Joint Fire Science Program
-Final Report-

Project Title: Patch Burning on Grasslands: Effects on Fuels, Fire Behavior, and Fire Spread

Project #: 03-1-4-09

Project Locations: Oklahoma State University Research Range, Stillwater, Oklahoma; Marvin Klemme Research Range, Bessie, Oklahoma; Tallgrass Prairie Preserve, Pawhuska, Oklahoma; Wichita Mountains National Wildlife Refuge, Lawton, Oklahoma

Principle Investigators: Dr. David Engle, Dr. Samuel Fuhlendorf, Dr. Terrance Bidwell, Dr. David Nofziger

Overview

Patch burning is a new approach to rangeland management that enhances biological diversity and controls invasive species while maintaining livestock production. The premise behind patch burning is the long history of herbivory by large ungulates and the fire–grazing interaction on native rangelands. Traditional rangeland management generally attempts to minimize inherent rangeland heterogeneity, which counters the evolutionary history of rangelands. Patch burning allows free selection by large ungulates among burned and unburned patches within a landscape unrestricted by fencing. Because ungulates prefer to graze within recently burned patches, intense grazing moves across the landscape following the pattern created by burning patches. The result is a shifting mosaic of patches at different stages of recovery from burning and grazing disturbance. Our work supported by the Joint Fire Science Program explored whether an emphasis on a heterogeneity-based approach to managing grasslands (i.e., patch burning) is a useful tool for wildland fire management while serving as a framework for rangeland conservation.

Research Approach

Fuhlendorf and Engle (2001) hypothesized that landscapes managed under a patch-burning approach would have less spatial heterogeneity than landscapes managed under traditional, homogenous approach when viewed at sub-pasture resolution but greater heterogeneity when viewed at the pasture level. This hypothesis implies that not only is heterogeneity per se important, but

that the specific spatial scale of heterogeneity is relevant. Thus we identified two fundamental questions relating to using patch burning as a land management tool; 1) the effect of altering spatial scale of fuel load heterogeneity on pattern of spread of prescribed fire and wildfire, and 2) the influence of patch burning on spatial heterogeneity of fuel load.

To evaluate the effect of spatial fuel load heterogeneity on fire behavior we employed two distinct experimental approaches. Computer simulations of fire spread through randomly generated landscapes with varying scale of fuel load heterogeneity were used to test the effect of spatial scale on fire behavior. Strengths of simulation studies include absolute control over experimental conditions (i.e. weather and fuel load) and ability to collect abundant samples for relatively low cost. However, realism and application of simulations are notable weaknesses. Our second experimental approach was a field test designed to complement the simulation experiment. Fine fuel loads were manually manipulated to alter the spatial scale of fuel heterogeneity and then burned while holding constant as many external variables, most notably weather conditions, as possible. To evaluate the changes in spatial heterogeneity of vegetation we used vegetation plot clipping to estimate fuel loads. Plot sampling was stratified to explicitly evaluate the heterogeneity of fuels across multiple spatial scales.

Results and Summary

Effect of spatial fuel heterogeneity on fire behavior: computer simulation

We created four heterogeneous landscapes modeled after those created by a fire-grazing interaction that differed in grain size of fuel patches. Fire spread was simulated through each model landscape from 80 independent, randomly located ignition points (Figure 1). Burn area, burn shape complexity and the proportion of area burnt by different fire types (headfire, backfire and flankfire) were all affected by the grain of fuel patch. The area fires burned in heterogeneous landscapes interacted with the fuel load present in the patch where ignition occurred. Burn complexity was greater in landscapes with small patch grain than in landscapes with large patch grain. The proportion of each fire type (backfire, flankfire and headfire) was similar among all landscapes regardless of patch grain but the variance of burned area within each of the three fire types differed among treatments of patch grain. Our landscape fire simulation supports the

