ENVIRONMENTAL EFFECTS OF GROWING SHORT-ROTATION WOODY CROPS ON FORMER AGRICULTURAL LANDS


ABSTRACT

Field-scale studies in the Southeast have been addressing the environmental effects of converting agricultural lands to biomass crop production since 1994. Erosion, surface water quality and quantity and subsurface movement of water and nutrients from woody crops, switchgrass and agricultural crops are being compared. Nutrient cycling, soil physical changes, and crop productivity are also being monitored at the three sites. Maximum sediment losses occurred in the spring and fall. Losses were greater from sweetgum planted without a cover crop than with a cover crop. Nutrient losses of N and P in runoff and subsurface water occurred primarily after spring fertilizer application. These field plot studies are serving as the basis for a watershed study initiated in 1997. Results from the two studies will be used to develop and model nutrient and hydrologic budgets for woody crop plantings to identify potential constraints to sustainable deployment of short-rotation woody crops in the southeastern U.S.

INTRODUCTION

Use of woody biomass as a feedstock for generation of electricity or conversion to liquid fuels is receiving considerable attention in part because of the potential environmental benefits projected with conversion of conventional cropland to short-rotation woody biomass crops (SRWC). Conversion of erosive or marginally productive agricultural lands to woody crop production has been identified as having both environmental and economic benefits. The potential for fast-growing woody crops, such as hybrid poplar (Populus sp.), sweetgum, sycamore, and eastern cottonwood, to be grown on thousands of acres of agricultural lands necessitates identification of the potential benefits and impacts of this land use conversion on water quality, soil stability, land resources, and biota (Ranney and Mann 1994). These questions are being addressed in various studies sponsored by the U.S. Department of Energy.
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
Department of Energy (DOE) through the Biomass Feedstock Development Program in areas where production of SRWC has been identified as economically feasible for energy production. These studies are designed to identify potential impacts and measures that should be incorporated into production of SRWC to minimize off-site effects or to enhance environmental benefits.

This paper describes a research study ongoing at three university sites in the Southeast. The study is funded jointly by DOE and the Tennessee Valley Authority with cost-sharing by Alabama A&M University, Mississippi State University, and The University of Tennessee. Replicate large-scale (0.25 to 0.5 ha) research plots are located at each of the three university's agricultural research stations. Each of the three sites represent distinct physiographic regions in the Southeast that have been identified as having the potential for biomass crop production (Downing and Graham 1996).

RESEARCH DESIGN

At each of the three research stations, crops and SRWC comparisons that would be typical of the regions were chosen. Two replicates each of sweetgum with and without a cover crop established between rows, switchgrass (a herbaceous bioenergy crop), and no-till corn are being compared at the Alabama site which is located in the limestone valley region of northern Alabama. Three replicates each of cotton and cottonwood were established as the study crops on a Mississippi Delta site, and three replicates each of sycamore and no-till corn were established on the loess belt in West Tennessee. Management practices for each SRWC were chosen to represent operational high-intensity management for maximum but cost-effective yield (use of mechanization, extensive fertilization, herbicides for weed control, and pesticides).

Each replicated site was enclosed by an earthen berm with a flume and flow-proportional water quality sampler installed at the center of the triangulated downslope wall to monitor runoff, water quality, and sediment transport. Four pan lysimeters were installed to depths of 1.5 m in central locations within each treatment to monitor subsurface movement of zero-tension water and nutrients, particularly nitrates. The 1.5 m depth was chosen as being below the rooting zone of the three SRWC.

Soil physical changes with conversion of lands formerly in agricultural production to SRWC production are being monitored. Soil samples from each treatment were taken at the initiation of the study for comparison with samples taken at intervals during the study. Physical changes being compared include infiltration rate, root penetration, and water holding capacity. These parameters are being compared by measuring aggregate stability, porosity, bulk density, hydraulic conductivity, and penetrometer resistance. Changes in build up or release of nutrients and/or loss of soil organic matter are being compared at the beginning and end of the woody crop rotation. Organic matter and nutrient build up is expected to occur as the result of extensive root production and penetration by the perennial switchgrass and woody crops and the root turnover over time opening pathways for increased water and nutrient infiltration.

