.07, 88.86)	(0.004, 0.165)
Treatment cost[a]	0.036	0.600	0.800	0.035
Net cost saving due to treatment	0.955	32.335	69.171	0.049
	(0.56, 1.35)	(24.82, 39.91)	(50.27, 88.06)	(-0.031, 0.130)

[a] Source: Rummer et al. (2005)
95% confidence intervals in parentheses.

Table 4 (reprinted from Rummer et al. 2005) summarizes the costs of fuel reduction treatment alternatives used in our simulation exercise for each vegetation type. Specifically, we used:

- The lower end of prescribed fire cost for land in T and A ($35 per acre)
- A point in the cost range for mastication in-woods for land in F ($800 per acre)
- A point in the cost range for cut/pile/burn for land in C ($600 per acre)

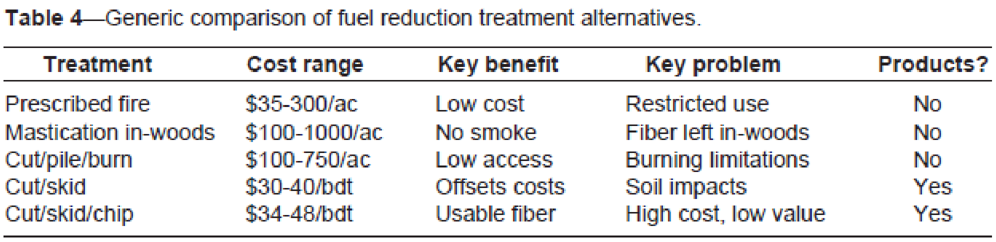

Table 4—Generic comparison of fuel reduction treatment alternatives.

Treatment	Cost range	Key benefit	Key problem	Products?
Prescribed fire	$35-300/ac	Low cost	Restricted use	No
Mastication in-woods	$100-1000/ac	No smoke	Fiber left in-woods	No
Cut/pile/burn	$100-750/ac	Low access	Burning limitations	No
Cut/skid	$30-40/bdt	Offsets costs	Soil impacts	Yes
Cut/skid/chip	$34-48/bdt	Usable fiber	High cost, low value	Yes

Source: Rummer et al (2005)

4. Implications, Limitations and Further Research

The purpose of this exercise is to apply an economically sound approach to estimate benefits of fuels treatments on sagebrush rangelands in terms of fire suppression costs averted, and to generate information that helps land management decision makers to prioritize treatments on a patchwork of lands of various types. It is rational to use a given budget first to treat lands with greatest return, then move to those with the next highest return, and so forth. It must be noted that the only treatment benefits included in this analysis are wildfire suppression costs avoided. Other potential benefits due to treatment are not included here, and by including them in future work, the relative importance of which lands to treat may change. For example, lands that have already transitioned to monoculture of annual weeds present more costs to society than wildfire suppression costs alone, due to permanently lost wildlife habitat and forage, increased erosion, alteration of hydrological function, and health problems from dust and smoke. In general, treatment benefits that consider only wildfire suppression costs averted therefore err towards undervaluing treatments.

It must also be noted here that the relevant decision problem addressed in the short summary is of how to allocate fixed funds among lands already in several different vegetation types. These results do not imply that it is efficient to leave healthier land in T or C and wait till it converts to F before treating. The optimal timing of treatment is a different decision problem that is the subject of a companion study.

And finally, the estimates of potential benefits treatment presented here are based on regional averages and not directly applicable to specific location. This application, based on data from the entire Great Basin, characterizes an average or “typical” area that could exist in the region. For an application to a specific area, the procedures described here would need to be replicated with more detailed data that fit the target area, including the probability of treatment success, fire return intervals, years to transition and other parameters. Thus, the monetary values for the benefits estimates presented here can only be viewed as being within a range that is possible for areas in the Great Basin region as a whole.

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Appendix

Table A. Additional Parameters Used in Simulation

	Fuel model T	**Fuel model C**	**Fuel model F)**	**Fuel model A**
	Healthy sagebrush	PJ, mature sagebrush with cheatgrass	Closed-canopy PJ with cheatgrass	Cheatgrass dominated
Fire return interval (years)	30	30	30	5
Annual fire probability	0.033	0.033	0.033	0.200
Transition interval (years)	100	50	34	NA
Treatment success rate	0.900	0.800	0.550	0.030
Time for success (years)	NA	15	30	75