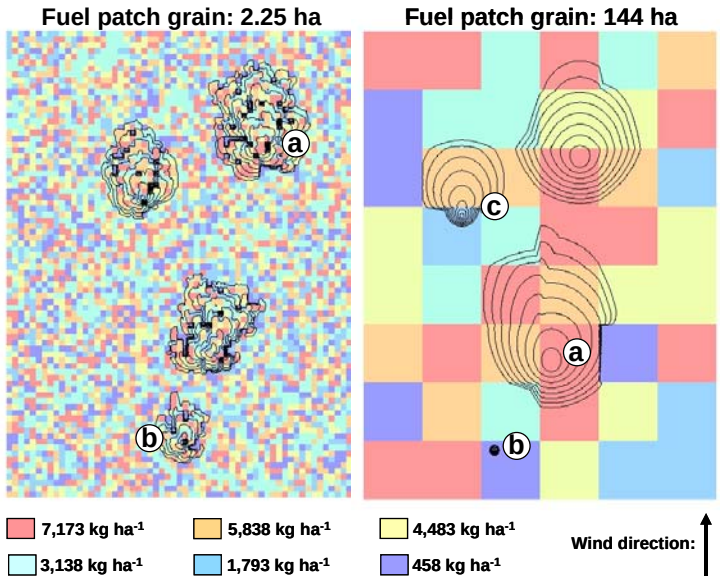


Figure 1. Illustration of landscape fuel maps with different fuel patch grains and different fuel load within fuel patches (458 to 7,173 kg ha^{-1}). Concentric rings demonstrate fire perimeter at 30-min intervals for of 4 hours $fire^{-1}$. All treatments of fuel patch grain (2.25-ha and 144-ha are shown as examples here) had equal fuel loading when averaged across the entire landscape (3,813 kg ha^{-1}). Fuel patch grain and ignition point fuel load influence burn area, fire shape complexity, and proportion of headfire, backfire and flankfire. Note that each fire was simulated independently and that multiple fire perimeters on these maps are for demonstration only.

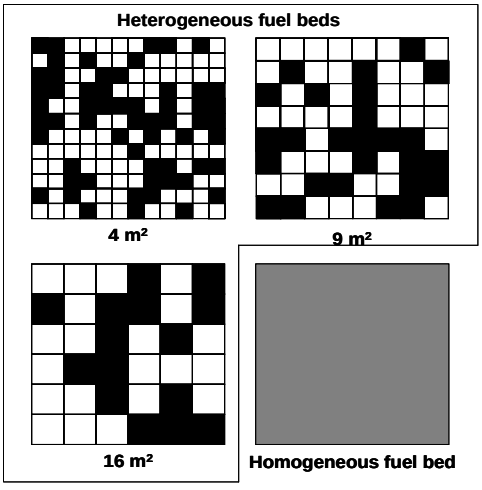
supposition that feedbacks between landscape patterns and ecological processes are scale-dependent, in this case spatial scale of fuel loading altering fire spread through the landscape.

Effect of spatial fuel heterogeneity on fire behavior: field experiment

We manipulated spatial scale of fuel heterogeneity while holding fuel load constant in a field experiment to test the effect of scale on fire behavior. We used spring wheat harvest residue at the Perkins Experimental Research Station (Perkins, Okla.), which was initially homogenous, as our fuel bed. Randomly generated patterns of fuel distribution were manually cut from the wheat residue to create heterogeneous fuel patterns (Figure 2). Three spatial scale treatments (patch scale 4 m^2, 9 m^2 and 16 m^2) and 1 homogenous fuel treatment were burned during a narrow window of similar weather conditions over two days

Figure 2. Photograph of experimental burn plots taken from elevated observation platform.

Figure 3. Example of fuel treatments applied to wheat stubble plots. Blackened areas indicate patches within plots where fuel was removed.



(Figure 3). Fires were carefully observed and video recorded to collect data on rate of spread, flame length, fire spread type (headfire, flankfire, backfire) and proportion of plots burned. Rate of fire spread and proportion of plot burned by headfire were greater in homogeneous treatments than heterogeneous treatments. However, there were no differences among three scales of patchiness in heterogeneous treatments (Figure 4). Our results suggest that the presence or absence of fuel heterogeneity is paramount to specific differences of scaling of such heterogeneity.

