CONF-9511191--1

# Environmental Enhancement Using Short-Rotation Woody Crops and Perennial Grasses as Alternative Agricultural Crops


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Sponsored by the Biofuels Systems Division, U. S. Department of Energy under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp.


## Abstract


Short-rotation woody crops and perennial grasses are grown as biomass feedstocks for energy and fiber. When replacing traditional row crops on similar lands, these alternative crops can provide multiple environmental benefits in addition to enhancing rural economies and providing valuable feedstock resources. The Department of Energy is supporting research to address how these crops can provide environmental benefits to soil, water, and native wildlife species in addition to providing bioenergy feedstocks. Research is underway to address the potential for biomass crops to provide soil conservation and water quality improvements in crop settings. Replacement of traditional erosive row crops with biomass crops on marginal lands and establishment of biomass plantations as filter strips adjacent to streams and wetlands are being studied. The habitat value of different biomass crops for selected wildlife species is also under study. To date, these studies have shown that in comparison with row crops biomass plantings of both grass and tree crops increased biodiversity of birds; however, the habitat value of tree plantations is not equivalent to natural forests. The effects on native wildlife of establishing multiple plantations across a landscape are being studied. Combining findings on wildlife use of individual plantations with information on the cumulative effects of multiple plantations on wildlife populations can provide guidance for establishing and managing biomass crops to enhance biodiversity while providing biomass feedstocks. Data from site-specific environmetal studies can provide input for evaluation of the probably effects of large-scale plantings at both landscape and regional levels of resolution.


## Introduction

Short-rotation woody crops (SRWC) and herbaceous crops (perennial grasses) are becoming increasingly identified as potential alternative energy sources to increase energy independence that can also provide extensive environmental benefits. These benefits can be viewed as occurring from a global scale through reductions in greenhouse gases to a site specific scale through decreases in erosion and the need for chemical additions compared to traditional row crops. When grown as biomass feedstocks, these woody and herbaceous crops are being shown to provide significant sources of energy and fiber in selected regions of the country. In addition to providing an alternative energy resource fuel, biomass crops can provide crop diversity and both economic and environmental benefits to local agricultural communities. The potential environmental benefits of short-rotation woody crops and herbaceous energy crops compared to traditional row crops include positive effects on soil quality and stability, cover for wildlife, and lower inputs of energy, water, and agrochemicals (Wright et al., 1992, McLaughlin, 1992, Tolbert and Downing, 1995).

The need to reduce national dependency on imported oils, and the opportunity to develop the nations' agricultural potential to produce high yielding crops as renewable bioenergy supplies have prompted significant national research on both the agricultural production and energy conversion technologies necessary to realize this potential (Wright, 1994; Lynd et al., 1991). To meet projected energy needs using biomass feedstocks could require tens of millions of hectares of primarily agricultural land to produce the large amounts of these feedstocks needed to supply alternative electrical generating facilities and for conversion to liquid fuels and chemicals (Ranney and Mann, 1994). Of the 74 Mha (million hectares) currently in cropland that were projected in 1994 as not required to meet U.S. agricultural needs to the year 2030, only 16 Mha were in regions determined to be well suited for energy crop cultivation (Graham, 1994). It was estimated that 8-16 Mha of this cropland could be converted to biomass production in the near future without displacing traditional row crops in any significant way. Energy crop production could extend beyond the 16 Mha without significant crop displacement if the additional land was drawn from pastureland or former cropland currently in long-term set-aside programs (Hohenstein and Wright, 1994). The woody and herbaceous biomass crops are not seen as competing with traditional row crops such as corn and soybeans for available farmlands but as perennial crops that can be grown on more marginal lands where concerns about erosion exist, where soil stabilization is needed, or where economic return for farmer investment of labor and resources is more limited. Once established, perennial biomass crops require minimal input of labor or resources for maintenance compared to annual cycles of planting and harvesting for traditional row crops.

