Environmental sustainability of dedicated bioenergy feedstocks: Progress and directions

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In the 1970s, the Bioenergy Feedstock Development Program was established at the Oak Ridge National Laboratory by the US Department of Energy to focus on identifying appropriate species as dedicated energy resources in response to concerns of energy independence and security. The focus of the Program into the 1990s was on development and improvement of the model woody (hybrid poplar) and herbaceous (switchgrass) crops. This remains a major focus to date. As the potential of these crops as dedicated resources for liquid fuels and electricity production increased, issues raised as part of the National Bioenergy Roundtable and later the Northeastern and Southeastern Regional Roundtables pointed increasingly to the importance of the environmental issues to environmental groups. The importance of addressing environmental issues early in the development process rather than waiting until the production technologies were developed and environmental issues became potential "show stoppers" was recognized. Environmental issues centered around concerns about the effects of adding other monoculture crops into agricultural landscapes, their effects on natural plant and wildlife diversity as well as on soil and water quality. A biodiversity question was whether bioenergy crops could provide habitat and increase biodiversity and whether the habitat provided would be better than that of annually harvested agricultural crops. Studies in the early 1990s showed that woody crops provided breeding bird habitat that was used more extensively than agricultural crops but was not equivalent to natural forests. Later studies (1996-98) compared plantings and natural forest patches of similar sizes and ages and determined that both supported greater species diversity when young and were used by similar species assemblages when mature. Comparison of the effects of harvesting and management practices for switchgrass on breeding bird diversity has shown that both harvested and unharvested switchgrass provided habitat for a variety of species including species of concern. Current studies of switchgrass habitat quality and use by wildlife are being conducted on larger-scale plantings established to provide feedstocks for large-scale testing of energy use potential.

Site-specific environmental studies were established in 1995-1997 in response to the identified need for environmental data on production of hybrid poplar and switchgrass. Research projects across the upper mid-West and Southeast have looked at how bioenergy crops can be established, managed, and harvested to provide benefits for soil quality and sustainability, carbon sequestration, and water quality. Research on sites established in upper Minnesota has compared movement of chemicals applied to hybrid poplar, switchgrass, an agricultural crop (wheat), and natural forests. Greater water use efficiency has resulted in less chemical movement under the hybrid poplar than natural forest. Herbicide movement from the energy crop plantings has not occurred. These have been important results for verifying the environmental acceptability of agricultural practices for managing these energy crops.

Determining whether changes in soil quality - increases in soil carbon pools, soil organic matter, soil stability, and ultimately nutrient use efficiency - can occur with production of energy crops are important components of both environmental and crop development research. Studies in the upper mid-West, Southeast, and Southern US show that changes in soil carbon and soil organic matter accumulation on site converted from annual agricultural crops to energy crop production vary according to soil type and the initial organic matter content. The greatest increases in soil carbon are being observed on soils that are lower in initial organic matter and carbon content. The initial increases in soil carbon were most pronounced in the upper few centimeters from surface and shallow organic matter incorporation and turnover. With increasing time, considerable increases in soil carbon have been observed at greater depths under switchgrass and on woody crop sites where cover crops were established to minimize soil

erosion during initial establishment and growth. These results provide important input to verify for stakeholders that bioenergy crops can contribute to site quality through improvements in soil quality.

Along with observed benefits for soil quality, researchers in the Southeast have measured improvements in water quality with bioenergy crop production. Comparisons of energy crops with agricultural crops showed nutrient losses in runoff were comparable and in most cases were less than from annual crops. These comparisons have allowed identification of management modifications such as selection of appropriate cover crops (e.g., crimson clover) during establishment that can minimize erosion as well as contribute to nutrient availability. Increasing nutrient availability at no cost to the grower is an economic as well as environmental benefit. Larger-scale plantings of woody crops are facilitating comparisons of traditional management and water-level manipulations to raise the water table under the plantings to increase water availability and potentially productivity during the growing season.

The BFPD is currently working with the USDA Agricultural Research Service to determine the environmental implications of harvesting corn stover for ethanol production. Studies at research sites in the mid-West are addressing how soil quality, soil carbon, soil organic matter accumulation, and soil stability would be effected in both the short and long term by corn stover removal. Determining these effects will help identify appropriate practices and locations for stover harvest and the quantities of stover that could be removed without adverse effects on soil and water quality. The results of these studies are providing input to the ongoing Life Cycle Analysis for corn stover to provide field data in support of the soil carbon and erosion modeling analysis.

Many of the studies in progress, while dealing with either woody or herbaceous or in some instances both crops, provide data upon which to base cross-cutting conclusions for establishment, management, and ultimately harvesting practices that can be beneficial to both energy crops. An environmental conference hosted by the BFDP in 1995 in Oak Ridge addressed the state of environmental knowledge and needs for energy crops and along with the Roundtables provided much of the background and direction for the environmental research that has been conducted over the last five-six years. The BFDP has been actively engaged with environmental groups and other stakeholder groups and government organizations over this same period to help ensure that appropriate issues continue to be addressed and that the information from the ongoing research is available to them. Identification of issues, research planning and conduct, and dissemination of results is an interactive process that must remain such to identify how energy crops and residues can be sustainably produced and harvested as energy feedstocks. Identifying sustainable practices can help ensure protection of soil and water quality and biodiversity and responsiveness to concerns of environmental, agricultural, and other stakeholder groups.

Over the next few months, the BFDP will be convening an advisory group composed of representatives from various governmental, environmental, agricultural, bioenergy, and other appropriate stakeholder groups. The combined task of the BFDP and this representative group is to summarize progress and plan for the future of environmental research associated with dedicated energy crops and residues. As part of this planning we will revisit the results of the 1995 conference "what we know, and what do we need to know" and the ensuing research to be sure that we have addressed environmental concerns, have conducted appropriate research, and have identified key concerns remaining. Based on the studies and results to date we will determine key issues for the future. These issues will then be addressed in preparing the "Five Year Strategic Plan for Environmental Research" which is part of the overall Bioenergy Feedstock Development Programs plans for the future. Goals and paths will be established to proactively initiate research to obtain the data required to increase the environmental benefits of bioenergy feedstocks and feed into decisions about where individual crops can best be established to increase environmentally and economically sustainability production.