

TITLE: Assessing indicator sensitivity for monitoring the effects of fire and species reintroductions on soils and plant communities during intensive restoration of oak savannas in Central Iowa

LOCATION: Iowa DURATION: 3 years FUNDING SOURCE: Fire Plan Evaluation Monitoring

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PROJECT OBJECTIVES: This study will evaluate the use of detection monitoring (DM) indicators to quantify changes during dynamic shifts in ecosystem state from degraded to experimentally restored oak savannas.

Specific objectives include:

- (1) Continue to evaluate concurrent measurements of Forest Health Monitoring indicators and more detailed, process-level indicators of forest health (species composition/structure, soil properties, fire dynamics) in replicate degraded/restored oak savanna research areas (n = 4 degraded savannas, n = 4 savannas undergoing restoration) to assess community and ecosystem response to woody encroachment and savanna restoration (thinning, burning, reseeding) (monitoring currently supported by FHM grants 03JV11231300012 and 03JV11231300023).
- (2) Initiate experiments to evaluate ecosystem change resulting from reestablishment of native understory species through reintroduction of diverse species mixes and reimplementation of understory fire regime.
- (3) Compare assessments of ecosystem function and restoration success obtained from DM indicators to more detailed ecosystem measurements to determine their sensitivity to restoration by species reintroductions and fire.

JUSTIFICATION: The health of oak savannas of the Central Plains states is of regional concern due to low rates of oak regeneration and widespread invasion by shade tolerant tree species, both of which alter the quality, composition, structure, and ecological functions of these forested systems. Restoring degraded savannas may have important management implications for *enhancing landscape-level biodiversity*, which may have cascading effects on *regional concerns with soil and water quality*. However, monitoring information is needed on current forest conditions and the effects of restoration treatments, to guide future management decisions.

The Forest Health Monitoring (FHM) program is responsible for reporting on indicators of forest health as part of the Montreal Process Criteria and Indicators of Sustainable Forest Management. DM indicators were designed to provide an easily measured, inexpensive, and repeatable index of ecological conditions that could be monitored over time to detect trends. In order for these measurements to be successfully used, indicators must be sensitive to both natural disturbances and management practices. However, few experiments have been conducted to evaluate the effectiveness of DM indicators at detecting and quantifying changes in site conditions resulting from known disturbances and intensive management practices that *specifically implement fire*. Without direct comparison to data collected from long-term controlled experiments, it is not possible to assess the utility of DM data for use in ecological contexts (O'Neill et al. 2005).

Development of a monitoring strategy to assess the ecological responses of degraded oak savannas to restoration treatments and landscape change is compatible with the following objectives of the Fire Plan Evaluation Monitoring component of the FHM program: (1) *fire risk*, which is an important consideration when using fire for management in suburban/agricultural landscapes, (2) *influence of fire* on dynamic ecosystem states (woodland/savanna), soil properties, and species composition, (3) effective control of *invasive species* (encroaching trees), and (4) evaluating *restoration* of degraded ecosystems undergoing prescribed fire and species reintroductions.

DESCRIPTION: Savannas were once a dominant ecosystem on the Midwestern landscape, occurring within the dynamic boundary between prairies to the west and forests to the east. Savannas are maintained in the landscape by complex interactions between fire, climate, topography, and human activities and are characterized by a continuous herbaceous layer and scattered oak trees (Anderson 1998). Today, savannas are extremely rare (<1% remain after extensive conversion to agriculture; Nuzzo 1986) and persisting remnants are often highly degraded by fire suppression, over-grazing, habitat fragmentation, and subsequent invasion by native and exotic woody species (Anderson 1998, Gobster et al. 2000). Savanna

restoration generally involves mechanical removal of encroaching woody vegetation and reintroduction of fire (McCarty 1998). However, reintroduction of native understory species may also be a critical tool during restoration (Brudvig and Mabry 2008). Without this final step, restoration efforts could fail to reestablish the characteristic herbaceous layer, which is an important fuel source for fire in this ecosystem (Anderson 1998).

A project was initiated in 2004 to assess the efficacy of FHM and ecosystem-process indicators to detect ecological responses to oak savanna restoration (USFS FHM grants 03JV11231300012 and 03JV11231300023). To date, short-term goals relating to restoration of overstory composition and structure have been achieved (Asbjornsen et al. 2005, Brudvig and Asbjornsen 2007). However, long-term structural outcomes are unresolved (Brudvig and Asbjornsen 2005, 2008, *In press a*), and reestablishment of native understory species and historic fire regime remain elusive (Brudvig *in press*, Brudvig and Asbjornsen *In press b*). Based on initial results from this long-term ecological study (see below), we propose that the savannas in this study have transitioned to an alternative stable woodland state (e.g., degraded condition resilient to traditional management; Suding et al. 2004), which will necessitate a second, more intensive phase of restoration. Alternative stable states commonly occur because of factors such as agricultural land-use and altered fire regime and more research is needed to understand restoration of these problematic systems (Suding et al. 2004).