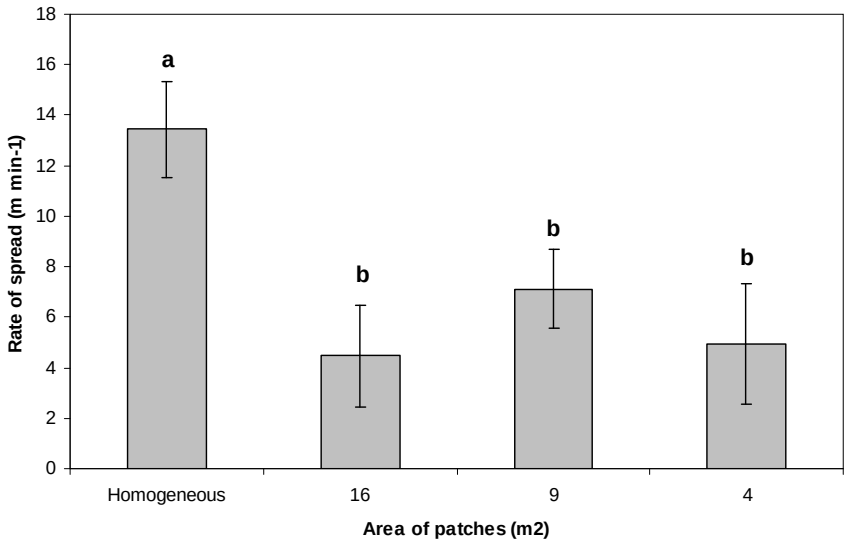


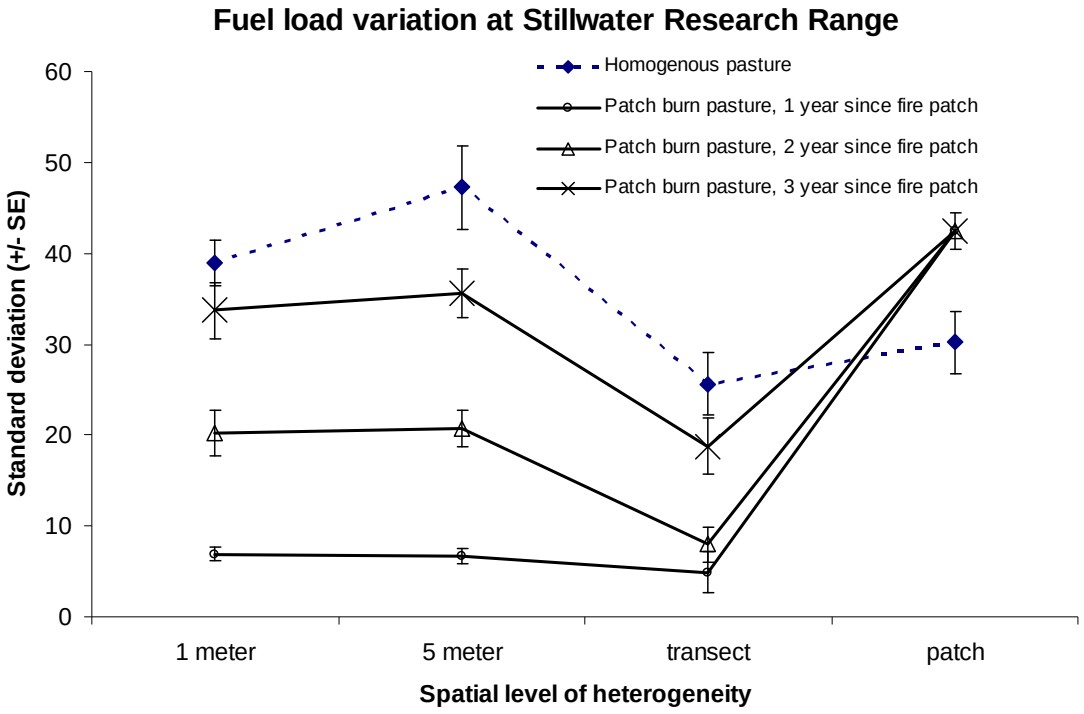
Figure 4. Mean rate of spread (ROS) across fuel treatment plots (+/- 1 SE). Letters indicate differences among means

