EFFECT OF LIVESTOCK GRAZING AND FIRE HISTORY ON FUEL LOAD IN SAGEBRUSH-STEPPE RANGELANDS

Keith T. Weber, Ben McMahan, and Glenn Russell
GIS Training and Research Center
Idaho State University
Pocatello, ID 83209-8130
(http://giscenter.isu.edu, e-mail: giscenter@isu.edu)

ABSTRACT
Measuring, modeling, and managing wildfire risk is an important and challenging task for land managers. We examined the effect of livestock grazing and previous wildfire events on fuel load in southeastern Idaho as part of a wildfire risk-livestock interaction study. Fuel load was estimated using ordinal fuel load classes at 128 sample sites stratified by current livestock grazing and documented wildfire occurrence (1939-2000). Fifty-nine percent of previous wildfire sites (n = 46) had a docuemented fire within the past 2 years. Livestock grazing was the most effective means to reduce fuel load (P < 0.0005) compared to recent wildfire (P < 0.05) and livestock grazing with previous wildfire (P < 0.05). Livestock grazing provides a viable management tool for fuel load reduction prescriptions that avoids the negative effect of extreme fire intensity where fuel load is high.

Keywords: Idaho, wildfire.

INTRODUCTION

There has been a critical need to predict and manage rangeland wildfire danger since the 1940's (Burgan and Shasby 1984, Burgan et al. 2000). Various studies have been conducted to measure fuel load and model fire behavior (Deeming et al. 1977, Anderson 1982, Andrews and Bradshaw 1997), while other studies have been conducted to determine the effect of various vegetation treatments on fuel load (Madany and West 1983, Tsiouvaras et al.1989, Blackmore and Vitousek 2000). In this study, we examined the effect of livestock grazing and previous wildfire on fuel load levels in sagebrush-steppe rangelands of southeastern Idaho.

Litter, percent bare-ground, vegetation composition, structure, and senescence are important components in the estimation of fuel load (Anderson 1982). Fuel load models have become a valuable tool for predicting fire behavior (Anderson, 1982) and managing wildfire risk. Understanding the factors that influence fuel load is also of value. This is especially true when management alternatives could be implemented to reduce fuel load and wildfire risk.

Study Area

This study was conducted on land managed by the USDI BLM, Upper Snake River District in southeastern Idaho. Sample points were located between 43^{0}36'00"N and 42^{0}48'00"N latitude and –113^{0}35'00"W and -112^{0}37'59"W longitude. This area is sagebrush-steppe semi-desert, with a history of livestock grazing and wildfire. Historically, sheep were the primary grazer. Currently, both sheep and cattle graze this area with cattle being the primary grazer. Deferred and seasonal grazing systems are used in the study area on allotments which range in area from 1,153 to 128,728 ha.

MATERIALS AND METHODS

Fuel load was estimated during the summer 2001 at 128 sample points randomly located across the study area (fig. 1). Fuel load estimation followed USDI BLM procedures (Anderson 1982). Each point was located $\geq$ 70 m from roads and other mapped features (e.g., fence lines) to avoid edge effects. Sample points were stratified by grazing treatment (grazed versus ungrazed) and fire history. Fire history was determined using an historic wildfire (1939-2000) GIS data set with samples categorized into no-fire, one-fire, or multiple-fire treatment classes (Table 1). Grazing treatment was determined using grazing allotment data provided by the USDI BLM. Each allotment was attributed as either being grazed (1) or not grazed (0).

Table 1.: Stratification of sampling points by treatment.

