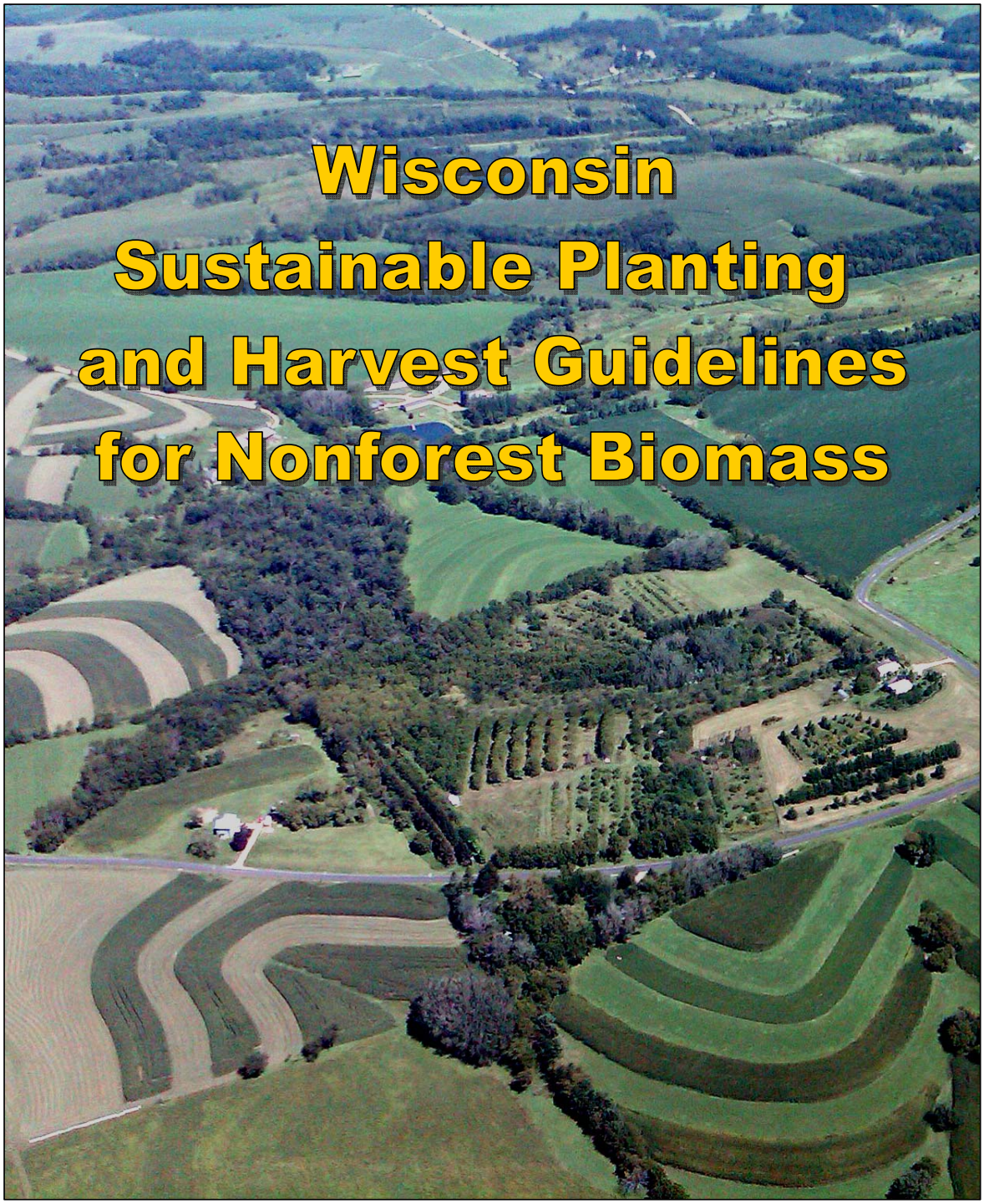

Wisconsin Sustainable Planting and Harvest Guidelines for Nonforest Biomass

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1. INTRODUCTION

Interest in bioenergy is increasing in response to concerns about energy security, energy independence, and environmental and climate impacts associated with use of non-renewable energy resources. The expansion the biomass energy industry has the potential to benefit Wisconsin's water resources, wildlife habitat, and agricultural sectors by reducing erosion, providing a market for materials removed during habitat management activities, expanding markets for agricultural products, creating jobs and reducing reliance on non-renewable fuels. However, concerns have arisen about the sustainability and impact to natural resources from increased nonforest biomass production in Wisconsin. Understanding these potential impacts and assuring that the production of nonforest biomass is conducted within the framework of sustainable resource management is a priority of the Wisconsin Department of Natural Resources (DNR) and Department of Agriculture, Trade and Consumer Protection (DATCP). The development of science-based voluntary guidelines in advance of widespread biomass planting and harvesting in Wisconsin is intended to help ensure sustainability of and, whenever possible, benefit the natural resources of the state. These voluntary guidelines will help users make informed decisions about bioenergy production on both public and private lands throughout Wisconsin and help inform policy decisions for future, emerging bioenergy programs.

Impacts from extensive land use conversion may be of concern, including cumulative impacts on habitat across the landscape, impacts on agricultural profitability and farm viability, and effects on communities in and around areas of bioenergy crop production. In general, these voluntary guidelines address the immediate resource management issues arising from biomass production and harvest, though broader impacts are noted when known.

1.1. Overview

1.1.1. GUIDELINE DEVELOPMENT

In August 2009, an effort was initiated to develop voluntary guidelines for the planting and harvest of nonforest biomass on Wisconsin's landscapes. Development of the voluntary guidelines builds on work completed by numerous other agencies and research teams including the Wisconsin Council on Forestry, and guidelines developed by other states. In November 2009, a technical team assembled to develop the guidelines including biologists, researchers, policy analysts, land managers, and administrators in DNR, DATCP, and the University of Wisconsin (UW-Madison). Simultaneously, an executive committee of administrators from DATCP, DNR and UW-Madison was formed to provide guidance to the technical team.

In 2010, the Wisconsin Legislature created the Bioenergy Council in Act 401. This body reviewed drafts of this document and provided additional input. Scientists and other experts have also reviewed recommendations, though it should be noted that this was not a rigorous double-blind process normally associated with scientific peer review. On XX/XX/XX, the Bioenergy Council adopted this document to fulfill their statutory obligation to publish voluntary guidelines.

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1.1.2. Intended Audience

These voluntary guidelines cover multiple biomass feedstocks from a broad perspective. They are intended to facilitate informed decision making about growing and harvesting nonforest biomass across Wisconsin for a diverse audience, from producers to policymakers. The Executive Report (will be updated upon completion/approval of main document) provides a list of specific guidelines for nonforest biomass establishment and harvest while the full technical report also provides the background behind those recommendations. In the future, a series of technical bulletins and targeted brochures aimed at educating different audiences will supplement the original full technical report.

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1.1.3. Purpose and Organization of the Guidelines

This document provides 1) an overview of the implications and issues surrounding future bio-energy/biomass programs in Wisconsin, 2) a summary of the science and rationale used to produce the specific guidelines, and 3) practical recommendations for site level implementation of biomass crop production.