Traditional agricultural crops need soils of good quality and water holding potential which are easy to work, and have adequate water and nutrient availability to support sufficient harvest for farmers to realize adequate profit to sustain an economic livelihood. Because the market and the economic needs of farmers drive what crops and how much of each crop are planted, agricultural production may extend onto more marginal sites to meet these needs. When production on more marginal, erosive sites occurs, agriculture can and does adversely affect the existing environment. With the need to feed, cloth and provide fuel sources, it is inevitable that agriculture will impact the very resources that it relies on for productivity and profitability. With the need to provide alternative fuel feedstocks, biomass crops may become an economically viable crop option for many farmers in the future. Whether these biomass crops can become economically viable crop options is yet to be determined (Walsh, 1995) and will depend on demand, economics, and other factors such as public acceptance that are not a component of the address of the environmental effects of energy crop production. Support by state or federal governments and utility commitments to purchase biomass feedstocks may be required initially to encourage production of these crops and a reasonable economic return to growers.

This paper focuses on three specific characteristics of the environment where biomass crops may provide benefits while providing income to farmers and agricultural communities: soil loss, water quality, and native wildlife habitat. Physical and management differences between traditional row crops and biomass corps, potential areas of benefit to the environments with deployment of these crops compared to row crops, and results of some of the research that the Biofuels Feedstock Development Program (BFPD) has supported or is supporting to quantify the potential environmental benefits of biomass crop production are highlighted.

**Potential Energy Crops**

**Herbaceous energy crops**. Perennial grass crops such as switchgrass (Panicum virgatum, a sod-forming, warm-season grass which historically has been an important component of the native North American Tallgrass Prairie) have the potential to provide farm income as both energy feedstock and forage sources (McLaughlin et al., 1994). After evaluating yield and agronomic data on 34 herbaceous species, the BFDP at Oak Ridge National Laboratory selected switchgrass for further research and development as a primary bioenergy candidate. This choice was made based on both the high yields and excellent versatility of switchgrass determined in early field trials as well as the many positive environmental attributes.

Switchgrass as both an energy crop and a forage crop provides an economic advantage to farmers because it can be harvested using traditional agricultural equipment to produce large round bales which can be stored either on-site until needed or transferred directly to conversion facilities following harvest. Depending upon the region where production occurs and when the grass is harvested as an energy source, farmers may be able to realize a second growth and use of the grass as forage for livestock on an annual basis. Switchgrass and other native prairie grasses have become increasingly important as forage grasses particularly in the Midwest because of their ability to grow during hot summer months when water availability can limit growth of most other grass and crop species (Moser et al., 1993).

Because of its extensive rooting system, switchgrass provides environmental advantages such as increased soil organic matter and stability, and lower inputs of energy, water, and agrochemicals over traditional row crops (McLaughlin, 1992). The extensive rooting system of this perennial grass increases the efficiency of nutrient and water acquisition, provides strong energy storage reserves, increased soil organic matter which decreases soil erosion, runoff, and loss of agricultural chemicals; thereby contributing to more stable yields during stress years. The environmental benefits of erosion reduction associated with the rooting system of individual perennial grass plants is enhanced by their ability to persist for a number of years without the annual replanting cycle and associated soil and nutrient loss associated with traditional row crops such as corn, soybeans, and cotton. The attributes of persistence and soil quality enhancement contribute to the benefit of perennial grasses as reclamation tools on marginally productive sites that have been degraded by erosion and soil depletion (Aguilar et al., 1988).

**Short-rotation woody crops**. A number of tree species have been examined by the BFDP since 1978 to identify species that have the greatest potential for rapid growth, wide site adaptability, pest resistance, and disease resistance. To date, the species chosen with the greatest potential for extensive development are poplar, willow, sweetgum, sycamore, and maple (Wright, 1994). Experimental yields of SRWC have shown yields 2-5 times those currently obtained in natural forest stands and conifer pulpwood plantations in the United States. The increased yields of these tree species is the result of good species/site matching, careful establishment techniques, use of improved clones or carefully selected seedlings, and recognition of the importance of weed control until tree crown closure occurs (Wright, 1994). Methods for establishing SRWC are the same as for almost any other agricultural crop; although no-till establishment techniques have not been effective because of the need to ensure weed removal and to break up any underlying hard pan for maximum root penetration. Wright (1994) provides more detailed information on site establishment, maintenance, and harvesting needs for SRWC. One consideration with production of woody crops is the need for more traditional forest harvesting equipment that may not be as readily available to agricultural growers.