Treatment	Wildfire occurence (1939-2000)			
	0	1	>1	Total
Grazed	16	13	20	49
Ungrazed	34	28	17	79
Total	50	41	37	128

Field observations were made within an area approximately 900 m^2 in size (the area occupied by 1, 30x30 m Landsat pixel) centered over each sample point. Fuel load estimates were made following "Field Survey Project for Fuels Management Planning GIS Mapping Standards" (BLM 2001) and Anderson (1982). Visual estimates made at each sample point included: (1) fuel load, (2) presence/absence of live fuels, and (3) percent bare ground. Fuel load was determined by comparing field observations with Fire Behavior Fuel Model descriptions provided in Anderson (1982) which enumerated thirteen fuel model groups having fuel loads ranging from 0.74 (grass group model 1) to 58.1 tons/acre (logging slash group model 13). The fuel load class that best fit field observations was used as the fuel load estimate.

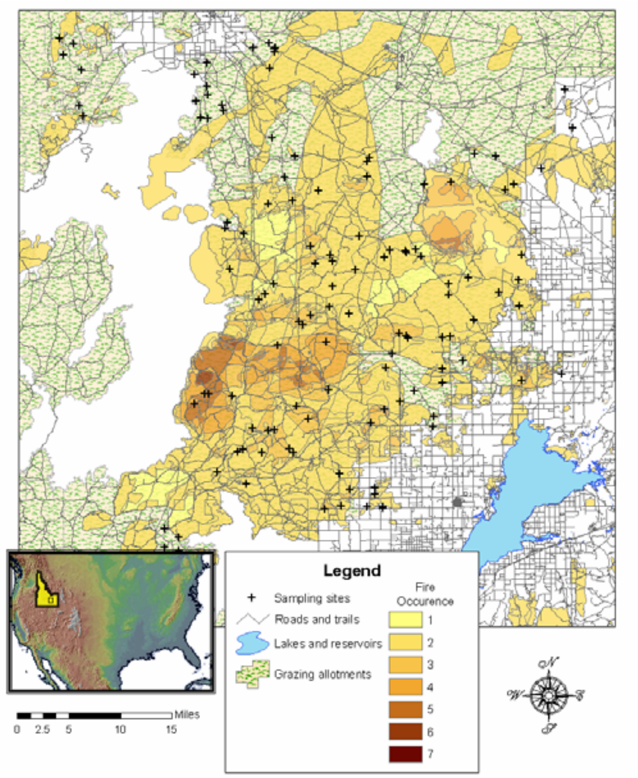

Figure 1. Sample locations, public land grazing allotments, and fire occurrence (1939-2000) for the study area.

Each sample point was classified into four categories representing the treatment type(s) found at that site; 1) grazed with previous wildfire, 2) grazed without previous wildfire, 3) no grazing with previous wildfire, and 4) no grazing or previous wildfire (i.e., control). A "previous wildfire" is one having occurred within the past 60 years, although most (59%) areas have had a fire in the past two years. Using these four categories, the effect of grazing and wildfire treatment on fuel load was tested using factorial ANOVA. We recognize the ordinal nature of our data violates the assumptions of both homogeneity of variance and normality. However, ANOVA is robust to these violations (Zar 1998) and should be fairly robust to a violation in homoscedasticity since each treatment contained approximately equal sample size. To further address these violations, we applied non-parametric Kruskal-Wallis and Mann-Whitney U with Bonferroni correction. While these non-parametric tests may have provided greater confidence and reliability in our results, they did not allow us to assess the interaction among treatments. For this reason, we examined the results from both factorial ANOVA and non-parametric tests.

RESULTS

Of 13 possible fire behavior fuel models we encountered three (types 1, 2, and 6) in the field (Anderson 1982). Fire behavior fuel models one and two belonged to the grass group, while model six belonged to the shrub group. The models used in this study correspond with National Fire Danger Rating System models of "annual" and "perennial" grasses, and "sagebrush/grass" and "inter. brush" shrub models (Deeming and Brown 1975, Deeming et al. 1977). Five ordinal fuel load classes were described during field sampling in the summer of 2001 (Table 2).

