STUDY PLAN #: **FS-SRS-4103-273** FY: **2006**

SHORT TITLE: **Effects of Fuels Management on a First Order Watershed**

RWUD PROBLEM: 1 (Wetland Ecology & Management)

Soil Productivity and Nutrient Management of Mid-rotation Sweetgum and Sycamore SRWC Plantations

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____________________/s/ Carl C. Trettin_____________________
Project Leader

Project Title:

Soil Productivity and Nutrient Management of mid-Rotation Sweetgum and Sycamore SRWC Plantations

Abstract:

Idle agricultural land is a potentially significant resource for producing woody crops as an energy or chemical feedstock. Intensive woody crop cultivation systems (e.g., short rotation woody crops [SRWC]) offer an opportunity to improve soil health, water quality, and to sequester soil carbon (C). Understanding the processes controlling the nutrient and C cycles are fundamental to developing management prescriptions that can insure long-term soil productivity while protecting or enhancing environmental quality. The focus of most fertilization trials with plantation hardwoods (e.g., sweetgum, sycamore, and cottowood) in the southern US have been during the establishment and early develop stages (1-6 yrs) of the plantation. While those studies typically show a productivity response to N additions, there is considerable uncertainty about potential productivity responses in the southeast and environmental effects of mid-rotation fertilization practices. Hence, the goal of this study is to develop the basis for managing nutrient availability in mid-rotation SRWC plantations to increase productivity and reduce the time to develop a commercially harvestable crop, while enhancing soil productivity potential of old agricultural fields.

Our approach includes field and modeling tasks applied within established SRWC experimental plantations that we established in 1996 to evaluate the environmental effects of operational SRWC practices for sweetgum and sycamore, in collaboration with Oak Ridge National Laboratory and International Paper. The basic premise of the current research is to test the productivity response of sweet gum and sycamore to mid-rotation fertilization regimes as a means of optimizing the prescription with respect to nitrogen use efficiency. The treatment design incorporates fertilization rate and frequency of application. The N fertilization rate schedule is designed to test a recent recommendation of 50 kg N ha^{-1} per 2000 kg foliage biomass. Three fertilization rates, 30, 50 and 80 kg N ha^{-1} per 2000 kg foliage biomass, will be tested, along with an unfertilized control. Each of the four fertilization regimes will be replicated. The same rates will be used for both sweetgum and sycamore. To test for the affects of timing, a single application versus bi-annual applications will be evaluated. Each plot will include provisions for measuring above-ground productivity, root biomass, soil nutrient pools, nutrient mineralization, and nutrient movement in soil water. The treatments will be applied in April, 2006 and monitored for two years.

Goal & Scientific Objectives

The goal of this study is to develop the basis for managing nutrient availability in mid-rotation SRWC plantations to increase productivity and reduce the time to develop a commercially harvestable crop, while enhancing soil productivity potential of old agricultural fields. The approach includes field and modeling tasks applied within established SRWC experimental plantations.

Specific objectives and supporting hypotheses are:

- Coordination of the fertilization regime with demand, uptake efficiency, and soil supply;
    - H: Periodic fertilization improves productivity and use-efficiency as compared to a single application in mid-rotation.
    - H: Soil N availability is not synchronized with uptake needs.
- Determining the interactions of N fertilization rates and timing on mid-rotation productivity response;
    - H: Mid-rotation fertilization yields more gain in productivity response as compared to early-rotation fertilization.
    - H: Current recommendations for N fertilization rates are insufficient.
- Quantify nutrient use efficiency and nutrient export, and determine the long-term (10 yr.) effects of SRWC cultivation on soil productivity.
    - H: Fertilization during plantation establishment develops the soil nutrient pool sufficiently to sustain productivity;
    - H: Nutrient management in SRWC plantations does not degrade surface water quality;
    - H: Development on SRWC plantations on agricultural fields improves soil tilth, thereby suggesting sustainable productivity with less inputs in future rotations.
- Apply a soil nutrient cycle model (e.g., NuCM, DNDC) and test its utility in developing a nutrient management strategy.

Scientific Approach

Background and Justification

Idle agricultural land is a potentially significant resource for producing woody crops as an energy or chemical feedstock. Intensive woody crop cultivation systems (e.g., short rotation woody crops [SRWC]) offer an opportunity to improve soil health, water quality, and to sequester soil carbon (C). Understanding the processes controlling the nutrient and C cycles are fundamental to developing management prescriptions that can insure long-term soil productivity while protecting or enhancing environmental quality.

