

TITLE: Assessing indicator sensitivity for monitoring the effects of woody encroachment and restoration on forest health in oak savannas and woodlands in Central Iowa

LOCATION: Iowa **DURATION:** Year 2 of 3 **FUNDING SOURCE:** Fire Evaluation Monitoring

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PROJECT OBJECTIVES: This study will evaluate the use of detection monitoring (DM) indicator measurements to quantify and monitor changes in ecosystem health in encroached (control) and experimentally restored (thinned and burned) oak savannas in central Iowa.

Specific objectives include:

- (1) Continue concurrent measurements of FHM indicators and more detailed, process-level ecosystem indicators of forest health (e.g., soil quality, species composition, stand structure, plant water uptake) to assess ecosystem functioning in response to woody encroachment and savanna restoration treatments (thinning and burning).
- (2) Initiate monitoring of additional process-level ecological indicators (soil respiration, soil carbon fractions, above- and below-ground productivity) to specifically detect effects of water and nutrient inputs from agricultural fields on carbon cycling and sequestration, productivity and forest health.
- (3) Compare assessments of ecosystem function obtained from DM indicator measurements to those derived from more detailed ecosystem measurements to determine their sensitivity to specific management practices, climatic variability and landscape processes.

JUSTIFICATION:

The health of oak savannas and woodlands of the central plains states is of regional concern due to low rates of oak regeneration and increasing domination of the understory by shade tolerant species, both of which alter the quality, composition, structure, and ecological functions of these forested systems. Restoring the composition and structure of these degraded ecosystems in critical landscape locations may have important management implications for enhancing water quality and flow and biodiversity in agricultural landscapes. However, monitoring information is needed on current forest conditions and the effects of restoration treatments to guide future management decisions.

The Forest Health Monitoring 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 if any experiments have been conducted to evaluate the effectiveness of current indicator protocols at detecting and quantifying changes in site conditions resulting from known disturbances and climatic variability. Without direct comparison to data collected from long-term controlled experiments, it is not currently possible to assess the utility of DM data as a monitoring tool for assessing ecosystem health.

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 Evaluation Monitoring (EM) component of the Forest Health Monitoring (FHM) program: (1) determine effects of disturbance (drought, management) on forest health, (2) document patterns of tree mortality in restored and encroached savannas, (3) monitor changes in soil conditions resulting from encroachment, restoration, and resource inputs from agricultural systems, (4) assess effects of (extensive) habitat fragmentation and land use conversion on forest function.

DESCRIPTION:

a. Background: Savanna ecosystems were once a dominant feature of the Western Corn Belt Plains Ecoregion, occurring within the dynamic boundary between prairies to the west and forests to the east, and maintained in the landscape by complex interactions between fire, climate, topography, and human activities. Characterized by their continuous grass layer and widely scattered oak trees, savanna ecosystems are today extremely rare, since the majority of these ecosystems have been converted to agricultural uses since the mid-1800's. Today, less than one percent of the original extent of savanna vegetation remains (Nuzzo 1986), mostly in a highly degraded state due to fire suppression, over-grazing, habitat fragmentation, and subsequent woody encroachment and invasion by exotic species (Anderson 1998,

Gobster et al. 2000). Restoring native savannas generally involves thinning and reintroduction of fire (McCarty 1998). A project was initiated in 2004 to assess the efficacy of FHM and ecosystem-process indicators to detect ecological responses to specific management practices and progress towards achieving short-term and long-term restoration goals.

Based on analysis of 2 years of preliminary data (see below), we propose to expand our FHM-ecosystem study on indicators for detecting change to examine in greater detail the extent to which woodland islands embedded within agricultural landscapes function as 'water pumps' and 'nutrient sinks', thereby increasing ecosystem productivity and carbon accumulation and potentially compensating for excessive nutrient and water loss from agricultural fields. Specifically, we seek to assess how carbon cycling and ecosystem carbon balance are affected by woody encroachment (carbon storage), thinning (immediate pulse of organic material followed by major shifts in plant composition and structure), and prescribed burning (combustion of organic material), as well as the potential long-term consequences for ecosystem health through effects on species composition and susceptibility to disturbance, disease, and exotic species invasions. Thus, building upon our current study, we propose to conduct a more detailed analysis of the carbon balance at our study sites in response to woody encroachment and savanna restoration, enabling us to better assess the degree of sensitivity of DM indicators to these key ecosystem processes. Additionally, more intensive sampling of fine-scale spatial variability in soil and understory vegetation parameters in relation to thinning and burn intensity is proposed in order to gain more in depth understanding of indicator sensitivity to environmental variability. Characterizing the implications of inter- and intra site variability for FHM indicators and their predictive capability is a recognized priority (O'Neill et al. 2004).