Chapter 2 contains an overview the potential impacts of biomass production, sensitive areas within Wisconsin, and other fundemental concepts that build the framework for sustainable biomass production. The information in Chapter 2 should be useful for addressing the questions: *What biomass crop should I grow or harvest? Where should I grow or harvest this biomass? What information do I need to make sustainable and ecologically sound decisions?*

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Chapter 3 contains the actual voluntary guidelines broken into 5 sections 1)General guidelines applicable to any nonforest biomass production, 2) Perennial grasses (including dedicated grass crops and lands with existing grass cover), 3) Trees and shrubs (including dedicated woody crops and lands with existing tree and shrub cover that are not considered forest), 4) Annuals and Crop residues, 5) Wetlands

The Guidelines are based on the best available science and the authors' professional experience and judgment and include recommendations for sustainable production and harvest of nonforest biomass within both natural and agricultural systems on public and private lands that will be used to generate electricity, liquid transportation fuel, and heat.The Guidelines **will not** address woody biomass from forested systems as such voluntary guidelines already exist[1].

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[1] http://council.wisconsinforestry.org/biomass/

KEY DEFINITIONS

Nonforest Biomass: non-woody cellulosic plant materials including leaves, stems and stalks of native and non-native perennial and annual grasses, forbs and legumes (e.g., switchgrass, cattails, orchard grass, reed canary grass, and native prairie plants); woody material from nonforested systems such as shrublands, non-merchantable woody material (e.g., materials removed in savanna management); woody material harvested from short-rotation hybrid poplar, willow, and other plantations; and crop residues (e.g., corn stover, wheat straw).

***Sustainability:** The stewardship of lands and resources dedicated to nonforest biomass production in ways that are environmentally, socially and economically sound across a broad range of scales, that does not negatively impact other ecosystems, and that can meet societal needs both now and into the future.*

**Comprehensive Glossary in Appendix*

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1.1.4. PRINCIPLES INFORMING DEVELOPMENT OF THE GUIDELINES

The bioeconomy is evolving rapidly so guidelines must be adaptable as new information becomes available. The recommendations within these Guidelines reflect the following principles:

- Soil quality should be maintained or improved by minimizing erosion, enhancing carbon sequestration, promoting healthy biological systems, and protecting chemical and physical properties.
- Surface and ground water quality and quantity should be maintained or improved.
- Habitat quantity and quality for game, non-game,rare, declining and endangered species of fish and wildlife should be maintained or improved.
- Conservation of biological diversity, in particular relatively intact natural communities, native plants, insects and wildlife (game and nongame), should be maintained or improved.
- Conversion of native or sensitive species' habitats and/or the introduction of invasive or non-native species should be avoided.
- Consideration should be given to of the impact of biomass programs on landscape scale land use changes and ecosystem services.

In addition, it is our intention that the Guidelines:

- Be implemented in addition to other applicable guidelines and best management practices (BMPs) addressing planting and harvest of grassland, short-rotation woody crops or crop residue.
- Be compliant with and complementary to existing rules and regulations addressing planting and harvest of grassland, short-rotation woody crops or crop residue, such as those defined in Federal Farm Bill Policy and state and federal water quality and endangered species laws.
- Recognize that there may be unknown and adverse impacts that result from new biomass programs and attempt to minimize and/or mitigate those impacts if they arise, and adapt accordingly.

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- Recognize other key components of sustainability, including economic viability of the entire chain of operations and practices that sustain healthy rural families, communities, and labor forces.

1.1.5. Uncertainty within the Guidelines

Dedicated nonforest biomass operations are not common in Wisconsin; however, research and experience in-progress will produce further information in years to come. Moreover, some potential biomass systems are well known with well-developed infrastructure while others are novel, resulting in asymmetrical treatment of their management and sustainability considerations in this document. The Bioenergy Council will review and update these voluntary guidelines as needed to reflect updates in knowledge and technological advances as they occur.

The Guidelines embody a *precautionary approach*. In the absence of scientific consensus or when scientific evidence is insufficient, and there is some risk of negative impact associated with an action, the recommendations are written to encourage prevention in the face of uncertainty. This approach is intended to ensure that biomass planting, management, and harvest do not degrade ecosystem services while also acknowledging that in the future, with greater scientific certainty, the voluntary Guidelines may be revised to reflect evidence-based knowledge.

These voluntary guidelines should not be construed as a constraint on the development of viable bioenergy initiatives in Wisconsin. The hope is that the guidelines will provide some assurance to land owners and entrepreneurs that they are investing in activities that will create a new energy future for Wisconsin based on methods and approaches that will not prove harmful in the long-run and will ultimately move Wisconsin along a path of energy independence.

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1.2. Biomass and Bioenergy in the U.S. and Wisconsin

1.2.1. What is Bioenergy?

Bioenergy is renewable energy derived from recently living biological material, or biomass. Fossil carbon sources of energy such as coal and petroleum are not sources of bioenergy since these materials are the result of geological processes that transformed plants living millions of years ago. Bioenergy is a form of renewable energy because the energy contained in biomass is energy from the sun captured through natural processes of photosynthesis, and so long as the quantity of biomass used is equal to or less than the amount that can be re-grown it is potentially renewable indefinitely. Bioenergy includes power and fuels derived from biomass. *Biopower*, for example, is electricity generated from combustion of biomass. Heat and steam, or a combination of both, may also be produced through combustion of biomass, and may be produced in

co-generation with electricity. *Biofuel* is commonly used to refer to biomass-derived liquid fuels and gases most typically used in transportation.

The majority of biomass for bioenergy comes from three sources: forests, agriculture, and waste (see Figure 1-1). Algaculture, the farming of species of algae, is a fourth source currently in development and not covered here. Forest-based biomass includes merchantable stem wood [wood in the stems of trees greater than 5" diameter at breast height (dbh)], tops and branches of harvested trees, non-merchantable trees, and understory trees (less than 5" dbh). Agriculture-based biomass includes crops grown specifically for bioenergy production (dedicated bioenergy crops) and plant residues collected after harvest of crops grown for food or feed. Dedicated bioenergy crops include annual crops grown for their sugars or starches, such as sugarcane and grains that can be fermented to produce alcohol and other liquid fuels, and perennial herbaceous and woody crops grown for their cellulose. Cellulosic bioenergy crops include grasses like switchgrass and woody plants like hybrid poplar trees. Waste-based biomass includes organic materials leftover from industrial processes such as mill and pulp production, municipal solid wastes, construction wastes, and landfill gas. Biomass from algaculture involves production of microalgae - organisms less than 0.4 mm in diameter and capable of photosynthesis. A more detailed overview of specific nonforest biomass types is provided in chapter three.