Nutrient management is implicit in SRWC systems because most sites are nutrient limited, usually by nitrogen (N), and supplemental inputs are necessary to achieve commercially viable yields. The focus of most fertilization trials with plantation hardwoods (e.g., sweetgum, sycamore, and cottowood) in the southern US have been during the establishment and early develop stages (1-6 yrs) of the plantation. While those studies typically show a productivity response to N additions, there is considerable uncertainty about potential productivity responses in the southeast and environmental effects of mid-rotation fertilization practices. However, work in Mississippi demonstrated that the fertilization response can be significant (Nelson and Switzer 1992, Nelson et al. 1995). Nitrogen demands are greatest following canopy closure in hardwood plantations (e.g., typically 4-7 yrs), hence managing the N supply in the mid-rotation period is probably critical to sustaining high levels of productivity. To satisfy the N demand and realize productivity potential, N must be supplied from the soil, internal translocation, and fertilizer inputs. Determining the site and stand constraints on the sources of N and the efficiencies of nutrient utilization are fundamental to sustainable management prescriptions for SRWC (Coyle and Coleman 2005).

We established a catchment-scale experiment in 1996 to evaluate the environmental effects of operational SRWC practices for sweetgum and sycamore; this study was a component of the Oak Ridge National Laboratory's biomass research program that was supported in the first phase of the DOE Agenda 2020 program. That project was developed in collaboration with International Paper and the Forest Service. That work demonstrated the early environmental benefits of converting idle agricultural land into SRWC plantations and has served as a contrast for comparing productivity responses from an operational-scale system with plot-scale fertilization and fertigation trials reported in the literature. Accordingly, that study provides the only basis in the southeastern US to evaluate the long-term effects of SRWC production management, and it also provides the capability to address specific questions due to the large size of the original experimental units (12-16 ha).

Process-based models are integral to evaluating the linkages between the soil-plant system and management prescriptions. The Nutrient Cycle Model (NuCM) and DNDC have been proven effective tool for evaluating the soil N cycle. Accordingly, we've incorporated a modeling task to provide the basis for applying our findings to other soil systems.

<u>Site Description</u>

The study site is located on International Paper's William H. Trice Forest in Sumter County, South Carolina. The Trice Forest includes a 200-ha watershed with agriculture, SRWC plantations, and natural pine/hardwood stands. Within the watershed, six gauged catchments have been instrumented since 1997. Four of the catchments were planted with sycamore and two were planted with sweetgum. Two of the sycamore catchments were fitted with a control drainage structure to regulate outflow from the site. Each catchment has been managed using a conventional SRWC plantation prescription. Each catchment has a complete record of vegetation development, soil properties and hydrologic setting, which coincides with the establishment of the plantations in 1997 and periodic measurements through 2002. The Trice Forest is within the upper coastal plain, and the surrounding area is typical of this region and includes urban/residential, agriculture, tree plantations, and natural mixed pine/hardwood forest stands.

<u>Treatment Design</u>

The treatment design incorporates fertilization rate and frequency of application. The N fertilization rate schedule is designed to test a recent recommendation of 50 kg N ha^{-1} per 2000 kg foliage biomass (Scott et al. 2004). Three fertilization rates, 30, 50 and 80 kg N ha^{-1} per 2000 kg foliage biomass, will be tested, along with an unfertilized control. Each of the four fertilization regimes will be replicated on three plots (0.15 ha). The same rates will be used for both sweetgum and sycamore. To test for the affects of timing (Van Miegrot et al. 1994), a single application versus bi-annual applications will be evaluated. The fertilization plots will be randomly assigned within catchments by species. One catchment will be allocated to each of the two frequency trials. The matrix of the catchments will also be fertilized (50 kg N ha^{-1} per 2000 kg foliage biomass) to allow catchment-level assessment of water quality.

<u>Measurements</u>

Each plot will include provisions for measuring above-ground productivity, root biomass, soil nutrient pools, nutrient mineralization, and nutrient movement in soil water (Table 1).

Table 1. Overview of the vegetation, soil and water measurements.

Vegetation	**Nutrient Pools & Fluxes**		**Soil Processes**
	Above-ground	Below-ground	
Productivity (Ht & Dia) - annual	Overstory (stem + foliage) [yr 1,3]	Forest Floor (yr 1,3)	N-Mineralization (monthly)
Litterfall – monthly		Mineral Soil (yr 1,3)	Foliage & root turnover (semi-annual)
Above & belowground biomass (yr. 3)		Soil water (monthly)	Soil gas flux (CO_2, N_2O) (monthly)

Water yield and nutrient content will be measured from each of the catchments, at the existing gauging stations. This measure will represent the entire catchment, not the individual fertilization treatments. We don't expect large differences in leaching among the fertilization treatments, and since the plots only comprise approximately 25% if the catchment the response will be driven by the matrix treatment. We will test that assumption directly, by measuring soil water quality, and my hydrologic simulations using DRAINMOD.

