United States Department of Agriculture

Final Report

Title:	**Provision of ecosystem services through pine savanna restoration on privately owned agroecosystems in the southeastern U.S. Coastal Plain**

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Non-Technical Summary

The original longleaf pine savannas of southeastern U.S. Coastal Plain have mostly been converted to other land uses, especially crop lands, pasture, pine plantation, and fire-excluded hardwood forests. There are concerns about the long-term sustainability of ecosystem services supporting these agroecosystems, such as plant diversity, pollinator diversity and abundance, soil health, storage of carbon in the soil to combat climate change, and maintenance of natural water cycles. Restoration of pine savanna is predicted to improve many such ecosystem services, although the benefits and their rate of increase with time since restoration remain largely unmeasured. The proposed study seeks to measure multiple ecosystem services provided by restoration of pine savanna on land that was previously farmed in the southeastern U.S., with a focus on how fast different ecosystem services change over time and effect of distance from native pine savanna communities which are a source of plants and animals.

The approach of the proposed study will be measure a large number of environmental variables relating to ecosystem services in areas that have been restored to pine savanna for different amounts of time over the past 100 years. The same variables will be measured in other common land uses (row crop agriculture, pine plantation, pasture, unmanaged forest) for comparison. The results will measure for the first time the broad range of ecosystem services provided by pine savanna restoration, as well as limitations, to provide guidance to policy in support of sustainable agroecosystems.

Accomplishments

Major goals of the project

The primary goals of the proposed project are to quantify multiple ecosystem services provided by restoration of pine savanna, assess the need for further study of effects of pine savanna restoration in agroecosystems at the landscape scale, and provide empirical data needed for the modeling portion of such a future study. The approach for the current project will be to measure multiple environmental variables that represent ecosystem services in restored pine savannas with particular emphasis on effects of time since restoration, distance from native communities, and previous land use, and to measure the same variables (as applicable) in unburned pine plantation, unmanaged pine-hardwood forest (both on post-agriculture land), native (never plowed) pine savanna managed with frequent fire, crop land, and pasture to demonstrate the value of pine savanna restoration by comparison. The current proposal seeks to provide the empirical basis for a larger grant proposal to be submitted to AFRI in the future, which will consider hypothetical scenarios where approximately 20% of the upland area of

an existing landscape (ca. 250 km^2) of mostly intensive land uses (crop land, pine plantation, pasture) in private ownership on the Coastal Plain is restored to pine savanna maintained with frequent fire on a long-term basis (>100 years), and predict resulting improvements in multiple ecosystem services at the landscape scale over time, estimate the cost of restoration and maintenance, and assess the feasibility in the context of landowner values and economic constraints.

What was accomplished under these goals?

Impacts

Completion of the two-year project has provided novel insights into the wide range of ecosystem services improved by passive restoration of pine savanna using only frequent prescribed fire and timber management on abandoned farm land in the southeastern U.S. Coastal Plain. Most of these services, including plant biodiversity, carbon sequestration, soil stabilization, increased water yield to aquifers and streams, and habitat for declining animal species of ecological and cultural significance, were evident in the first decade following restoration and continued to increase over a 100-year period, as inferred using a space-for-time approach. Most also exceeded services of other common rural land uses (pasture, pine plantation, unmanaged forest). While restoration of longleaf pine is already supported by existing incentive programs, these results quantify far more benefits than previously appreciated, but only if accompanied with frequent prescribed fire, regardless of pine species used. The results strengthen the justification for investment in incentive programs to restore pine savanna but also emphasize the need to prioritize or require frequent prescribed fire for the highest provision of ecosystem services at a given level of investment.

The results will likely influence land management actions and ecosystem conditions. They clarify priorities for restoring pine savanna and associated ecosystem services, including prescribed fire, long-term restoration over short-term management actions with high rates of discontinuation, and training for private landowners including organization of Prescribed Burn Associations in which landowners help each other burn without external funding. These priorities are supported by state forestry agencies for reducing the threat of wildfire. The results have been and will continue to be presented to a wide range of stakeholders and disseminated through peer-reviewed publications. Results also provide the foundation for a second proposal to NIFA to use the empirical data generated in the completed study to model future changes in ecosystem services at the landscape scale under the most likely scenarios of pine savanna restoration predicted through a socio-economic study of private landowners' ' values, knowledge, and economic constraints.