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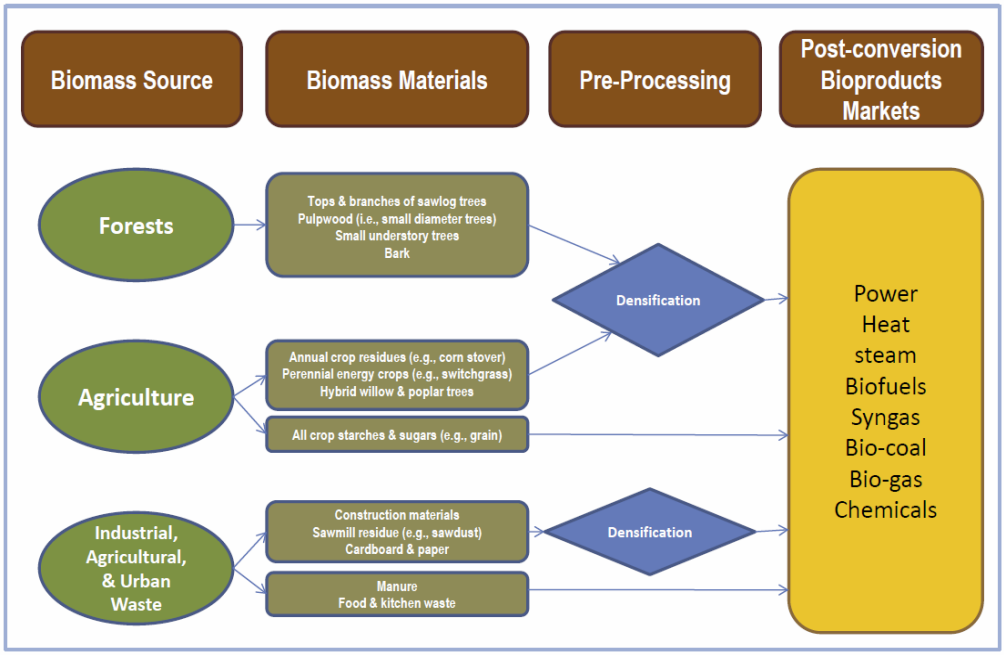

Figure 1-1. Current major biomass materials and feedstocks. (CL Williams after Baye, 2010).

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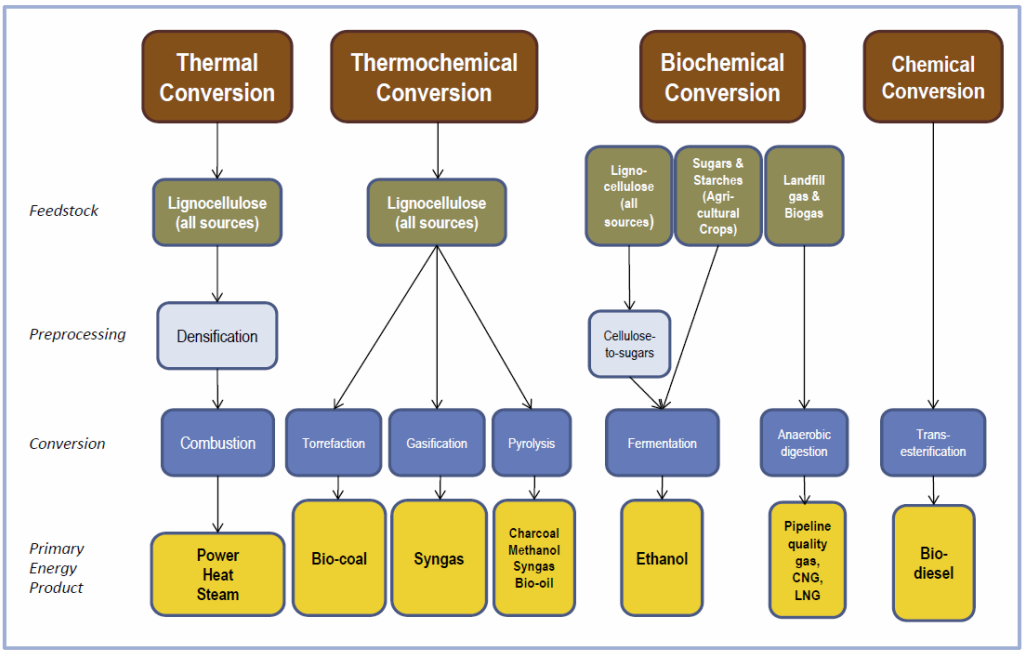

Figure 1-2. Bioenergy conversion pathways. (CL Williams after Baye, 2010).

To make use of the energy available in biomass it is necessary to utilize technology to either release the energy directly, as in burning of biomass materials for heat, or to convert it into other forms such as solid or liquid fuel. There are three types of conversion pathways currently being developed, each appropriate for specific biomass types and specific energy products: thermal, chemical and biochemical (Figure 1-2). As implied by its name, thermal conversion uses heat to convert biomass into other forms. Thermal conversions processes include combustion, torrefaction, pyrolysis and gasification.

Chemical conversion involves use of chemical agents to convert biomass into liquid fuels. Biochemical conversion involves use of enzymes from bacteria or other microorganisms to break down biomass through processes of anaerobic digestion, fermentation or composting. Although relevant technologies exist and continue to be developed, some are not yet cost-effective, particularly for large-scale conversion of cellulosic biomass to transportation fuels. The Energy Center of Wisconsin's Biorefine website http://www.biorefine.org/index.php) has more details on feedstocks and conversion processes.

Bioenergy production and use occurs along a continuum of scales. While residential use of biomass for heat and cooking has long been a part of human history, new technologies are enabling more efficient use of a wider variety of biomass types for these and other uses. At the other end of the bioenergy production spectrum are large transnational energy companies who own the means of biomass production and conversion, as well as the means to distribute bioenergy products. Utility companies and others take advantage of economies of scale to acquire vast quantities of biomass, converting the biomass into bioenergy and making it available for thousands if not millions of consumers. In between the individual household and large utilities, are numerous production and distribution arrangements and organization types, including mixed-scale operations, cooperatives, and community-based, or small-scale distributed energy projects. There are eco-

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nomic and societal benefits and costs associated with different scales of bioenergy production and use. Trade-offs among these benefits and disadvantages often occur. See chapter 2.1 for a more detailed discussion of the costs and benefits related to biomass energy.

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1.2.2. Current Trends in U.S. Energy Production and Consumption

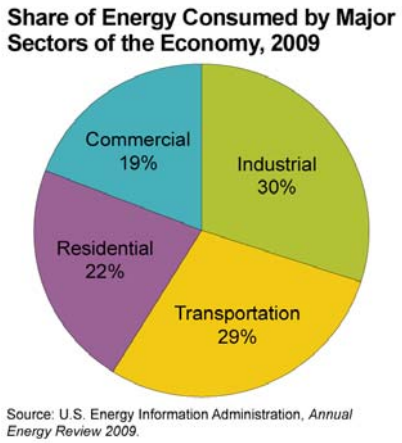

Figure 1-3 Share of energy consumed by major sectors of the economy, 2009

Approximately 92% of the energy used in the U.S. comes from non-renewable sources (nuclear and fossil fuels). Renewable energy (biomass, solar, wind, hydro) provides the other 8%. Approximately one-third of this energy is used for industry and manufacturing, one-third for transportation and one-third for commercial and residential use (Figure 1-3). The pattern of fuel use varies widely by sector (i.e. transportation relies heavily on oil while electrical generation uses mainly coal).

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By 2035 total energy use is projected to increase with fossil fuel's share decreasing slightly (from 84% to 78%) as renewable fuels increase (from 10% to 14%). This projected fuel shift is due largely to changes in federal and state policies (i.e. CAFE standards, EISA, RES, RPS and the American Recovery and Reinvestment Act). Among the fossil fuels, natural gas will likely play a larger role in the future, as the U.S. has recently discovered vast new supplies of natural gas (ex. shale gas deposits) and economists are projecting low prices for decades to come. Coal will likely remain the dominant fuel source for electric energy production. Very few if any new coal plants will be built, but it is projected that coal use will increase gradually over this time as current coal facilities are used more intensively and old plants are shut down.

Twenty-nine states have established targets for renewable energy production (www.DSIREUSA.Org) including wind, solar, hydropower and biomass. Although the total amount of power or heat generated from biomass is fairly small, biomass (biomass waste + biofuels + wood) makes up the largest percentage (50%) of renewable energy.