Spatial scale and fuel variation under patch-burning management

To evaluate the changes in spatial heterogeneity of vegetation we used vegetation plot clipping (plot size = 0.25 m^2) to estimate fuel loads. Data were collected at 3 sites where patch-burning is employed (Tallgrass Prairie Preserve, Pawhuska; Stillwater Research Range, Stillwater; Marvin Klemme Research Range, Bessie). These three sites represent a strong productivity and

precipitation gradient across Oklahoma. Plot sampling was stratified to explicitly evaluate the heterogeneity of fuels across four spatial scales (1 m, 5 m, transect level, patch level). Standard deviation was calculated to estimate the spatial variation among plots at each spatial scale. Spatial heterogeneity at smaller resolutions (1 m, 5 m, transect level) was generally greater in pastures managed with traditional, homogeneous fire and grazing, but patch-level heterogeneity was greater in patch-burn pastures. Heterogeneity at spatial scales smaller than the patch was least in recently burned patches (1 year since fire) and increased with longer time since burning (Figure 5).

Figure 5. Spatial scale of fuel load variation in homogeneously managed pastures and patch-burned pastures. Heterogeneity at smaller spatial scales is greater in homogeneously managed pastures but greater at the patch-level in patch burn pastures. Vertical bars represent +/- one standard error.



Important research conclusions

- Juxtaposition of a fire ignition point strongly influences the outcome of fires in larger scale landscapes but the influence of ignition point juxtaposition diminishes with smaller patch scale.
- The importance of fuel heterogeneity is likely subject to amplification or nullification depending on other fire-related variables such as weather.
- Analysis of fuel heterogeneity confirms the hypothesis by Fuhlendorf and Engle (2001) that patch-burning management enhances spatial variability within pastures as opposed to homogenous management.
- Synthesis between our simulation, fuel modification experiments and observations of actual fuel heterogeneity shows that presence of heterogeneity, such as that created by patch-burning, can markedly alter fire spread. Fire followed by focal grazing under patch-burning management increases spatial heterogeneity at the pasture level, which is more beneficial to fire management efforts than presence of heterogeneity at smaller resolutions, such as that created by traditional, homogeneous management.

Status of Research Objectives

Our overall goal was to quantify the consequences of heterogeneous fuel patterns created by patch-burning for fire spread and fire behavior on grassland landscapes. Our objectives stated in the research proposal and our efforts to meet those objectives are as follows:

1. **Objective**: Evaluate heterogeneity of fuels in response to the grazing-fire interaction.

   Status: Accomplished by estimating fuel loads across a wide range of grassland sites managed with patch-burning.

2. **Objective**: Evaluate fire behavior in response to changes in fuel characteristics created by the grazing-fire interaction.

   Status: Accomplished through computer simulation of heterogeneous fuels and fire spread and through field experimentation.

3. **Objective**: Develop a model of fire spread across grassland landscapes.

   Status: We used existing fire spread models such as FARSITE to evaluate the potential for patch-burning and heterogeneity to affect fire behavior. In fact, reviewers of this proposal suggested that this objective was unnecessary. While we found that existing models were sufficient to test such hypotheses, our results suggest that the spatial scale of fuel heterogeneity is highly interactive with other factors (e.g., fire ignition point and weather). Because of the limits of spatially explicit data to support existing model application in an operational sense, this merits further research, beginning with a conceptual model of fire behavior and spatial scale with the goal of improving model application for predicting fire behavior in heterogeneous fine fuels.

4. **Objective**: Compare model output of fire spread across landscapes managed with traditional practices that promote homogeneity compared to fire spread across landscapes managed with patch burning to create heterogeneity, and determine the optimum landscape pattern of patch burning to reduce fire potential.

   Status: Achieved by comparing landscapes managed with patch-burning to those managed for homogeneity using computer simulation and using field observations.

5. **Objective**: Develop effective technology transfer mechanisms to address technology deficits with regard to fuel modification on a landscape basis, and deliver traditional technology transfer programs to fire management personnel.

   Status: Achieved effective technology transfer via a broad range of approaches, including field tours and consultations, publication of peer-reviewed journal articles and general audience articles, invited and volunteered oral presentations, and web site development. Please refer to the following summary of deliverables for more details.