Goal 1) Quantify multiple ecosystem services provided by restoration of pine savanna

Objective 1: Measure multiple environmental variables that represent ecosystem services in restored pine savannas at different times since restoration from 5-100 years

Measurements for the study were stratified equally over four local landscapes (ca. 100 km^2) in northern Florida and southern Georgia. Historic aerial photographs were acquired from earliest dates available to the present for each landscape and used to assess when currently existing post-agricultural pine savannas were initiated by abandonment of agriculture and initiation of frequent prescribed fire (2-year interval average). Study locations were identified to represent categories of number of years since initiation of pine savanna restoration (current cropland, 0-15, 15-30, 30-50, 50-75, 75-100 years) with 12 or more replicate locations per category. Within each site we measured variables that represented or were used to calculate ecosystem services including plant species composition and cover, leaf area index, herbaceous plant productivity, soil bulk density and texture, soil total carbon, nitrogen, and mineral nutrients, tree diameters, density, height, and age, total ecosystem carbon, bee pollinator abundance and diversity (5 visits per location using pan traps), and predicted rates of erosion, sedimentation, evapotranspiration, and water yield using the WEPP model and local climate inputs. We also collaborated with a mycologist who used rapid cycling DNA sequencing techniques to identify "operational taxonomic units" of soil fungi.

Results showed nearly all ecosystem services to be greater in pine savannas than in row crop agriculture at 5-15 years and to continue to increase. Changes from row crop to 75-100 years post-agriculture included an increase from nearly no native plants to 66 native plant species per 100 m^2 and 27% perennial grass cover, a 39% increase in soil carbon, 85% decrease in predicted soil loss, 75% decrease in runoff, and 83% increase in water yield. An exception to the trend was no statistical change in bee abundance and diversity, although most bee species trapped are dependent on plants only in pine savannas.

The results emphasize the strong potential for increasing services on marginal or abandoned farm land with the relatively simple and inexpensive practice of prescribed fire and planting or allowing colonization of pine trees, with the implications discussed above.

Objective 2: Measure the same variables in pasture, unburned pine plantation, unmanaged pine-hardwood forest, and native (never plowed) pine savanna managed with frequent fire to demonstrate the value of pine savanna restoration by comparison

The same set of variables were measured in 12 or more replicates of the land uses listed above. Most ecosystem services in restored pine savannas eventually exceeded those of other non-native land uses. Exceptions were lower production of merchantable timber compared to pine plantations, lower total ecosystem carbon compared to pine plantations and unmanaged forest, and lower perennial grass cover and comparable levels of soil carbon and soil stability compared to pastures. Plant and fungi species composition in restored pine savannas became increasingly similar to native pine savannas. Nitrogen and mineral nutrients decreased over time and became more similar to native pine savannas, presumably reducing

nutrient pollution of water bodies.

These results predict the potential for pine savanna restoration to have a net positive influence at the landscape scale of agricultural landscapes and identify the potential to nearly restore native plant and fungal communities and habitat for declining wildlife species.

Objective 3: Assess the influence of distance from existing pine savanna at the time of restoration on rates of plant community development

Analyses were run to assess the possible influence of proximity of existing pine savannas on rates of accumulation of native plant species in restored savannas. Results were not significant, suggesting that the potential for plant seed dispersal is robust and likely to result in the observed plant community succession under a wide range of landscape contexts.

Goal 2) Assess the need and feasibility for further study of effects of pine savanna restoration in agroecosystems at the landscape scale in a subsequent grant proposal

Objective 1) Analyze data to identify predictable patterns of change in pine community ecosystem services

The results were promising for use in models to be used in a second grant proposal. It will incorporate a socio-economic study to estimate private landowners' desire to convert existing land uses to frequently-burned pine savanna, what kind and level of assistance would be required, which land uses would most likely be converted, and what would be the resulting landscape-level changes in ecosystem services.

Goal 3) Provide empirical data needed for the modeling portion of a future study

Objective 1) Build a database of measured and calculated variables representing ecosystem services for use in models in a future study.

This database has been created and is ready for use in work to be proposed as described above. In addition to providing the basis of further grant-funded work, the database provides a rich source of information on pine savanna restoration and plant community succession that will used in future publications and to providing research opportunities for graduate students mentored by the PD through university adjunct faculty appointments.

What opportunities for training and professional development has the project provided?

The project involved training and participation of multiple researchers from the undergraduate to professional scientist levels. PD Dr. Kevin Robertson, Fire Ecology Program Director, supervised Co-PD Dr. Monica Rother, Fire Ecologist, who assisted with grant preparation with hiring and training the full-time grant-funded technician (Cinnamon Morrison, Field Ecologist) who had recently graduated with a masters degree in biology. Morrison was trained in plant identification (although this was already her strong suit), field techniques, laboratory soil analysis, and use of Access relational database and statistical software. Over the course of the study she hired six undergraduate student researchers from Florida State University, Juniata College, and University of Kansas to work during summers and trained them in plant and soil field measurement techniques, laboratory soil and plant analysis, use of photographic equipment for measuring canopy cover and leaf area index, data processing, and other skills, including ecological principles and management implications of the research project. During the project Co-PD Rother took a position at the University of North Carolina, so Field Ecologist Morrison was hired to take her place as Fire Ecologist and continued to work on the project, and one of the exceptional undergraduate students, Allison Snyder, was hired to be the new Field Ecologist after her graduation until the end of the study.