RESULTS

During the first year of establishment, no differences were expected in erosion or runoff from the different treatments at any of the three sites. All crops were in the initial stages of
establishment and there was little difference in aboveground biomass among the tree and agricultural crops. Most of the runoff was found to occur during rainfall events. Runoff differences were greater between cotton and cottonwood as the result of closely spaced rainfall events. When data were compared of two years, there was no significant difference in overland flow, infiltration, or evapotranspiration between cotton and cottonwoods (Joslin and Schoenholtz 1997). Runoff of nitrogen and phosphorus from the SRWCs was negligible in the year of establishment compared with no-till corn. Sweetgum and sycamore nutrient requirements during the year of establishment were met by residual nutrients in the soil. During the second year, all SRWCs received fertilizer but at levels approximately half those of the row crops. To date, nutrient transport has been greater from row crops than from either switchgrass or SRWCs.

Nitrate leaching from row crop sites was accompanied by two- to three-fold increases in calcium, magnesium, and potassium losses below 1.4 m at the Tennessee site. Runoff losses of nutrients was also higher from the no-till corn than from the sycamore plots. During the second year of growth, soil water storage at depths of 0 to 1.8 m was higher in cottonwood plots than in cotton plots. Established root systems under the SRWC and switchgrass plots increase the uptake of spring applied nutrients and the minimization of off-site movement through runoff or infiltration below the rooting zone. By comparison, annual row crops must develop their root stocks in the spring and nutrients applied prior to development of these root systems are more subject to erosion and infiltration losses (Thornton et al. 1996).

At the Tennessee field site, three 0.5 ha sycamore plots were established adjacent to additional sycamore plantings for a total of 5 ha. Avian and small mammal use of this larger planting is being compared over time with row crop use. Results are showing that the sycamore plantings are used as habitat to a greater extent than the field crops. Breeding territories were not established in the plantings and nesting was not observed. Use of the young plantings was found to be more similar to that of row crops than to forested areas surveyed (Ettel 1996).

In 1997, a watershed study was established on a coastal plain site in eastern South Carolina. This study is building upon the design used with the field-scale plot studies to compare environmental responses to conversion of agricultural lands to SRWC production. Three treatments (sweetgum, sycamore, and sweetgum with a cover crop) were established on replicated "sub-watershed" plantings of 5 to 20 ha within an operational planting of approximately 100 ha. Berms were established around each of the identified sub-watersheds to channel runoff to their respective existing, central drainage ditches. These ditches are being fitted with flumes, flow-proportional water quality sampling devices, and stage-height recorders. Twelve tension lysimeters have been installed at 1 m depths at 10 and 20 m from the central drainage ditches to monitor subsurface water movement. These data will be used to parameterize hydrologic and nutrient models to predict water and nutrient movement on the sites. The six sub-watersheds lie within a watershed that is dedicated to either SRWC research or to commercial production of SRWC. The volume and quality of water leaving this dedicated watershed is to be compared with that from an adjacent watershed currently divided between traditional agricultural crops, idle land, and SRWC production.

FUTURE DIRECTIONS

Data will continue to be collected and analyzed over a three- to four year rotation at the three
field-plot scale study sites to determine changes with SRWC crown closure and maturity. This study can provide guidance to woody crop producers on timing and quantity of nutrients to apply to SRWC to maximize productivity while minimizing off-site transport and environmental impacts. Information on changes in soil chemical and physical properties can verify the potential to improve overall soil quality by conversion of agricultural lands to biomass crop production. This has particularly important implications for lands that are erosive or are marginally productive.

The data from the watershed study in South Carolina will be compared with the ongoing southeastern study to determine the ability of field-scale studies to predict the environmental benefits and effects of conversion of agricultural lands to biomass crop production. This study is using hydrologic modeling to predict changes that can occur from conversion of extensive acreage to SRWC production. Model validation with field data will allow determinations of nutrient and chemical movement that can direct operational management practices to minimize off-site effects. Monitoring nutrient movement at a watershed scale can provide guidance on the quantity and timing of nutrient application to maximize feedstock production and minimize economic costs and environmental effects.

REFERENCES


Report Number (14) ORNL/CP--96173
CONF--970856--

Publ. Date (11) 1997 10
Sponsor Code (18) DOE/EE, XF
JC Category (19) UC--900, DOE/ER