Studies of small-scale plantings of hybrid poplar in the the north-central states (Hansen, 1993) showed that over time trees grown on tilled agricultural lands that were previously in prairie grasslands sequestered significant quantities of soil carbon as organic matter compared with traditional row crops and grasslands. Unlike perennial grasses that can blanket the soil surface in one to two years, tree crops continue to leave most of the soil surface exposed (assuming weed control/removal) until canopy closure occurs 3-5 years after establishment. Until canopy closure, soil erosion and loss of organic matter continue to occur although to a lesser degree than with annual crops. Once the tree crops have closed canopy, weed control is no longer required as light penetration and consequently weed growth are minimized. Fertilization requirements for SRWC depend upon the soil type and fertility. Fertilization is required to maintain productivity and to sustain the fertility of the land. Studies are currently being conducted by the BFDP to determine fertilization and irrigation requirements of hybrid poplars in the Pacific northwest and of sweetgum, sycamore, and cottonwood in the Southeast to maximum yield while limiting production costs.

**Environmental Enhancement Using Biomass Crops**

The BFDP's environmental research task is currently supporting a number of studies to help determine the environmental effects of conversion of agricultural lands to biomass crop production. These studies, being conducted by several universities under subcontracts with the BFDP, are designed to develop data that will help us determine how soil characteristics change with conversion of agricultural lands to biomass crop production, what is the fate of chemicals applied to energy crops compared to annual agricultural crops, and what are the effects of converting agricultural lands to tree crops and grassland production on habitat availability for native wildlife species. The information from these studies will help determine how environmental enhancement can be achieved through biomass crop production as part of existing agricultural setting.

Studies of soil characterization conducted by the University of Minnesota, Duluth on agricultural soils planted to biomass crops can provide information of how change in organic matter composition occurs with time. This information will allow determinations of whether biomass crops can be used as a reclamation tool for eroded sites and with time return these sites to increased productivity. The results of this study address the potential for establishing biomass crops in a farm rotation system to increase crop diversity, minimize erosion, and increase soil fertility while diversifying the economic base for individual farm systems.

Studies of the fate of chemicals applied to short-rotation woody crops both with and without cover crops, a herbaceous crop (switchgrass), and traditional row crops will quantify movement of nutrients and herbicides applied to energy crops into the soil and groundwater beneath research-scale sites. The study in Alabama, part of a three site southeastern study jointly funded with the Tennessee Valley Authority, is also addressing the volume and chemical composition of surface water runoff from switchgrass, corn, and tree crop plantings to quantify erosion and nutrient movement across the ground surface as well as through the soil. These studies will provide information on uptake, release, and off-site movement of nutrients and pesticides on a variety of soil types, and will help predict the hydrologic and environmental pathways of chemical applied to biomass energy crops and their long-term effects on the agricultural environment.

A study being conducted by the BFDP in conjunction with an industrial partner in the coastal plain area of South Carolina is determining the growth response of cottonwood clones, sycamore, and sweetgum to different irrigation and fertilization regimes. Growth of these species is being compared to sites receiving no amendments. The nutrient content of water infiltrating each experimental study plot is being monitored to determine nutrient uptake and movement and to provide guidance on the quantity and timing of application of nutrients and water to maximize growth and minimize costs to growers. Clemson University is conducting a related study with support from the BFDP and the National Council for the Pulp and Paper Industry for Air and Stream Improvement (NCASI) to address use of paper and pulp sludges applied either alone or in combination with agricultural wastes as soil amendments for production of hardwood crops. This study offers the opportunity to determine the potential to utilize agricultural residues to enhance productivity and soil quality, to address the quantity and composition of the residue required to increase productivity, to provide environmental benefit, and to minimize economic costs for agricultural producers. These and studies sited above offer opportunities for comparisons of nutrient and water movement to help address how different tree crops in different soils and under different climatic regimes respond to different nutrient regimes and to predice the effects and benefits of large-scale deployment of biomass crops in agricultural landscapes.