Table 2. Ordinal fuel load categories and associated fire behavior models

	Fuel Model Descriptions (Anderson 1982)		
	Grass group		Shrub group
Fuel load class	Model 1	Model 2	Model 6
1 (0.74 kg ha^{-1})	X		
2 (1.00 kg ha^{-1})	X	X	
3 (2.00 kg ha^{-1})	X	X	
4 (4.00 kg ha^{-1})		X	
5 (6.00 kg ha^{-1})			X

Grasses were the dominant fuel load component (>50% grass cover in all grazed areas and 26-50% grass cover in burned areas that had not been grazed) in all treatment types except the control, where shrubs were the dominant fuel load component (31-60% shrub cover)(Table 3). Grazed areas consistently had a higher percent grass cover (>51%, n = 49) compared to ungrazed areas (26-50%, n = 79).

Table 3. Median vegetation cover class by treatment type.

Treatment	Grass (%)	Shrub (%)	Forb (%)	*n*
Grazing and fire	>51%	1-5%	1-5%	33
Grazing without fire	>51%	1-5%	1-5%	16
Fire without grazing	26-50%	1-5%	1-5%	45
Control	26-50%	31-60%	1-5%	34

Seventy-eight sample points were in areas of previous wildfire. The mean number of years since a fire was 16.3 (fig. 2) with most sites (n = 46) having a fire in the previous 2 years. The remaining sample sites (n = 50) had no record or indication of a wildfire since 1939. Mean fuel load was 1.34 kg ha^{-1} (n = 44) in all areas with a wildfire in the past 2 years, 1.59 kg ha^{-1} (n = 19) in non-grazed areas with a wildfire in the past 2 years, and 1.25 kg ha^{-1} (n = 27) in grazed areas with a wildfire in the past 2 years.

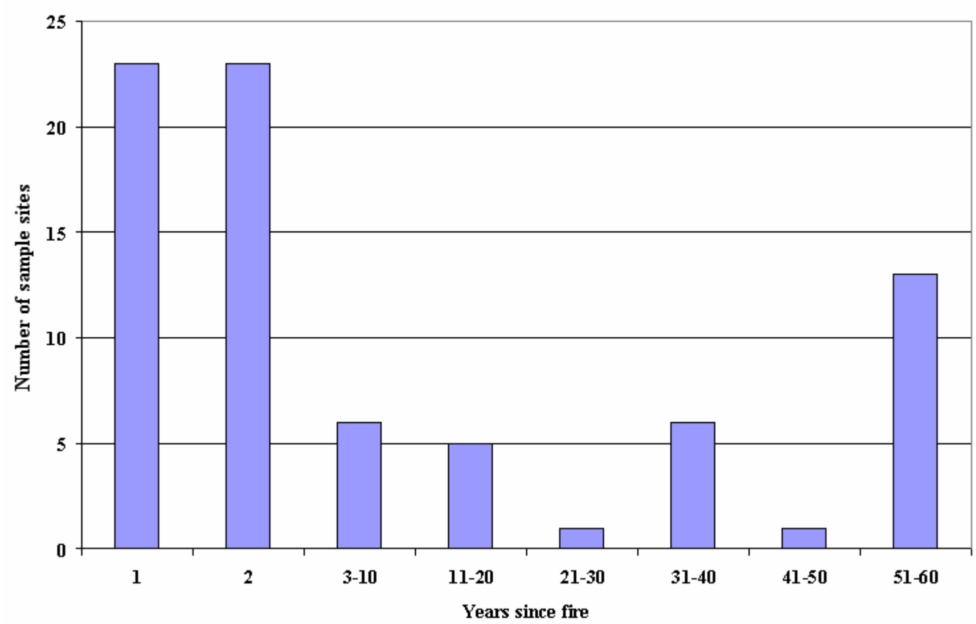

Figure 2. The number of years since a fire occurrence at sampling sites (1939-2000). Mean years since fire = 16.3. Fifty sample sites had not burned during this period (>60 yrs.).