b. Methods. This research is being conducted at two sites in Central Iowa: the Neal Smith National Wildlife Refuge (NSNWR; Jasper County, IA)¹ and Saylorville Lake ('SL'; Polk County, IA)². Vegetation at the sites is characterized by an overstory of widely dispersed, open grown savanna tree species (*Quercus alba*, *Quercus macrocarpa*, *Carya ovata*, *Juglans nigra*), with a dense understory of younger shade tolerant species (*Ulmus americana*, *Carpinus virginiana*, *Fraxinus pennsylvanica*, *Celtis occidentalis*). Study plots are located on 6 parallel ridges with similar topographical orientation and biophysical conditions (SL) and in small woodland patches embedded within an agricultural matrix (NSNWR; total n=12). Restoration thinning treatments have been conducted on half of the sites (the others serving as controls), while prescribed burning is planned for fall 2006 (previously scheduled burns were delayed due to unfavorable weather conditions). FHM experimental plots have been established in treatment and control areas at both sites following standard FHM protocol. A long-term ecological study was initiated on the same sites to conduct detailed, process-level measurements on key indicators of forest health. For pre- and post-treatment data were collected within 10-m wide, 200m long transects in each treatment and control site. All trees >2.5 cm dbh were measured for dbh and height; shrubs and saplings were measured within 1-m on either side of the transect. Herbaceous cover and species composition was determined for 20 1m² plots along each transect. Soil moisture was measured using a neutron probe at 20 cm intervals to a depth of 1 m, and a thetaprobe used to measure surface soil moisture (0-10 cm). Transpiration of dominant tree species (*Q. macrocarpa*, *U. americana*) was measured using Granier-type sap flow sensors. This ecosystem study is linked to the Forest Health Monitoring program through concurrent monitoring of FHM Phase 3 indicators (understory vegetation, soils, overstory structure and growth, DWM, crowns, damage) following DM measurement protocols. Burn intensity will be measured this fall 2005 using a combination of buried data loggers supporting thermocouples and pyrometers (constructed by applying temperature-sensitive paints that fire-sensitive paints applied to metal probes) to assess the relationship between fire intensity and response variables (e.g., vegetation, soil nutrients, soil moisture).

In conjunction with continuing the above measurements for an additional 3-year period, we propose to assess ecosystem carbon cycling and in response to woody encroachment and savanna restoration, based on measurements of soil respiration (Infrared Gas Analyzer-Licor with PVC collars; Ryan and Law 2005), fine root productivity (root ingrowth cores; Raich et al. 1994), litterfall production (collection baskets), understory biomass production (destructive harvests) and fine-scale tree growth (dendrometer bands). Sampling of these parameters will occur within the study transects in order to correlate measurements with other ecosystem and FHM indicators. Additionally, the sampling design for understory vegetation and soils will be expanded to incorporate greater fine-scale spatial variability using geospatial statistics and semi-variogram analysis. Data collected from the P3 plots will be compared to data obtained from intensive ecosystem measurements to assess differences in detection capacity of ecosystem health and response to management treatments and environmental variability, with an emphasis on determining the sensitivity of DM indicators to changes in different components of the ecosystem carbon cycle and effects on other ecosystem health and function indicators.

¹ NSNWR is a unit of the National Wildlife Refuge System administered by the US Fish and Wildlife Service; created by an act of Congress in 1990, its long-term mission is to re-create 8000 acres of tallgrass prairie and oak savannas.

² SL is a 5,400 acre US Army Corps of Engineers flood control reservoir on the Des Moines River, located in Polk County, IA, 11 miles north of the city of Des Moines.

c. Products. This research is providing the first field comparison for DM indicator variables on experimentally thinned and burned plots in savanna-woodland ecosystems and will contribute to the development, refinement and interpretation of forest health indicators. Products from this study will inform federal research efforts on the efficacy of FHM indicator variables, as well as researchers and land managers working with ecosystem restoration and monitoring. Results will be presented at scientific and professional meetings and will be made available to land managers and scientists on FHM websites.

d. Schedule of Activities:

- Year 1: Continue data collection, monitoring, and evaluation of FHM and ecosystem indicators; initiate data collection of carbon cycling and ecosystem carbon balance and fine-scale spatial variability of vegetation and soil indicators. Continue data analysis and publication of preliminary results.
- Year 2: Laboratory analysis of soil, root and leaf tissue samples related to carbon balance assessments. Continued monitoring of soil and vegetation parameters and ecosystem processes to repeated prescribed burning.
- Year 3: Continue data collection; analysis and comparison of FHM and ecosystem data and publication of results.

e. Progress/Accomplishments. Based on our preliminary data analysis, we observed a consistent pattern in both the vegetation and soils data of a higher degree of variability (as indicated by the standard deviation and variance) for the ecosystem data compared to the FHM data. We are in the process of developing a more fine-scale, spatially-explicit sampling design for soils and understory vegetation to enhance our assessment of environmental variability and provide a stronger basis for making specific recommendations regarding FHM sampling protocol to enhance detection capability. The ecosystem study also detected higher levels of plant species richness than the FHM monitoring, while both methods detected similar patterns in stand structure. With regard to soils, both the FHM and ecosystem data for NSNWR revealed exceptionally high levels of P (42.0-48.8 mg kg⁻¹) and relatively high levels of N (0.36-0.41%) in the upper soil horizon compared to SL (6.2-7.1 mg kg⁻¹ and 0.17-.18%, respectively), potentially reflecting the different landscape matrices at the two sites (NSNWR: woodland patches surround by agriculture; SL: relatively contiguous upland woodlands). We propose that woodland patches embedded in agricultural landscapes may function as 'nutrient sinks' for excess nutrients from fertilizer applications and runoff, which could lead to increased plant productivity and soil respiration.

Estimated mean daily stand transpiration in the woodland was nearly 10-fold greater compared to the savanna (1-2 mm and 12-14 mm, respectively). These differences in plant water uptake patterns were further supported by groundwater level data, indicating levels up to 4 m lower under woodland compared to savanna. Interestingly, our values for woodland transpiration are exceptionally high compared to values typically reported in the literature (ranging 2-5 mm). We suggest that small patches of tall vegetation (savanna-woodlands) embedded within a matrix of open agricultural fields may result in high amounts of advective sensible energy at the field-forest edge providing a driving force for increased transpiration (i.e., an 'oasis effect'). Thus, these small woodland islands may essentially function as 'water pumps' – removing large amounts of excess water from the soil back to the atmosphere, and potentially reducing the losses of water (and nutrients). The function of these woodland islands in regulating hydrological processes and nutrient cycling in agriculturally dominated landscapes is currently poorly understood and essentially undocumented.

Thus far, two manuscripts have published, one is in press, and three are in preparation related to the savanna restoration research. Results were also presented at the World Conference on Ecological Restoration in Sept. 2005.

f. Progress Report

During the first year of this project, we have completed the following activities:

- Six new FHM plots (3 treatment and 3 control sites) were established and baseline data collected using FHM standard protocol, with assistance from the FHM crew.
- Understory vegetation was sampled for herbaceous and woody plants
- Intensive sample of soils was conducted, and soils are currently being analyzed in Dr. Cindy Cambardella's laboratory in the National Soil Tilth Lab (Ames, IA).
- Gradient analysis study was conducted to determine changes in herbaceous vegetation, soil nutrients, soil moisture, and soil texture along changes in microsite conditions under trees compared to open areas. Oak seedlings were transplanted into shady and open microsities to test effects of microclimate conditions on oak regeneration.
- A prescribed burn is planned for this fall of 2006, and we are coordinating with the Army Corps of Engineers and the U.S. Fish and Wildlife Refuge to conduct this burn as soon as conditions are favorable (anticipated timeline: between late October and early December). During the burn we plan to measure fire intensity and correlate those measurements with responses by the vegetation and soils.

COSTS:

	Item	Year 1	Year 2	Year 3	TOTAL ³
Administration	Summer salary 6 wks (H. Asbjornsen)	\$9,173	9,539	9,921	28,633
	Field technician (4 mo @ \$12/hr)	8,343	8,677	9,024	26,044
	Benefits	2,711	2,820	2,933	8,464
	Travel (field vehicle rental)	2,000	2,000	2,000	6,000
Procurements	Dendrometers (tree diameter growth measurements)	4,000			4,000
	Pyrometers (fire intensity measurements)	2,000			2,000
	Supplies (litter baskets, ingrowth cores, soil probe, etc.)	4,000	1,000	1,000	6,000
TOTAL (USFS)		\$32,227	\$24,036	\$21,878	\$80,141

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