Expected Results

This study will provide the basis for managing soil productivity in mid-rotation SRWC plantations in the southeastern US. The known stand development history along with the measured changes in soil properties will establish a unique long-term record on which to assess the sustainability of SRWC plantations and to demonstrate the environmental benefits of SRWC cultivation. In addition to the general merits of a coherent, long-term study, specific results that will further the science supporting SRWC and soil productivity are:

* This is the only study in the southeastern US that will allow the continuous assessment of sweetgum and sycamore SRWC plantations. The work will establish the extent to which changes in soil productivity are manifest during early stages of plantation management and the opportunity to further ameliorate the degradation from agricultural practices while enhancing woody crop productivity.

* This work will establish a foundation for mid-rotation fertilization prescriptions in sweetgum and sycamore SRWC plantations. At present the empirical basis is very limited and models have not been validated. This work will provide a critical benchmark for managing soil fertility in hardwood SRWC plantations.

* There are no-long term studies on the environmental effects of SRWC practices. This work builds on a strong foundation of soil, water and vegetation assessments to quantify the environmental benefits of SRWC cultivation. The study also provides the basis for economic assessments including direct (e.g., wood biomass) and indirect values (e.g., soil C sequestration, water quality) that are derived from the SRWC system.

* This work provides for a unique synchronized assessment of sweetgum versus sycamore. Although, sweetgum is the favored species in the southeastern US because of its adaptability to many sites and having few disease problems, a direct comparison is valuable to demonstrate the potential of sycamore.

* This work will advance the application of NuCM and DNDC for SRWC assessments by validating the model at a critical juncture in the development of the plantation. Similarly, the utility of DRAINMOD-N for assessing the potential of N export from the catchments will be determined.

Value & Merit Relative to the Agenda 2020 Program

The fundamental basis of this project is to establish the basis for sustainable soil productivity of SRWC on idle agricultural land. If SRWC systems can be developed for agricultural lands, it represents an opportunity for landowners to diversify their cropping system while achieving positive environmental benefits.

This project will provide the Agenda 2020 Program a unique opportunity for considering mid-rotation fertility management in hardwood SRWC plantations. While N is typically recognized as a limiting nutrient, there is a very limited basis for determining the fertility needs in mid-rotation plantations.

Effective management of soil productivity involves partitioning the nutrient supply among internal (e.g., tree and soil) and external (e.g., fertilizer) sources. Understanding the processes controlling nutrient availability within a mid-rotation plantation will provide the basis for effective nutrient management prescriptions.

This study will sustain a valuable and productive partnership for the development of SRWC production technologies in the southeastern US. The value derived from long-term studies far exceeds those from short-term research. The foundation for this study avails the capability to integrate productivity and environmental effects from the time of plantation establishment through mid-rotation.

Project Organization & Management

This project is a partnership between the US Forest Service - Southern Research Station, International Paper Inc., and the College of Charleston. The Experimental Forest is owned and managed by International Paper Inc., and they will also provide expertise in plantation silviculture and fertilization. The Forest Service will provide capabilities in soil science, hydrology and productivity; the College of Charleston provides expertise in hydrology and environmental sciences.

Selected References

Coyle, D.R. and M.D. Coleman. 2005. Forest production responses to irrigation and fertilization are not explained by shifts in allocation. For. Ecol. Mgt. 208: 137-152.

Nelson, L.E. and G.L. Switzer. 1992. Response of nine-year old plantation sweetgum to nitrogen fertilization in Mississippi. So. J. Appl. For. 16:146-150.

Nelson, L.E., M.G. Shelton, and G.L Switzer. 1995. Aboveground net primary productivity and nutrient content of fertilized plantation sweetgum. Soil Sci. Soc. Am. J. 59:925-932.

Scott, D.A., J.A. Burger, D.J. Kaczmarek, and M.B. Kane. 2004. Nitrogen supply and demand in short-rotation sweetgum plantations. For. Ecol. Mgt. 189:331-343.

Van Miegroet, H., R.J. Norby, T.J. Tschaplinski. 1994. Nitrogen fertilization strategies in a short-rotation sycamore plantation. For. Ecol. Mgt. 64:13-24.

Environmental considerations

This study will be conducted in an existing plantation, located on prior-converted agricultural land. The principal environmental risk is the application of water into the stream systems. That risk will be mitigated by ground-application of the fertilizers, use of a buffer zone around the streams according to South Carolina Best Management Practices, and the water quality of the streams will be measured to ensure the integrity of the water. Monitoring will be ongoing for two years.