Field Ecologist Morrison received prescribed fire training, including the Florida Burn Boss Certification, Georgia Burn Boss Certification, and federal "red card" certification. She was supported to attend the Project Director's Meeting in Washington, DC. The replacement Field Ecologist Snyder also received her federal red card certification. Both attended several training events at Tall Timbers provided to other natural resource professionals, including visits from the National Interagency Prescribed Fire Training Center, Women in Fire Training Exchange, Yale School of Forestry and Environmental Studies Field Course, and a LiDAR and photogrammetry workshop.

Dr. Michael Ulyshen of the USDA Southern Forest Research Station in Athens, Georgia and his graduate student Conner Fair, Ph.D. candidate at the University of Georgia, were instrumental in training the PD and Field Ecologist in collecting and mounting bees, and Dr. Ulyshen identified the bees to species, a major contribution to the study.

Dr. Benjamin Sikes at the University of Kansas trained his post-doc Tanya Semenova-Nelsen and undergraduate research Paige Hansen (now a master's candidate) in conducting the rapid cycling DNA sequencing technique to identify operational taxonomic units or species of soil fungi and bacteria.

How have the results been disseminated to communities of interest?

Results have been distributed through training of six undergraduate researchers, presentations to a wide range of stakeholders, and training on the research topic as part of larger professional training programs. Manuscripts are also being prepared for publication in peer-reviewed journals. A list specific presentations and training follow.

1) Ecological Society of America Annual Meeting, New Orleans, LA - Professional ecological research scientists from around the country and world, mostly focused on ecosystem restoration science

2) Yale Forest Forum, New Haven, CT - Graduate students and faculty from the Yale School of Forestry and Environmental Studies and other departments studying in a wide range of natural resource management fields

3) Southern Fire Exchange Webinar - Stakeholders in positions relating to land and fire management from various agencies, conservation groups, and private lands
4) North Florida Prescribed Fire Council Meeting, Tallahassee, FL - Professionals and private landowners with careers relating to prescribed fire from various state and federal agencies, conservation organizations, and properties
5) Florida State University Natural History Seminar, Tallahassee, FL - Faculty, students, and local researchers and conservation biologists
6) NIFA Project Director's Meeting, Washington, DC - NIFA Project Directors representing a wide range of natural resource and agricultural scientists and policy makers
7) University of Florida Institute of Food and Agriculture Sciences (IFAS) leaders' visit to Tall Timbers, Tallahassee, FL - Field visit and presentation to the IFAS Dean and Director, the Senior Vice-president, Associate Dean of Florida Extension, and others
8) Tall Timbers Research Station Board of Trustees and Committee Members - Wealthy and influential corporate leaders and philanthropists, state and federal agency leaders, and scientists invested in natural resource research and conservation on private lands
9) Yale School of Forestry and Environmental Studies Forestry Field Course, Tallahassee, FL - graduate students and faculty visit to Tall Timbers for two days
10) Southern Fire Exchange Native Groundcover Restoration Workshop, Nature Conservancy Apalachicola Bluffs and Ravines Preserve, Bristol, FL - State and federal agency and conservation organization natural resource managers
11) Women's Fire Training Exchange (WTREX), Tallahassee, FL - Federal fire fighters, prescribed fire training in field and classroom
12) North Florida Prescribed Burn Association, Gainesville, FL - Private landowners and some state agency trainers
13) National Interagency Prescribed Fire Center, Tallahassee, FL - Federal wildland fire managers from around the country receiving field training at Tall Timbers
14) Seminole Nation of Oklahoma field trip, Tallahassee, FL - Seminole tribal leaders and university students tour of Tall Timbers and surrounding natural areas

What do you plan to do during the next reporting period to accomplish the goals?

{Nothing to report}

Participants

Actual FTE's for this Reporting Period

Role	Non-Students or faculty	Students with Staffing Roles			Computed Total by Role
		Undergraduate	Graduate	Post-Doctorate	
Scientist	0.5	0	0	0	0.5
Professional	1	0	0	0	1
Technical	0	1	0	0	1
Administrative	0	0	0	0	0
Other	0	0	0	0	0
Computed Total	1.5	1	0	0	2.5

Student Count by Classification of Instructional Programs (CIP) Code

Undergraduate	Graduate	Post-Doctorate	CIP Code
4			26.01 Biology, General.