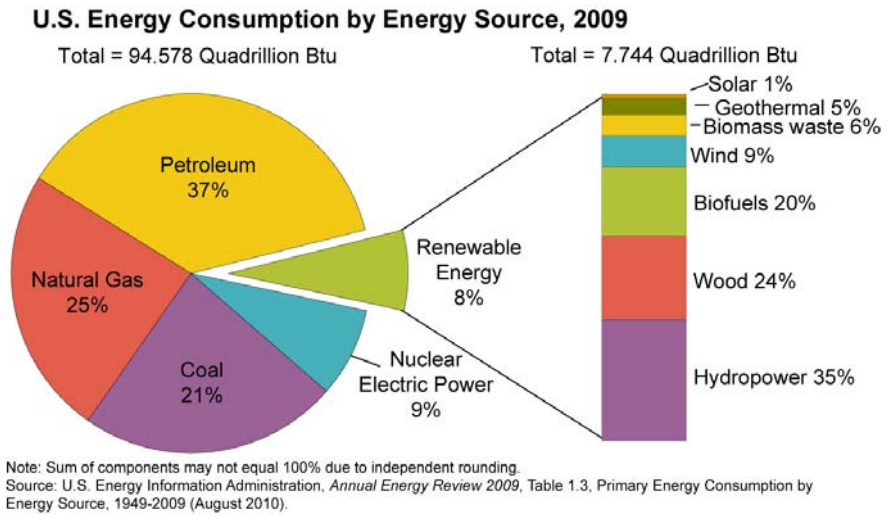

Figure 1-4. Biomass (as represented by wood, biofuels, and biomass waste) represents a large part renewable energy in the US.

U.S. efforts to expand biomass as a renewable fuel have focused on electric power generation (co-firing biomass with coal) in part due to new state renewable energy standards mandating utilities supply a specified portion of their electricity with renewable energy. Biomass co-fired in a coal power plant can assist the utility in meeting renewable energy standards and help cut pollution from coal burning.

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1.2.3. BIOMASS CURRENT TRENDS AND POLICY IN WISCONSIN

In Wisconsin, the use of renewable fuels is below the national average at 4.5% of our total energy use, of which biomass accounts for 60% (Wisconsin Energy Statistics 2009, Figure 1.7). Coal dominates Wisconsin's electricity generation, fueling about two thirds of power plants (US Energy Information Administration website). As these plants age, co-firing with biomass may increase to meet Clean Air Act standards.

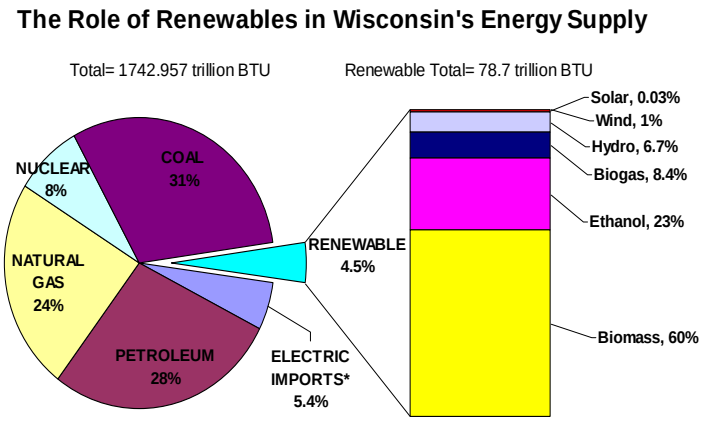

Figure1-5. The role of renewables in Wisconsin's energy supply. 'Electric imports' is the estimated resource energy used in other states or Canada to produce the electricity imported into Wisconsin. Note: sum of percentages may not equal 100 due to independent rounding. Source: Wisconsin Office of Energy Independence, Wisconsin Energy Statistics 2009.

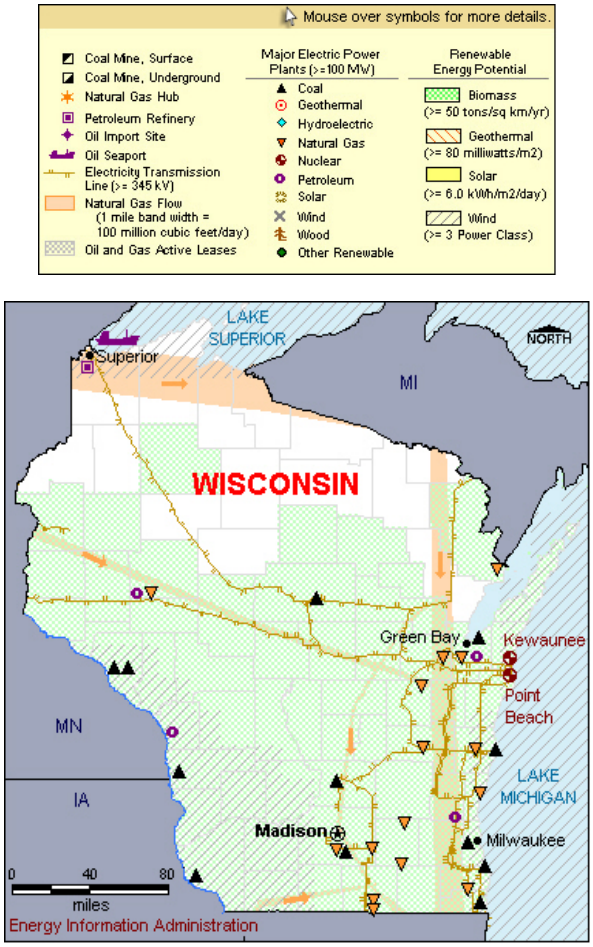

Figure1-6. Potential biomass available in Wisconsin according to the Energy Information Administration.

1.2.4. Drivers of Bioenergy Development

Interest in bioenergy is increasing in response to concerns about energy security, energy independence, and environmental and climate impacts associated with use of non-renewable energy resources. Proponents of agriculture and forestry see bioenergy as a tool to protect productive working lands and provide new markets for these volatile industries. Bioenergy is seen as a potential stimulus for economic development, particularly in rural areas. As interest in bioenergy grows, challenges related to knowledge, technology, economics, and society must be identified and overcome.

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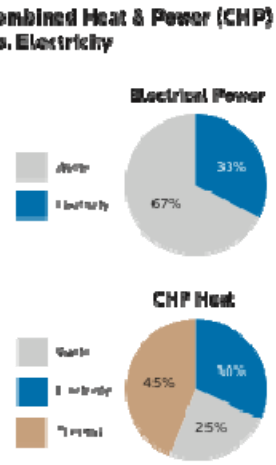

Figure1-6 Efficiency of Combined Heat and Power and Electricity (District Energy, St. Paul)¶

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1.2.4.1. Federal Policy

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Although used in the United States since 1908 in the Ford Model T, interest in ethanol as a transportation fuel grew in the late 20th century as a result of oil supply disruptions in the Middle East. Ethanol production in the U.S. grew with support from federal and state ethanol tax subsidies and the mandated use of high-oxygen gasoline. Additional incentives in the 80s and 90s, and passage of the Clean Air Amendments of 1990, further incentivized expanded U.S. ethanol production. Today nearly all ethanol produced in the U.S. uses corn grain fermentation to create this first generation biofuel. Current bioenergy research and development focuses primarily on advanced biofuels and biopower projects, as well as next-generation biomass crops. Policy at national and state levels provides major incentives for these development agendas.