Technology Transfer and Impact

As stated in the objectives for this project (objective 5), we engaged in a broad range of technology transfer efforts including interaction with the scientific community via oral presentations at many meetings and symposia, publication of findings in respected, peer-reviewed journals, hosting a field tour, and participating in consultations with various agencies and organizations regarding land management changes to incorporate patch-burning. Within a relatively short time frame, we influenced meaningful, observable change to on-the-ground management across a wide region in the central US (See map below). Several examples follow.

- Wichita Mountains Wildlife Refuge: Following multiple consultations, refuge and regional USFWS personnel have begun to implement a patch-burning management approach on much of the refuge's 60,000 acres to enhance habitat for native species, including free-ranging bison.
- Charles M. Russell Wildlife Refuge: Have begun to implement management and research on fire and grazing, specifically adopting a patch-burning approach in conjunction with grazing by cattle and elk to conserve rare and sensitive species.

- DeSoto National Wildlife Refuge: Refuge staff plans to explore patch-burning as an alternative to burn-only management of restored prairie. They see improved habitat for grassland birds as a primary benefit.
- Neal Smith National Wildlife Refuge: The first patch burn was applied in 2007 to the Refuge's bison unit. Preliminary reports indicate the bison are preferentially grazing the burned patch, and the Refuge biologist is encouraged by the results.
- Iowa River Corridor. This former cropland landscape, placed in the Wetland Reserve Program following the floods of 1993, is cooperatively managed by the US Fish & Wildlife Service, Iowa DNR, and USDA-NRCS. Working with these agencies. A patch-burning experiment was initiated by Iowa State University and Oklahoma State University in 2007.
- The Nature Conservancy: TNC has been a pivotal cooperator on patch-burning research since 2001. TNC manages most of the 39,000 acre Tallgrass Prairie Preserve using a patch-burning approach, and TNC (together with US Fish & Wildlife Service, Iowa DNR, and Missouri Department of Conservation) is a cooperator on ISU-OSU research conducted on public and private land in the 70,000-acre Grand River Grasslands of southern Iowa and northern Missouri.
- Other important interactions and consultations regarding patch-burning with state and federal agencies in Iowa, Kansas, Missouri, Nebraska, New Mexico, Oklahoma, and Texas.

★ -Sites of patch-burning research funded specifically by JFSP

● -Locations where patch-burning has been implemented or consultations regarding patch-burning have occurred, partially supported by JFSP funding

Oklahoma State University and Iowa State University scientists interacting with USFWS refuge managers, fire personnel and biologists on the Patch-burning field tour, July 2006

Deliverables Table

Selected publications	**Status**
Landscape heterogeneity and fire behavior: scale-dependant feedback between fire and grazing processes	Published Kerby, Fuhlendorf and Engle. 2007. Landscape Ecology (22) 507-516
Does changing scale of fuel patchiness affect fire behavior?	In review Kerby, Fuhlendorf, and Engle Journal of Applied Ecology
Shifting spatial scale of heterogeneity with a patch-burning approach to grassland management	In prep Kerby, Fuhlendorf, and Engle. Anticipate manuscript submission by Sept 1, 2007
Patch-burning: Using fire and grazing to restore diversity in prairie.	Published Engle. Pages 6-7, *in* Prairie Network News, Fall Edition 2006. Iowa Prairie Network