We propose to expand our FHM-ecosystem study on indicators for detecting change, *by specifically investigating reestablishment of a native savanna understory and subsequent reimplementation of the historic understory fire regime*. Thus, building upon our current study, we propose to conduct a detailed analysis of soil and plant communities in our experimental savannas undergoing restoration by fire and seed sowing, *enabling us to better assess the degree of sensitivity of DM indicators to these key restoration activities*. Additionally, this study will allow us to *assess DM indicator sensitivity to major changes in ecosystem state*. Our experimental savannas are an excellent study system for this purpose, as the Midwestern landscape was historically defined by shifting mosaics of alternate stable ecosystem states (prairie, woodland, savanna; Anderson 1998). This represents a major innovation, as it will allow us to test the sensitivity of FHM monitoring in dynamic landscapes. Characterizing the utility of FHM indicators for assessing targeted research like this is a recognized priority (O'Neill et al. 2005).

b. Methods. This research is being conducted within 8 oak savanna research areas in Central Iowa, along Saylorville Lake¹. These sites are characterized by an overstory of widely dispersed, open grown savanna tree species (e.g., *Quercus alba*, *Quercus macrocarpa*), which has been aggressively invaded by younger shade tolerant species (e.g., *Ulmus americana*, *Ostrya virginiana*, *Fraxinus americana*). Experimental research areas (2.0 – 3.5 ha, n = 8) are located on upland ridge tops within a woodland/degraded savanna matrix. Restoration treatments involving removal of invading woody vegetation have been conducted on half of the areas (the others serving as controls) and prescribed understory fires will commence fall 2008. FHM survey plots have been established in all treatment and control areas following standard FHM protocol. A long-term ecological study was initiated at the same sites in 2002 to conduct detailed, process-level measurements on key indicators of forest health. Pre- and post-treatment data (vegetation in five classes: trees, saplings, shrubs, seedlings, herbaceous; soil nutrients; soil moisture) have been collected annually within 10-m wide transects running the length of each treatment and control site. This ecosystem study is linked to the FHM program through concurrent monitoring of Phase 3 indicators (understory vegetation, soils, overstory structure and growth, DWM, crowns, damage) following DM measurement protocols.

To complement the above ongoing measurements (supported by previous FHM grants), we propose to assess the ecosystem impacts of reintroducing native savanna understory species in degraded and restored savannas, based on measurements of soil properties (nutrients, organic matter, moisture), understory species composition, fuel loading, and fire dynamics. We have identified understory species of high restoration priority and suggest that by reintroducing these species, management might successfully shift these sites away from the woodland and toward the desired savanna state (Brudvig and Mabry 2008). We propose to use a split-split-plot design, where main plots are the restored savannas or degraded control areas (n = 4 for each), split-plots are prescribed fire units (half of each main plot), and split-split plots are 10 x 10 m plots that are either seeded with two different diverse understory seed mixes or remain as controls (3 total seeded plots per prescribed fire unit). To understand interactions between species reintroduction and reimplementation of the historic fire regime, we will monitor the following response variables: under-, mid-, and overstory species diversity, stand structure, fuel loading, fire intensity (using pyrometers - temperature-sensitive paints applied to metal probes), and soil properties (nutrients, organic matter, moisture). Specifically, we hypothesize that seed additions will: 1) increase diversity of understory savanna species (Brudvig and Mabry 2008), 2) increase fuel loading and fire intensity (Rossiter et al. 2003), 3) control invasion by woody species, through direct stem mortality during fire and increased competition by the herbaceous layer (Scholes and Archer 1997), and 4) increase soil organic matter production and nutrient cycling rates (Scholes and Archer 1997). The mechanism that we propose to account for these effects is initiation of the grass/fire cycle – a positive feedback loop whereby herbaceous

¹ A 5,400 acre US Army Corps of Engineers flood control reservoir on the Des Moines River, 11 miles north of Des Moines, Polk County, IA.