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In 2006 President Bush introduced the Advanced Energy Initiative which included increased research funding for cutting edge biofuel production processes. In early 2007,he announced the "Twenty-in-Ten" initiative, a plan to reduce gasoline consumption by 20% in 10 years. Congress responded in December 2007, by passing a Renewable Fuel Standard (RFS) as part of the Energy Independence and Security Act (EISA) of 2007 (http://energy.senate.gov/public/index.cfm?FuseAction=IssueItems.Detail&IssueItem_ID=f10ca3dd-fabd-4900-aa9d-19de47df2da&Month=12&Year=2007). The RFS requires production of 36 billion gallons annually of biofuels by 2022, and includes specific provisions for advanced biofuels, paving the way for advanced technologies (see Figure 1-5).Many states have adopted similar policy initiatives and programs. In 2007, the Bush Administration proposed and in 2008 Congress passed a Farm Bill that included funds for new renewable energy and energy efficiency-related spending at the US Department of Agriculture (USDA; http://www.usda.gov/wps/portal/usda/usdahome), including support for cellulosic ethanol projects and mandatory funding for bioenergy activities (http://www.usda.gov/wps/portal/usda/farmbill2008?navid=FARMBILL2008).

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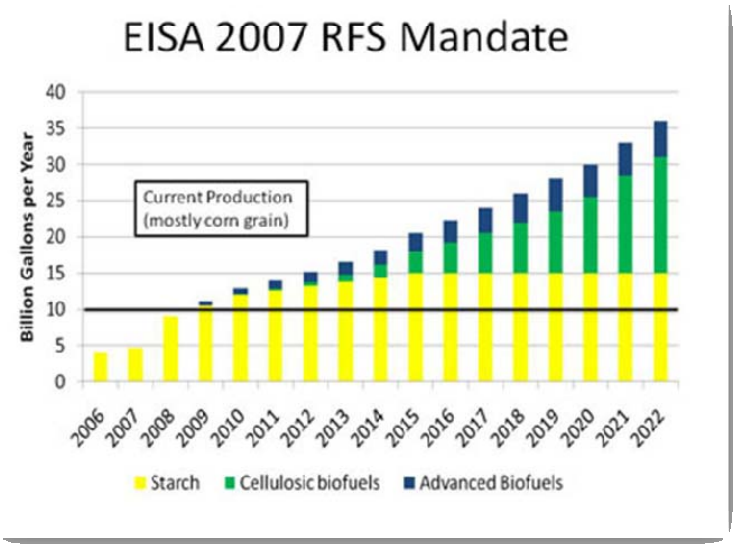

Figure1-7. Production Goals set by the Energy Independence and Security Act (2007). (University of Wisconsin-Extension; http://www.extension.org/pages/Biomass_Feedstocks_and_Energy_Independence).

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1.2.4.2. Federally Funded Programs and Projects

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New or expanded federally funded or sponsored research initiatives, programs and offices have spurred growth in the bioenergy sector. Mostly notable are those associated with the U.S. Department of Energy (DOE; http://www.energy.gov) and the USDA. Chief among the research centers are the National Renewable Energy Lab (NREL; http://www.nrel.gov), Idaho National Lab (INL; https://inlportal.inl.gov/portal/server.pt?open=512&objID=255&mode=2), Sandia National Labs (SL; http:/www.sandia.gov) and the DOE's suite of three bioenergy research centers: Oak Ridge National Laboratory (ORNL; http://www.ornl.gov) and collaborators; the Great Lakes Bioenergy Research Center (GLBRC; http://glbrc.org) and collaborators; and the Joint BioEnergy Institute (JBI; http://www.jbei.org) led by the Lawrence Berkeley National Laboratory (LBNL; http://www.lbnl.gov). The DOE's Office of Energy Efficiency and Renewable Energy (EERE; http://www.eere.energy.gov) sponsors energy initiatives and leads ten programs including a biomass research, development and demonstration (RD & D) program. The USDA leads in bioenergy R&D through its Economic Research Service (ERS; http://www.ers.usda.gov), and Agricultural Research Service (ARS; http://www.ars.usda.gov/main/main.htm). Through the Farm Service Agency (FSA; http://www.ars.usda.gov/main/main.htm) the USDA administers important bioenergy crop production programs, such as the Biomass Crop Assistance Program (BCAP; http://www.fsa.usda.gov/FSA/webapp?area=home&subject=ener&topic=bcap).

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1.2.4.3. Wisconsin Bioenergy Policy and Programs

- In 2006, WI Governor Doyle established a "Declaration of Energy Independence" (ACT 141-renewable portfolio standard) including WI's goal of using 25% renewable energy by 2025.
- In 2006, Wisconsin created the Office of Energy Independence andadopted a renewable portfolio standard that requires utilities to produce 10% of their electricity from renewable sources – including solar, wind, hydroelectric power, biomass, geothermal technology, tidal or wave action, and fuel cell technology that uses qualified renewable fuels – by 2015.
- In 2007, USDOE awarded $125 Million to UW to launch Great Lakes Bioenergy Research Center (GLBRC). Goal of center, one of three nationally, is to conduct basic research to advance cellulosic ethanol and make it "cost-competitive with gasoline by 2012, and assist in reducing America's gasoline consumption by 20% in ten years."
- In 2007, Wisconsin Bioenergy Initiative created by University of Wisconsin-Madison College of Agricultural and Life Sciences. The Wisconsin Bioenergy Initiative (WBI) seeks to cultivate bioenergy expertise among UW-Madison, UW-System and Wisconsin stakeholders to anchor the innovative research that is being conducted within our great state.
- In 2008, WI signed the Midwestern Regional Greenhouse Gas Reduction Accord: agreement establishing greenhouse gas reduction targets and timeframes, taking steps to achieve reduction targets

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- In 2008, the Wisconsin Council on Forestry published Wisconsin's Forestland Woody Biomass Harvesting Guidelines
- In 2009, Nonforest Biomass Guidelines production began by UW, DATCP, and DNR
- In 2009, The Bioenergy Council was created (2009 Wisconsin Act 401) and charged with identifying "voluntary best management practices for sustainable biomass and biofuels production…"

1.3. Bioenergy Sustainability: Why is it important?

There are many definitions of sustainability, each supporting various principals and concepts. Essentially, sustainability can be described as 1) a set of goals 2) practices and behavior that support such goals and 3) a branch of science. As a set of goals, sustainability describes desired conditions of the environment, biotic abiotic components, and the ability of humans to receive benefits directly and indirectly from the environment, in the present as well as the future. Sustainable practices and behaviors occur when humans interact with the environment in ways that support human well being without decreasing present or future benefits, they support sustainability. Sustainability science is an emerging academic discipline that integrates scholarship and practice, and disciplines across the natural and social sciences, engineering, and medicine to advance both knowledge and action to evaluate, mitigate, and minimize the consequences of human impacts on planetary systems and societies. Sustainability of bioenergy, therefore, will depend on the goals defined (and when, where and by whom those goals are defined), what actions and behaviors people are willing and able to adopt to support those goals, and the ability of science to assist human knowledge of connections between the many aspects of bioenergy and sustainability goals.