Since there are no adverse environmental impacts associated with the activities of this project, a Categorical Exclusion is deemed appropriate for the NEPA assessment.

Safety and health considerations

The health and safety plan provides protocols necessary for the protection of scientists, technicians, students, or any individual taking part in activities associated with the study, and for the protection of the general public from any physical, chemical, and/or biological hazards that may be encountered during the period of the study.

In general, the scope of this plan requires that all individuals participating in the study follow safety procedures as outlined in the USDA Forest Service: Health and Safety Code Handbook, 1999 (FSH 6709.11). It is the responsibility of the work group supervisor to ensure that these regulations are followed. The appended Job Hazard Analysis form documents possible hazards and relevant safety practices applicable to the study plan. Pre-job briefings (e.g. tailgate safety review following the outline appended) shall be conducted to review potential hazards and response protocols in case of emergency. Study participants will be provided with protective equipment and gear (e.g. hardhats, safety glasses, hearing protection, waders) as warranted. Field workers will be expected to carry a cell phone or two-way radio for use should emergencies arise. Handling and use of equipment or chemicals shall be limited to those individuals who have met FS training requirements for the operation in question.

Any laboratory procedures and lab safety practices must be performed in accordance with those outlined by the Center for Forested Wetlands Research laboratory manager, and/or OSHA laboratory safety guidelines.

<table>
<tr><td rowspan="2">USDA Forest Service

JOB HAZARD ANALYSIS
(Ref. FSH 6709.12)</td><td>1. Primary Job/Project
Trice Agenda 2020</td><td>2. Location
Trice Forest, Sumter SC</td><td>3. Unit
SRS-4103</td></tr>
<tr><td>4. Name of Analyst
Carl Trettin</td><td>5. Job Title of Analyst
Project Leader</td><td>6. Date Prepared
12/02/05</td></tr>
<tr><td>7. Tasks/Procedures</td><td>8. Hazards</td><td colspan="2">9. Abatement Actions</td></tr>
<tr><td>Driving off-road vehicle.</td><td>Accidents</td><td colspan="2">Only government licensed employees will operate motor vehicles. All passengers will wear seatbelts. Do not keep loose articles or aerosol cans in passenger compartment.</td></tr>
<tr><td>Gathering data in forest; installing data gathering equipment.</td><td>Head injury from falling objects

Slips/trips/falls

Injury to eyes from brush and limbs.

Lightning/storms.

Poisonous plants/snakes. Stinging insects.

Heat cramps, heat exhaustion, heat stroke.

Slips, falls while working in standing water (ponds or wetlands).

Hearing injury from noise from power equipment, etc.</td><td colspan="2">Use hard hat when working in forested areas.

Watch for stump holes, vines, and other tripping hazards. Wear leather boots.

Use safety glasses when working in dense brush.

Take shelter in vehicle. Do not park under snags or diseased trees.

Learn to identify and avoid poisonous snakes and plants, stinging and biting insects. Use insect repellent and wear long sleeved shirts as desired.

Review symptoms and treatment for heat-related illnesses. Drink plenty of water. Schedule more demanding work during early morning and late afternoon.

Wear appropriate foot gear (rubber boots, waders, etc.); watch or probe for holes or ditches that may be concealed under water.

Wear ear protection when using loud equipment.</td></tr>
<tr><td colspan="2">10. Approved by:
Carl Trettin</td><td>11. Title:
Project Leader</td><td>12. Date:</td></tr>
</table>

TAILGATE SAFETY MEETING

STAFF:_________　　**PROJECT:__________________________________**　　**DATE:_______________**

LIST OF HAZARDS　　　　　　　　　　**LIST OF REQUIRED PPE**

See attached JHA

BRIEF DESCRIPTION OF DISCUSSION TOPICS TO INCLUDE HAZARDS, HAZARD MITIGATION AND PPE.

See attached JHA

EMPLOYEE(S) HAVE RECEIVED PERSONAL PROTECTIVE EQUIPMENT (PPE) TRAINING WHICH INCLUDES:

- What PPE to wear
- When to use it
- How to properly wear it
- Proper care and maintenance
- Limitations

CREW LEADER: _____________________________________

CREW MEMBERS SIGNATURES:

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SUPERVISOR:____________________________　SAFETY COORD:__________________________

QA/QC Protocol for Field Data Collection and Data Management
Center for Forested Wetlands Research

This document contains guidelines for maintaining high-quality data collection and data management procedures and for facilitating data dissemination.