Fuel load was decreased significantly by previous wildfire and/or grazing treatment (Fig. 3). The most significant treatment effect however, was grazing (P < 0.0005, Table 4). The effect of grazing and previous wildfire on fuel load was significant (P<0.05) as was the effect of fire alone (P<0.01) and the effect of grazing alone (P<0.01). Non-parametric Kruskal-Wallis analysis revealed a significant difference in fuel load among the four treatments and control categories (P<0.00005). A post-hoc non-parametric Mann-Whitney U test with Bonferroni correction was used to evaluate the effect of each treatment on fuel load. Once again, a significant effect was observed for both grazing (P<0.01) and fire (P<0.01) treatments. However, when tested against the effect of fire with grazing, fire alone did not produce significant results (P=0.84).

Table 4. Effect of treatment on fuel load[1].

Treatment	Type III Sum of Squares	df	Mean Square	F	P
Fire	13.77	1	13.77	7.62	0.00665
Grazing	33.10	1	33.10	18.32	0.00004
Grazing and Fire	8.48	1	8.48	4.69	0.03223
Error	224.03	124	1.81		
Total	287.15	127			

[1] Dependent Variable: Fuel load estimate.

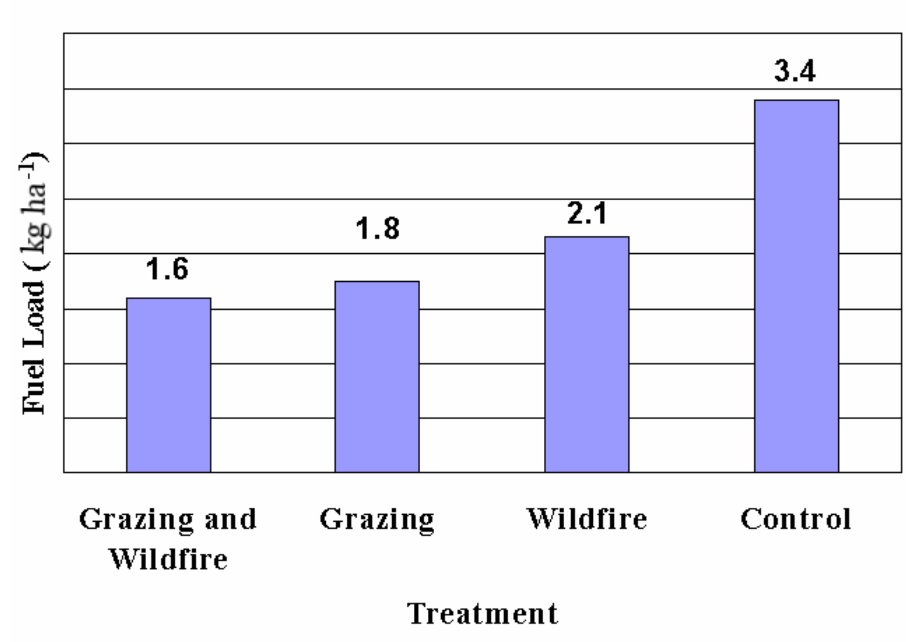

Figure 3. Mean fuel load (kg ha-1) by treatment type. Fuel load estimations are from field observations.

DISCUSSION

Historic fire suppression efforts have interrupted the natural fire cycle allowing fuel loads to reach unprecedented levels. Recent catastrophic wildfires, such as those seen in Idaho, Montana, Colorado, and Arizona, have the potential to produce extremely intense and severe burns. While these fires reduce fuel load, they may also sterilize soils (Wells et al. 1979). These extensive fires may result in loss of biodiversity and the destruction of critical habitat for native plants and animals, which often leads to invasion by cheatgrass (B*romus tectorum)* and other invasive species.

This study examined the effect of and interaction between two fuel load reduction treatments (livestock grazing and wildifire). We found livestock grazing to be as effective in reducing the primary fuel load component of the sagebrush-steppe ecosystem (herbaceous material) when compared to wildfire. Additionally, grazing reduces fuel load in a more selective fashion (Archer 1999) avoiding the potential sterilizing effect that an extremely intense fire may have on soil.