Bioenergy is frequently evoked as an important tool in improving environmental sustainability, as well as the sustainability of energy, agriculture, forestry and other sectors of human activity. However, much remains to be understood about the impacts of bioenergy on the environment and human society. Regardless, bioenergy currently provides a focus for improving our understanding and communications about sustainability, therefore increasing the likelihood of achieving desired outcomes.

Renewable bioenergy crops can and should be grown in Wisconsin. The state has vast biomass resources on its 30 million acres of crop and forestland. Because growing biomass for energy at a large scale is in anemerging stage, Wisconsin has a unique opportunity to create broader use of best land use practices and enhanced eco-system benefits. These voluntary sustainable planting and harvesting guidelines are written to guide land owners and managers to achieve appropriate and sustainable land use practices. Wisconsin's emerging bioenergy industry, if planned carefully, can provide an opportunity for strengthening our economy and diversifying markets for agriculture and forestry sectors.

Overwhelming scientific evidence shows that current energy consumption trends are unsustainable and change is needed. Global energy demands, even with increased efforts on energy efficiency, will increase due to population growth and greater wealth accumulation in emerging economies such as China, India, South Korea and elsewhere. We are in a transition to what some call the new energy economy and moving away from the legacy carbon energy economy. This change is occurring globally, domestically and in our state. Wisconsin has no oil, coal, natural gas or uranium. Thus, Wisconsin is much more dependent on the importation of fossil fuels than most states. While policy, such as the Wisconsin Renewable Portfolio Stan-

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dard (RPS) have resulted in utilities using more wind, solar and hydro energy for power, the largest amount of renewable energy in the U.S. and Wisconsin comes from biomass. New opportunities to use biomass for heat (thermal energy), combined heat and power (CHP), and potentially advanced biofuels or cellulosic ethanol are expected during this transition time to the new energy economy. Therefore, the state of Wisconsin with its robust forests and associated paper and pulp industry, and rich farmlands and the infrastructure associated with the food and fiber sector, will be considered for biomass to energy opportunities.

The key to next generation energy and fuels is, *"can they be done sustainably with good land use practices?"* As a relatively new enterprise, we have the opportunity to guide growth in a direction that will ensure that it is done safely and sustainably. We seek to find a balance – guidelines that encourage growth (it cannot be sustainable if landowners and entrepreneurs cannot make a profit) while protecting the assets that contribute to Wisconsin's quality of life such as clean water and healthy habitats.

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It will likely be necessary for landowners, biomass processors and energy end users to assess the potential benefits and costs associated with the various components of bioenergy systems including biomass production, conversion technologies, distribution and use; moreover, stakeholders will need to make decisions regarding what costs are associated with each benefit and which costs comprise tolerable trade-offs. At present, bioenergy trade-off decisions are complicated because markets for biomass and bioenergy are immature. Willingness-to-pay for bioenergy and other eco-system services potentially provided by biomass production systems is uncertain and widely variable. Life cycle analysis may help with this decision process. Which crops are grown where, and under which cultivation methods, will determine whether the bioenergy industry is sustainable or potentially harmful to the environment.

1.4. Summary

Bioenergy is renewable energy derived from recently living biological material.Bioenergy is a form of renewable energy because the energy contained in biomass is energy from the sun captured through natural processes of photosynthesis, and so long as the quantity of biomass used is equal to or less than the amount that can be regrown it is potentially renewable indefinitely. Bioenergy includes power and fuels derived from biomass. The majority of biomass for bioenergy comes from three sources: forests, agriculture, and waste. To make use of the energy available in biomass it is necessary to utilize technology either to release the energy directly, as in burning of biomass materials for heat, or to transform it into other forms such as solid or liquid fuel. Interest in bioenergy is increasing in response to concerns about energy security, energy independence, and environmental and climate impacts associated with use of non-renewable energy resources. Policy, government programs and sponsored research are major drivers of bioenergy development. The sustainability of bioenergy will depend on the goals defined, what actions and behaviors people are willing and able to adopt to support those goals, and the ability of science to assist human knowledge of connections between the many aspects of bioenergy and sustainability goals.

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1.5. Crops Identified as Potential Nonforest Biomass sources in Wisconsin

All biomass crops have similar heat energy content potential, ranging from 5000-7000 BTU per pound of material. Exact content will depend upon species, harvest techniques and water content.

Table 1-1. Potential dedicated biomass crops for Wisconsin.

Biomass Type	Pros*	Cons*
Switchgrass	perennial, low input, native species, potential to build soil carbon and reduce erosion	slow to establish, weed management costly in establishment,
Miscanthus x giganteus	perennial, low input, potential to build soil carbon and reduce erosion, potential high yields	slow to establish, established by root, weed management costly in establishment, overwinter hardiness, cost and availability, uncertainty of root clearing, uncertainty of long-term invasiveness, short history in US and WI
Other native prairie grass	perennial, native species, potential to build soil carbon and reduce erosion, high potential wildlife value,	slow to establish, weed management costly in establishment, little research for biomass yields
Dedicated Perennial Grass Mixes	perennial, native species, high potential for many ecosystem services	slow to establish, weed management costly in establishment
Corn Residues	high yield, multiple uses, well-known production and marketing system	annual, relatively high levels of nutrient removal and soil erosion, low environmental benefits, low wildlife value
Short-rotation woody	long rotation, potential for ecosystem services	slow to establish, intensive weed control in establishment,

Table 1-2. Potential existing biomass sources for Wisconsin

Biomass Crop	Pros*	Cons*
Conservation Grasslands (e.g. public lands, CRP)	perennial, native species, high environmental benefits, some harvesting may improve habitat for wildlife	little research for biomass yields, yields variable based on species composition, only periodic harvest likely, pre-existing contracts may not allow harvesting,
Existing nonforest woody (e.g. shrublands, habitat restoration debris, treerows)	woody waste material from habitat restoration or other management could be utilized	usually only a 1-time source, potentially costly to harvest/remove
Cattails	waste material from habitat restoration could be utilized	not long-term harvest, harvest difficult/costly in sensitive environment, little research for biomass yields
Reed Canary Grass	waste material from habitat restoration could be utilized	not long-term harvest, harvest difficult/costly in sensitive environment, little research for biomass yields

*The Pros and Cons listed above are production-focused generalizations. Actual values depend upon current technologies and local markets, these local markets will add constraints on crop choice and harvest methods.

1.6. Additional Resources

Baye, T. 2010. (Further reference needed.)

Bioeconomy Institute, Iowa State University (http://www.biorenew.iastate.edu/research.html)

Biomass Conversion Research Laboratory (BCRL; http://www.everythingbiomass.org)

Bioenergy Feedstock Information Network (BFIN; http://bioenergy.ornl.gov)

Biomass Energy Resource Center (BERC; http://www.biomasscenter.org)

Purdue University – Extension, Renewable Energy: Bioenergy (http://extension.purdue.edu/renewable-energy/bioenergy.shtml)

Renewable Energy Policy Project, Bioenergy (http://www.repp.org/bioenergy/index.html)

United States Energy Information Agency, "Energy in Brief". (http://www.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm)

United States Environmental Protection Agency, "Biomass Conversion: emerging technologies, feedstocks, and products": (http://www.epa.gov/sustainability/pdfs/Biomass%20Conversion.pdf.)