1. Data Collection

A. DOCUMENTATION: Prior to fieldwork, consider the nature of the data to be collected and the way it will be managed. The protocol to be followed (including all data checks) should first be summarized in a written document (*e.g.* a study plan). This ensures that field workers perform data collection correctly and also is essential to those who later make use of the data. If changes to the protocol become necessary, these should be noted in an amendment to the appropriate document, along with the reason(s) for the change. Any such changes should also be recorded later in the working/master electronic data sets.

B. DATA COLLECTION: Data may be collected in either a field notebook or on data sheets (or both). If they are to be used, field data sheets suitable for the expected conditions (*e.g*., on water-resistant paper) should be prepared in advance. During data collection, it is preferable to involve at least two people. One person acts as the data recorder, while the other(s) serves as the data provider. Field location and date of collection **must** be noted; the names of the data collectors should also be noted (including who does what). General field conditions may also be appropriate to record. Data collection is often best served if workers exchange jobs periodically (again, noting when such exchanges occur).

C. FIELD DATA CHECKS: As part of documentation (above), before any measurement and/or classification work is conducted, a method for performing field checks of data collection should be prepared in advance and described in the study plan. Tolerance limits should be also be set in advance, as well as what to do if limits are exceeded. As much care should be taken in collecting and recording the data during any field checks as was expended during the original data collection. Field check information should be included in the final data set.

2. Data Entry and Checks (QA/QC)

A. WORKING DATA FILE: A working data file serves as a repository for raw data. Ideally, spreadsheets for the working data file should be prepared in advance so that the data can be entered as quickly as possible once the collection phase is finished (this preparation may also help focus attention on desirable information that might otherwise have been overlooked; it is not always possible to return to the field after some time has elapsed for data that is missing). Appropriate labeling is critical, beginning with the file name. File names should indicate something of the site location, date, and nature of the data set. All descriptive headers should be concise but clear, with the units of measurement (if any) indicated. Although this is a working data set, it may be helpful to attach a brief statement describing the purpose of the project for which the data are being collected and any other pertinent information. Once data entry and checks have begun, it is essential to document all modifications to the data set (see below).

B. RAW DATA ENTRY AND PROOFING: Field data should be entered into the working data file as soon as possible after fieldwork has been completed. After data entry, the working data file should be proof-read against that in the field notebooks. This works well with two people. If a discrepancy is noted, the working data file should be corrected. Completion of the visual inspection process should be recorded on the spreadsheet (date and person(s) that performed it).

C. ADDITIONAL DATA CHECKS: One or more QA/QC procedures should be initiated soon after the working data set has been proofed. The specific procedure(s) to be followed for a particular data set should be described in the study plan. Examples of such procedures include the following:

i. comparison test (measurement data): Current-year data can be compared with that from the previous year to check for obvious discrepancies. This check can be built into the working data spreadsheet itself, or can be done by graphing data from consecutive years against each other. If no prior year data are available, then an alternative is to regress two variables, or appropriate transformations of those variables, against one another and to graph the calculated results for the dependent variable against the actual values. These tests may reveal suspect measurements that require evaluation of the data in the field notebook and/or follow-up checks in the field.

ii. max/min test: Data points near the maximum or minimum values of the range can be identified (by filtering and/or sorting) and examined more closely.

iii. frequency tests: Data that have been incorporated into a statistical program can be evaluated with frequency tests (*e.g.* PROC FREQ command in SAS). These tests are especially helpful in revealing missing data, duplicated values and/or typographical errors

D. MASTER DATA FILE: After the working data have been checked and approved, they should be saved to a master data file. No "working data set" should be permitted to exist beyond this point (or if so, only in an Archive folder). This reduces the risk of releasing flawed data and also saves valuable storage space. The master data file will serve as the basis of any publications and/or data dissemination to outside users. As such, it requires more detailed documentation (metadata) than the working data set. Metadata should include the following:

a. site location
b. study plan number
c. principal investigator
d. others (students, technicians, etc.)
e. dates of project
f. statement of project hypothesis or purpose
g. methods employed in data collection
h. keywords and missing data codes (e.g., ".")
i. any data set number or file codes
j. format and location of raw data (e.g., field notebooks in CFWR vault)

This information should be included both in the master data file itself (as a separate spreadsheet page) and also in a data dictionary / file summary for the particular project.

3. Preparation of Data for Release

A. INTERNAL USE: Assembly of a package including the master data set and all accompanying documents is the minimum requirement.

B. EXTERNAL USE: In addition to the above, conditions for data release (a form of written contract) must be defined and included in the package.

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