Studies in other regions have reported results that corroborate well with our findings. Within montane forests of Zion National Park, Madany and West (1983) considered livestock grazing the primary factor in the reduction of herbaceous cover. Tsiouvaras et al. (1989) reported that grazing by goats effectively reduced 1- and 10-hour fuel load in coastal forest areas of California. Similarly, Blackmore and Vitousek (2000) found grazing in dry forest ecosystems of Hawaii to be an effective means to reduce continuity of fuels, fire intensity, and fire risk.

CONCLUSIONS

In conclusion, livestock grazing can be viewed as a viable land management tool for fuel load reduction prescriptions when proper consideration has been given to other ecological effects not discussed here.

ACKNOWLEDGEMENTS

This study was made possible by a grant from the National Aeronautics and Space Administration Goddard Space Flight Center. ISU would also like to acknowledge the Idaho Delegation for their assistance in obtaining this grant.

LITERATURE CITED

Anderson, H.E., 1982. Aids to Determining Fuel Models for Estimating Fire Behavior, USDA Forest Service General Technical Report INT-122.

Andrews P. L. and L. S. Bradshaw. 1997. FIRES: Fire Information Retrieval and Evaluation System- A Program for Fire Danger Rating Analysis. USDA Forest Service, General Technical Report INT-GTR-367. August 1997, Ogden, Utah 84401.

Archer, S. 1999. Woody Plant Encroachment into Southwestern Grasslands and Savannas: Rates, Patterns, and Proximate Causes. pp 13-68 *in* Ecological Implications of Livestock Herbivory in the West (2nd Edition), Vavra M., W. A. Laycock, and R. D. Pieper (Eds.), Society for Range Management, Denver, Colo.

Bureau of Land Management (BLM), Upper Snake River District, 2001. Draft-Field Survey Project for Fuels Management Planning GIS Mapping Standards (May 9, 2001). 51pp.

Blackmore, M. an d P. M. Vitousek. 2000. Cattle Grazing, Forest Loss, and Fuel Loading in a Dry Forest Ecosystem at Pu'u Wa'aWa'a Ranch, Hawai'i. Biotropica 32(4a):625-632.

Burgan, R.E., Klaver, R.W., and Klaver, J.M. 2000. Fuel Models and Fire Potential from Satellite and Surface Observations, USDA, FS, Rocky Mountain Research Station, Missoula, MT.

Burgan, R.E. and Shasby, M.B. 1984. Mapping Broad-Area Fire Potential From Digital Fuel, Terrain, and Weather Data, J. For. 8:228-231.

Deeming, J. E. and J. K. Brown. 1975. Fuel Models in the National Fire-Danger Rating System. J. For. 73:347-350.

Deeming, J. E., R. E. Burgan, and J. D. Cohen. 1977. The National Fire-Danger Rating System-1978. USDA Forest Service, General Technical Report INT-39. October 1977. Ogden, Utah 84401.

Madany, M. H. and N. E. West. 1983. Livestock Grazing-Fire Regime Interactions within Montane Forests of Zion National Park, Utah. Ecology 64(4):661-667.

Tsiouvaras, C. N., N. A. Havlik, and J. W. Bartolome. 1989. Effects of Goats on Understory Vegetation and Fire Hazard Reduction in a Coastal Forest in California. Forest Science. 35(4):1125-1131.

Wells, C. G., R. E. Campbell, L. F. DeBano, C. E. Lewis, R. L. Fredriksen, E. C. Franklin, R. C. Froelich, and P. H. Dunn. 1979. National Fire Effects Workshop (1978:Denver, Colo.). USDA Forest Service General Technical Report WO-7. 34pp.

Zar, J. H. 1998. Biostatistical Analysis (4th Edition). Prentice-Hall, 929 pp.