University of Wisconsin – Extension, Biomass Feedstocks and Energy Independence (http://www.extension.org/pages/Biomass_Feedstocks_and_Energy_Independence)

2. Considerations when choosing to plant or harvest nonforest biomass

HOW TO USE THIS CHAPTER: Section 1 outlines the positive and negative effects of biomass. Section 2 outlines sensitive geographical areas of WI where further considerations and caution need to be taken. Chapter 3 identifies strategies for maximizing environmental benefits

2.1. Benefits and Costs

Renewable energy, including biomass, has the potential to simultaneously meet local energy needs, increase economic development opportunities and reduce negative environmental impacts compared to traditional energy sources. However, the simultaneous demand for energy and sustainability depend on numerous environmental, ecological and socio-economic factors varying from place-to-place and over time. As a result, it may be difficult form a definitive answer on whether or not bioenergy is a net benefit everywhere, all the time, and for all stakeholders. Discussions of sustainability must be grounded by asking: *sustainable for what, for whom, at what cost, and for how long* (Allen *et al*. 2003)? These are social and political considerations that will vary with time and place.

Chapter 2: Section 1

- Balancing Trade-offs
  - Life cycle assessment
- Environmental and Ecological Impacts
  - Land use change
  - Emissions and the carbon cycle
  - Water quality and quantity
  - Soil quality
  - Wildlife and natural areas
  - Invasive species
- Economic and Commercial impacts
- Social Impacts
- Conclusion

HOW TO USE THIS SECTION: There is no 'one size fits all' answer when it comes to choosing and managing a sustainable biomass feedstock crop. This section is designed to help you understand the nature of the various benefits and challenges inherent to biomass production on local and statewide scales and provides tools for comparing those trade-offs.

2.1.1. Balancing Costs and Benefits: Trade-offs of biomass production

Stakeholders need to assess the potential benefits and costs associated with the components of bioenergy systems including biomass production, conversion technologies, distribution and use; but moreover, stakeholders will need to make decisions regarding what costs are associated with each benefit and which costs

comprise tolerable trade-offs. At present, bioenergy tradeoff decisions are complicated because markets for biomass and bioenergy products are immature, and because the overall impacts of bioenergy crop production are very complicated, involving tradeoffs between fuel inputs for crop growth and energy generated, changes in soil and water quality, impacts on other ecosystem services, and value-added use of co-products and by-products of the systems. For example, Kim and Dale (2005) found net positive energy produced in a corn stover based system, but with impacts on soil quality that would bring into question long-term environmental sustainability.

Under current economic conditions and assumptions, biomass will not replace fossil fuels based strictly on economic criteria. Transitioning to renewable energy sources will depend on some combination of public support (e.g., subsidies, low cost loans, incentive programs, tariffs, carbon credits or taxes) and private initiative. Absent public support, private initiative will be driven by individual or organizational interest in contributing to the general welfare (e.g., reducing environmental impacts of energy consumption and/or dependence on fossil fuels). Willingness to pay for bioenergy and other ecosystem services potentially provided by biomass production systems is uncertain. Research is currently underway at the University of Wisconsin-Madison to survey farmers and rural landowners in southwest Wisconsin to find out their beliefs and attitudes about bioenergy crops. Such research can help determine what combinations of private interest and public support will be necessary for a bioeconomy to emerge. Landowners, managers, and entrepreneurs will need a variety of tools to decide if and how to engage in a bioeconomy. Tools such as cost/benefit analysis, life cycle analysis, and whole farm planning may help guide this decision process.

ECOSYSTEM SERVICES: A CONCEPTUAL TOOL FOR DECISION-MAKING

Many material resources, such as trees and minerals, are readily valued through established markets where price signals determine the amount to be extracted, where they will be distributed and when. Similarly, agricultural commodity markets regulate the production and flow of food, feed, fiber and fuel. Not all resources are readily adjusted to such economic structures but are nonetheless essential to human well-being, particularly non-material resources and some kinds of *ecosystem services*.

In 2005, the Food and Agriculture Organization of the United Nations popularized and formalized the concept and definitions of ecosystem services. The Millennium Ecosystem Assessment (2005) organized ecosystem services into four broad categories:

- Provisioning services, or the goods and products obtained from ecosystems, including food and fiber - both cultivated and wild;
- Regulating services, or the benefits derived from ecosystem's control of natural processes such as erosion and natural hazards;
- Supporting services, or services that are necessary for non-humans and maintenance of all other ecosystem services;
- Cultural services, such as recreational or educational benefits

As the supporting category implies, ecosystem services are not independent of each other .As a result, attempts to maximize a particular ecosystem service typically leads to reduction of other ecosystem services in what are known as ecosystem service trade-offs (Rodriguez et al., 2006). These tradeoffs are an inherent consequence of human activity that changes the type, magnitude or relative mix of services provided by ecosystems (Rodriguez et al., 2006). Ecosystem services and management of trade-offs are key conceptual issues in the sustainability of bioenergy.

Wisconsin landowners interested in biomass production may want to consider using a matrix like the one below when deciding what type of biomass product to grow or harvest. This document contains numerous examples of ecosystem services tradeoffs.

	Grass Monoculture	Conservation Grasslands	Short-rotation Hybrid Willow	No-till Corn
Provisioning				
Fuel (energy yield)	+/-	+/-	+/-	+
Regulating				
Air Quality	+	+	+	-
Water Quality	+	+	+/-	-
Erosion control	+	+	-/+	-
Nutrient management/ regulation	+/-	+	+	-
Supporting				
Wildlife Habitat	+/-	+	+/-	-
Soil carbon sequestration	+	+	+	-
Cultural				
Hunting/Fishing	+/-	+	+/-	-/+

Example of an ecosystem service matrix. This matrix can be used to visualize the different benefits / impacts of different crops on ecosystem services. [(+) indicates a general benefit, (-) indicates a negative benefit, (+/-) indicates some benefit]
* This is an example of how you could compare services, the relationships above do not hold for every situation; different site conditions could create drastically different results.

2.1.2. LIFE CYCLE ANALYSIS OF BIOMASS BIOENERGY

There are many potential benefits of biomass production and many potential negative impacts as well. People want to understand the nature and extent of specific impacts to the environment, economies, communities, human health, and climate. They also want to know whether biomass energy is a net benefit, and whether biomass energy results in greater sustainability. Of particular interest is whether bioenergy systems reduce greenhouse gas (GHG) emissions and whether bioenergy systems provide a net energy gain over other energy systems. Understanding these questions requires an ability to identify all potential effects - from construction of a project, to the production, processing and transportation of feedstocks, to conversion technology, to the delivery and use of energy products and co-products, and to disposal of by-products and wastes (Figure 2.1).