Target Audience

Target audiences for dissemination of results from the funded research project included a wide range of stakeholders and citizens. Stakeholder groups addressed are listed listed below with the number of people reached in parentheses.

1) Ecological scientists - Presentations at the Ecological Society of America Annual Meeting (55), NIFA Project Director's Meeting (60), Yale Forest Forum (3), Yale School of Forestry and Environmental Studies Field Course (3), Florida State University Natural History Seminar (12), Tall Timbers Board of Trustees (3), Seminole Nation of Oklahoma university student tour Tall Timbers (15)
2) University students - Training and mentoring of undergraduate student researchers for the funded project (6), Yale Forest Forum (29), Yale School of Forestry and Environmental Studies Field Course (18), Florida State University Natural History Seminar (90)
3) Conservation and land management professionals - Southern Fire Exchange Webinar (165), North Florida Prescribed Fire Council Meeting (120), Southern Fire Exchange Native Groundcover Restoration Workshop (43), Women's Fire Training Exchange (WTREX) (60), National Interagency Prescribed Fire Center (67)
4) Policy makers and leaders - University of Florida Institute of Food and Agriculture Sciences (IFAS) visit to Tall Timbers by Dean and Director, Senior Vice-President, Associate Dean of Florid Extension, and others (5); Tall Timbers Research Station Board of Trustees and Committee Members (23); NIFA Project Director's Meeting (7)
5) Private Landowners - North Florida Prescribed Burn Association Meeting (31); Southern Fire Exchange Webinar (18)

Products

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2018	YES

Citation

Robertson, K.M. 2018. Restoring ecosystem resilience through frequent fire and succession of pine-grassland communities on post-agricultural land in the southeastern U.S. Annual Meeting of the Ecological Society of America, August 7, 2019, New Orleans, LA.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2019	YES

Citation

Robertson, K.M. 2019. Our emerging understanding of natural processes in longleaf pine savannas and their implications for management. Yale Forest Forum, April 11, 2019, New Haven, CT.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2018	YES

Citation

Robertson, K.M. 2018. Disturbance and succession in southeastern pine savannas: Applying old concepts to new paradigms. Florida State University Natural History Seminar, October 5, 2018, Tallahhassee, FL.

Type	Status	Year Published	NIFA Support Acknowledged
Conference Papers and	Published	2018	YES

Citation

Robertson, K.M., M. Rother, and C. Morrison. 2018. Provision of ecosystem services through pine savanna restoration on privately owned agroecosystems in the southeastern US Coastal Plain. National Institute of Food and Agriculture Project Director's Meeting, December 6, 2018, Washington, DC.

Other Products

Accession No. 1012447 **Project No.**

Product Type

Audio or Video

Description

Robertson, K.M. 2019. Fire history paradigms in North America –
controversy and consensus. Southern Fire Exchange Webinar, May 30, 2019. https://www.youtube.com/watch?v=-XdMhYptt7Q&feature=youtu.be

Product Type

Physical Collections

Description

Mounted specimens of 2793 bees with identification to species and date and location of collection, including research plot treatment category. Contributed to the USDA Forest Service Southern Forest Research Station Insect Collection curated by Dr. Michael Ulyshen.

Product Type

Databases

Description

Georectified time-series aerial photograph collections from 1938 to the present covering the Red Hills Region of southern Georgia and northern Florida.

Product Type

Databases

Description

Microsoft Access Relational Database housing and integrating all data collected during the study, including data on plant species composition, herb and litter biomass, woody plant biomass, fuel loads, tree and herb canopy cover, tree and herb leaf area index, soil bulk density, total C, total N, and mineral soil nutrients, tree basal area, density, height, and age, and calculations for soil erosion, runoff, sedimentation, evapotranspiration, and water yield from WEPP in 120 research plots categorized by research treatment.

Product Type

Data and Research Material

Description

Plant specimen vouchers collected for the 449 species identified in the study with date and location of collection.

Changes/Problems

There were no major changes to the proposed work. Most changes were improvements, for example, we were able to collect data for an average of 12 plots per treatment instead of 10. The project benefited greatly from unplanned collaborations with Dr. Michael Ulyshen, who encouraged us to collecte bees over five or six separate weeks instead of the proposed three, did most of the bee identification, and advised us on bee collection methods, and from Dr. Benjamin Sikes, who added the soil fungal community composition aspect to the project, using funds from a separate source. We have been behind schedule on publishing in peer-reviewed journals, having proposed to have them submitted before the final report, but they are close to submission at this time.