vegetation (predominantly graminoids and prairie forbs; Tester 1996) is supported by frequent understory fires (D'Antonio and Vitousek 1992). Prescribed fire units will be established within existing FHM plots, in order to correlate measurements with other ecosystem and FHM indicators. Data collected from the Phase 3 plots will be compared to data obtained from the intensive ecosystem measurements to assess differences in detection capacity of ecosystem health and response to management treatments, with an emphasis on determining the sensitivity of DM indicators to changes in fire regime and species composition. By comparing the ecosystem and FHM sampling designs, results will provide specific recommendations regarding FHM sampling protocol to enhance detection capability. Furthermore, this will provide an opportunity to understand linkages between vegetation and soil indicators during intensive ecosystem management, which is a noted research need (O'Neill et al. 2005).

c. Products. This research will provide the first evaluation of DM indicator variables in experimentally thinned, burned, and reseeded plots in oak savannas and will contribute to the development, refinement and interpretation of forest health indicators in dynamic landscapes. Results from this study will inform federal research efforts on the efficacy of FHM indicator variables and aid land managers working with fire in suburban/agricultural landscapes, reduction of invasive woody species, and ecological impacts of fire for restoring oak savannas. Findings, including a broad assessment of this project (Brudvig et al. *in prep*), will be published in peer-reviewed journals, presented at meetings (including annual posters at the FHM Working Group Meeting), and made available to land managers and scientists on FHM websites.

d. Schedule of Activities:

- Year 1: Reintroduce native savanna understory species from seed. Initiate prescribed fire regime.
- Year 2: Monitor FHM and ecosystem indicators (soil, vegetation, fire). Initial data analyses and presentation of preliminary results. Soil and data analyses and presentation of results.
- Year 3: Complete data collection; analysis, and comparison of FHM and ecosystem data. Publication of results.

e. Progress/Accomplishments (Budget years 1-2). Msc. Graduate student Anthony Beringer began work in February 2008 to oversee this project. We initiated site preparation in February 2008 with the layout of prescribed burn units and seed addition plots. Based on Brudvig and Mabry (2008), we selected 25 savanna understory plants to form the diverse seeding mixture and purchased seeds from Ion Exchange (Harpers Ferry, IA). Anthony conducted the seed additions in March using a 'snow seeding' technique (Packard and Mutel 1998) and conducted extensive rethinning of the four encroachment removal areas between March and June (necessary due to regrowth since initial thinning in 2002-03). In July, five 1x1m plots were sampled for understory vegetation in each seed addition plot (240 total understory plots) and each 10x10m seed addition plot was surveyed shrubs and overstory trees. In addition, the FHM crew led by Peter Koehler resurveyed the Type 3 plots in each research area during August 2008. Anthony is presently working with the ISU and FIA data sets and a meeting is scheduled for October 2008 to begin data analysis. Prescribed fires are scheduled for November 2008 and pyrometers have been constructed to monitor fire intensity during these burns. Finally, Anthony has initiated additional graduate research to understand how carbon storage is altered by thinning, burning, and seed addition at these sites.

To date, 12 manuscripts have been published (including four in 2007, two in 2008, three *In press*) related to the savanna restoration research. Results have been and will continue to be presented at prominent meetings (Society of American Foresters, Ecological Society of America, etc.). We are conducting data analysis for presentation at the 2009 FHM meeting.

COSTS:

	Item	Year 1	Year 2	Year 3	TOTAL ²
Administration	MSc. graduate student assistantship; 11.5% benefits ³		\$19,513	20,098	39,611
	Out-of-state travel and expenses to Iowa study sites (L.A. Brudvig; 2 x / year)	\$1,500	1,500	1,500	4,500
	½ time Field technician (4 mo @ \$9/hr + 4.6% benefits)	3,012	3,102	3,196	9,310
Procurements	Savanna seeds (for understory species establishment)	6,000			6,000
	Pyrometers (fire intensity measurements)	2,000	1,000	1,000	4,000
	Soil analyses (nutrients, organic matter)	4,000	4,000	4,000	12,000
	Supplies (soil probes, flags, tags, etc.)	2,000	1,000	1,000	4,000
TOTAL (USFS)		18,512	30,115	30,794	79,421
Cost-Share (ISU; 50%)	H. Asbjornsen salary (10.3% FTE), Indirect costs	22,355	28,218	28,959	79,532
TOTAL (w/ cost-share)		\$40,867	58,333	59,753	158,953

² Additional support for this project is provided by the US Army Corps of Engineers (implementation of annual prescribed fires).

³ We anticipate additional funding through Iowa State University to fund the MSc. student during the first year of this study.

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* Indicates paper supported by previous USFS FHM grants for this project.