Selected public presentations and published abstracts

Fuhlendorf, S.D. 2004. **Visiting Scientist Program**. Moving cattle with fire: Fire, grazing and land management in the Southern Plains. Eastern Oregon Agricultural Research Station. USDA-ARS. Burns Oregon.
Fuhlendorf, S.D. 2004. Planning Grassland Ecosystem Diversity based on an historical framework. **Plenary Session**: The 2nd Grassland Symposium of the Thunder Basin Grasslands Prairie Ecosystem Association. May 12-13, 2004. Parkway Plaza, Casper, Wyoming
Fuhlendorf, S.D. 2005. **Keynote Address**: Heterogeneity and conservation of grassland ecosystems. Conference: Great Plains Grasslands Conservation: Progress, Priorities, and Strategies for the Future. Fort Collins, Colorado. February 22-25, 2005.
Fuhlendorf, S.D. 2005. **Keynote Address:** Fire-grazing interaction for heterogeneity. Fire Learning Network. Tallgrass Prairie Preserve, March 29, 2005. Pawhuska Oklahoma.
Fuhlendorf, S.D. 2005. **Keynote Address:** Promoting heterogeneity on rangelands. US Forest Service- 2005 National Grassland Managers Meeting. May 10-12. Pueblo Colorado.
Kerby, J.D., S.D. Fuhlendorf and D.M. Engle. 2005. **Poster Session.** Simulation of fire behavior in response to fuel variation caused by a fire-grazing interaction. International Association of Landscape Ecology Annual Meeting, Syracuse, New York. March 15, 2005.
Kerby, J., D. Engle, S. Fuhlendorf. 2005. **Oral Presentation**: Spatial variation of fire behavior on simulated grassland mosaics. Ecological Society of America Annual meeting, Montreal, Canada. August 7-12, 2005
Fuhlendorf, S.D. and D.M. Engle. 2005. **Closing Keynote Address**: Using the fire-grazing interaction to restore heterogeneity on rangelands. TallTimbers Fire Ecology Conference, Bartlesville Oklahoma, October 17-20, 2005.
Engle. D. M. **Invited Presentation**: Patch burning (rotational grazing without fences): A win-win for grazing agriculture and grassland species conservation. "Our Value Added Environment", 60th Annual Meeting of the Iowa SWCD, Ames. November 16, 2006.

Selected public presentations and published abstracts cont.

Bidwell, T.G. 2007. **Invited Presentation**: Wildland fuel reduction: proactive management to reduce the impacts of wildfires. Building a disaster resistant community: bridging research and practice. Tulsa Partners, Inc., Academic Symposium, Tulsa, Oklahoma.
Cummings, D.C., S.D. Fuhlendorf, K.R. Hickman, and D.M. Engle. 2007. **Oral Presentation**: The altered grazing selectivity hypothesis: A management option for exotic invasive forage species. 60th Annual Meeting of the Society for Range Management.
Fuhlendorf, S.D. 2006. Restoring heterogeneity on rangelands. **Keynote Speaker of the Plenary Session**. Grassland Society of Southern Africa. Warmbaths, South Africa. July 17, 2006.
Fuhlendorf, S.D. 2006. **Invited Presentation**: Restoring heterogeneity on rangelands. University of Kwa-Zulu Natal, Pietermaritzburg, South Africa. July 23, 2006.
Fuhlendorf, S.D. 2006. **Invited Presentation**: Restoring heterogeneity on rangelands. University of Fort Hare, South Africa. July 28, 2006.
Bidwell, T.G. 2007. **Invited Presentation**: Eastern redcedar control and management. Tallgrass Legacy Alliance, Wichita, Kansas.
Fuhlendorf, S.D. 2007. **Invited Presentation**: Restoring heterogeneity to rangelands: Ecosystem management based on evolutionary fire-grazing interactions. Scientific Seminar Series, Archbold Biological Station. March 22, 2007.

Field tour and selected educational materials

Field tour: Patch-burning and heterogeneity on Oklahoma grasslands. July 5-7, 2006 Coordinated by Sam Fuhlendorf, Dave Engle, Terry Bidwell, refreshments, educational materials and transportation funded by JFSP	Toured sites at The Tallgrass Prairie Preserve, Stillwater Research Range, Marvin Klemme Research Range, and Witchita Mountain Wildlife Refuge. Interacted with: -Jeff Rupert and Ralph Bryant, refuge manager and assistant manager, Wichita Mountain Wildlife Refuge -Ralph Godfrey, refuge FMO, Rob Wood, assistant FMO, Richard Baker, Rx Fire tech -Joe Kimball and Chip Kimball, refuge biologists -Mark Kaib, regional fire ecologist, USFWS -visiting scientists from Iowa State University
OSU Fire Ecology Website http://fireecology.okstate.edu/index.html	Development partially supported by this grant, includes summaries and results of research directly and indirectly related to this grant.
Prescribed fire ignition techniques video	Under development in cooperation with OSU Ag Comm, partially supported by this grant, demonstrates various techniques for Rx fire ignition patterns.