**Biodiversity.** Short rotation woody crops and switchgrass energy crops can provide benefits to the biological diversity of native species by creating or increasing habitat for a variety of species. For example, fast-growing energy trees planted in the landscape around existing forest remnants may "buffer" the forest habitat from predation from edge using species such as raccoons and brown-headed cowbirds. The additional wooded area provided by these buffers may increase the habitat value of the adjacent forest remnants for a variety of "disturbance sensitive" species, including an entire suite of migrant birds that need interior forest habitat to survive and breed. Many of these interior forest habitat birds are neotropical migrants such as the prairie warbler and yellow breasted chat that migrate between breeding areas in temperate North America and tropical wintering areas in Latin America and the Caribbean. These migrants are declining at an accelerated rate as the result of forest fragmentation and competition from edge utilizing wildlife species (Wilcove, 1985; Blake and Karr, 1987; and Robinson et al., 1995). Some of these neotropical migrants, such as the prairie warbler and yellow breasted chat, require large expanses of regenerating forest and may benefit directly from habitat created by short rotation woody crops. Other neotropical migrants such as sedge wrens rely on grassland habitats, and could benefit from switchgrass energy crops directly, or from planting switchgrass to "buffer" existing native grasslands from other land uses, including traditional row crops. In other areas, small plantings or "windbreak" plantings of native grasses or short rotation woody crops can provide additional edge habitats in primarily agricultural landscapes for a variety of species that benefit from the ability to access different habitat types in close proximity to their preferred habitat. Placing native grasses and short rotation woody crops to buffer existing forests, to form linear "corridors" for wildlife movement between otherwise isolated forests or grasslands, or to provide greater habitat diversity in agriculturally dominated areas, is a process that could enhance biodiversity, but is dependent on how species use the habitat provided by energy crops.

How large a role these crops can play in providing benefits to native biodiversity has been an area of active research supported by the BFDP on a variety of sites since 1992. To date, research on bird use of small-scale hybrid poplar plantings in Minnesota has shown that these tree plantings support increased bird diversity compared to row crops; however, the habitat value of the young tree plantations studied was less than that of forest and shrub habitats adjacent to poplar plantings (Hanowski et al., 1994). Few bird species that require mature forest habitat have been found in the young woody plantings; more common species have been found to dominate the avifauna of these plantings (Hanowski et al., 1994). Studies of small mammals on the same small-scale plantings in Minnesota has shown that those sites without canopy closure have shown that these smecies use these plantings in a manner similar to grasslands rather than to forested lands; small mammals requiring mature forest habitat have not yet been found using young woody energy crops (Christian et al. 1994). Energy crop management, including ground-level vegetation cover and diversity, has been found to be of critical importance for small mammal habitat value. National Audubon Society studies of switchgrass plantings in Iowa (Hoffman et al., 1993 and 1995) have determined that these plantings extended habitat for grassland birds but that not all of the species in the surrounding landscape used these plantings. Additional studies of larger-scale plantings are needed to validate the results of the small-scale studies and to determine the value of more extensive plantings of biomass crops.

New research being conducted in the Southeast by the BFDP in conjunction with the National Audubon Society and an industrial partner is addressing which energy crops, planting sizes, ages, management regimes, and placement in the landscape are of most benefit to enhancing regional biodiversity. Based on research to date on habitat characteristics of biomass tree and grass crops compared to row crops, it is likely that energy crops will provide greater habitat benefit for native biodiversity than row crops, and could benefit biodiversity on a regional level with large-scale production of biomass energy crops.

## Conclusions

Conversion of agricultural lands to energy crops is being closely monitored to determine the environmental effects and benefits of production. Environmental research on short-rotation woody crops and herbaceous energy crops conducted or supported by the U.S. Department of Energy's BFDP has shown that there are significant environmental benefits from production of biomass crops that can contribute to the economic viability of these crops and economic diversification of individual farms and agricultural communities. To date, studies at research scales have shown that biomass crops grown on more erodible agricultural lands provide greater soil stability and increase nutrient retention as well as soil organic matter. Results of these studies can provide initial guidance in determining potential environmental effects and benefits of converting larger areas of land in different regions of the U.S. to biomass crop production.

If biomass crops, specific management techniques, and arrangements on the land are found to be of most value for improving soil and water quality, decreasing chemical use and/or runoff, and improving native biodiversity compared to row crops, it will be important to determine cost/benefit ratios and management techniques for growers who may want to consider including environmental considerations in their energy crop plantings so that both environmental and economic benefits can be fully realized. Determining what works best and developing guidelines on how to produce energy corps at a profit while benefiting the environment is an important priority. Information on wildlife use of biomass crops can help determine ways that it can be worth the time and interest of growers to incorporate environmental considerations into location and management of biomass plantings to provide additional economic value from such activities as hunting and wildlife viewing leases. It is important to develop an environmental decision structure to help determine the best locations for biomass energy crops and the best measures to deploy, manage, and harvest large-scale planting to achieve regional environmental benefits for soil, water, and wildlife diversity while meeting the economic needs of individual growers and regional and local agricultural communities.

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