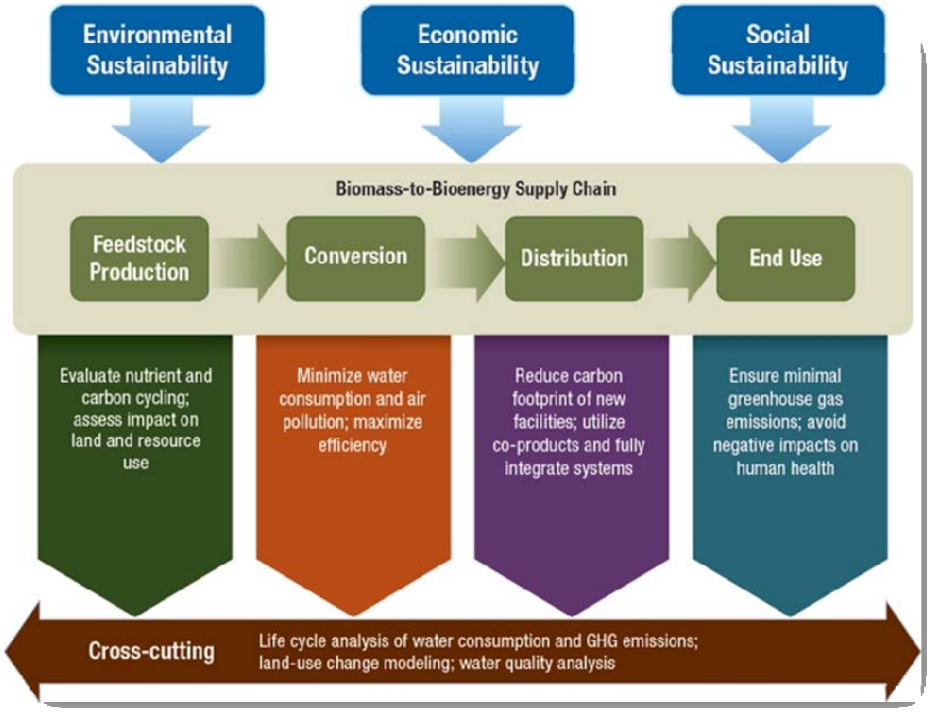

Figure2-1. Impacts of bioenergy are measured across the supply chain as contributing to or impeding sustainability. (USDOE, Energy Efficiency and Renewable Energy Program)

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Life-cycle assessment (LCA) is an approach for evaluating the impacts associated with a product or activity on human health and the environment in a cradle-to-grave appraisal of benefits and detriments and the balance among them over a product or activity's life span. Life-cycle assessment examines the entire life span of a product or activity, from extraction of raw materials through production, transportation, use and disposal. The LCA process is useful not only for understanding the specific impacts and net effect of bioenergy systems; it is an important tool for comparing alternative systems (Figure 2.1).However, to-date no single

LCA has been able to comprehensively model all impacts of either a single bioenergy system or all bioenergy systems combined on all environmental, economic and societal aspects at any particular location or for the earth as a whole. While much research is needed to improve LCA methodology, it has become a widely heralded approach to quantitative analysis of bioenergy.It is generally seen as a tool in an on-going process for organizing information and knowledge regarding impacts of bioenergy.

2.1.3. Environmental and Ecological Impacts

Impacts of biomass systems include effects on ecosystems and species within them (including humans), termed *ecological impacts*; and effects on geophysical systems such as water and climate, termed *environmental impacts*. Impacts may be direct (e.g., emissions from burning biomass) or indirect (e.g., soil erosionlosses from biomass production). We can generally measure incremental impacts of a specific activity (e.g., soil loss rate from a particular farm field). More challenging and less certain are cumulative impacts such as the degradation of water quality downstream from numerous small pollution sources or the cumulative impact of land use change due to bioenergy crop production.

Biomass systems and specific biomass projects can have positive and negative ecological and environmental impacts, and the overall net impact can be positive or negative depending on the particular system or project under consideration. Specific impacts and net impacts depend on the feedstock type, biomass production system, conversion technology, transportation/distribution system, and use or disposal of co-products and by-products, respectively. As discussed above, life-cycle assessment is an important tool for understanding net impacts of bioenergy.

Conversion, transportation/distribution and consumption of biomass products potentially affect ecological and environmental systems. However, many of the ecological and environmental impacts of bioenergy are associated with land use and land use change connections to feedstock production. Land-use decisions may affect local, regional and global ecological and environmental systems. The remainder of this section focuses on these high-priority concerns:

- Land-use and land-use change
- Emissions and carbon cycle
- Wildlife and natural areas
- Water quantity and quality
- Soil quality and erosion
- Invasive species

2.1.4. Land use and Land use change impacts

Those who choose to produce biomass feedstocks must consider *land use* and potentially *land use change*. Land use is management of land resources for economic benefit and includes tillage, maintenance and harvest activities as well as conservation practices. Land use change includes conversion of native ecosystems

into agriculture use (i.e., land cover change), as well as switching from one crop type to another (or switching from one forest type to another)

Native and managed ecosystems are a source of financial benefit when materials are removed from these systems and exchanged in markets. Native and managed ecosystems also provide many benefits that indirectly affect human financial benefit. Ecosystems provide many non-financial benefits as well. Water and nutrient cycling are two examples of the benefits ecosystems provide for which there is no direct economic value. Land use change associated with bioenergy feedstock production can increase or decrease the direct, indirect and non-financial benefits of native and managed ecosystems. Whether land use and land use change increase or decrease these benefits depends on site characteristics present prior to conversion to bioenergy feedstock production. In the case of managed ecosystems, the type and amount of benefits depends on the combination of land use history and current land management for bioenergy feedstock production.

2.1.4.1. Use of marginal lands for biomass production

The definition of "marginal" with regard to productivity of arable lands varies greatly but in general, marginal lands are those that have one or more characteristics not conducive to annual crop production. Such characteristics as steep slopes, shallow soils, excessive wetness, or drought-proneness generally have negative effects on profitability of agricultural use and hence marginal lands usually are of fairly low value[2] (i.e., comparatively low price per acre for rent or taxation purposes). Some marginal lands are remnants of native plant and animal communities persist, having never been plowed. Marginal agricultural lands are typically used as pasture or hay production, but in times of high row crop prices, marginal lands are sometimes converted to row crops. Row crop production on some marginal lands is associated with high soil erosion rates and decreased productivity over time. In the U.S., various public policies and federal programs such as the Conservation Reserve Program (CRP) have been created to slow or reverse such trends. Marginal land, as a broad category, provide a variety of environmental benefits. The exact type and extent of benefits is influenced by the location of marginal lands, their use and management. Policies and programs like CRP aim to protect the ecosystem services that marginal lands provide.

Marginal lands have been highlighted as possible places for the production of biomass for bioenergy, not only for meeting mandated renewable fuel mandates, but also as a potential means for avoiding land use conflicts contributing to a "food *v*. fuel" debate. The 2007 U.S. Census of Agriculture identifies approximately 30 million acres of land including idle lands, land in cover crops for soil improvements, and fallow

[2] Land values are driven by markets. Land that is marginal from an agricultural perspective may have considerable value for residential purposes if it is near developed areas or may have significant value as recreational property, particularly if it is near amenities such as water features or extensive tracts of public land.

rotations as potentially available for biomass production including grasses and short-rotation woody species. A University of Wisconsin-Madison analysis found that Wisconsin has between 2.8 and 3.3 million acres of non-forest marginal land not currently in row crop production that might be suitable for bioenergy crops.

Conversion of steep or wet land currently in row crop production to less intensive bioenergy crops such as *high-diversity, low-input* perennial mixes has the potential to generate more ecosystem services. Wisconsin currently has about 1.5 million acres of land classified as "highly erodible land" in row crop production – the same kind of land taken out of production through the CRP. Bioenergy programs that provide incentives to put environmentally sensitive land into permanent cover such as grasses would have benefits similar to CRP.

Some researchers caution that conversion of marginal lands to more intensively managed bioenergy cropping systems could lead to permanent land degradation and net increase in greenhouse gases. Additional research is needed to assess whether and to what degree marginal lands can and should be relied upon for meeting future bioenergy demand.Much of that work is underway at UW-Madison.Extra caution must be used when implementing bioenergy crop programs on marginal lands so that sensitive natural resources are maintained. *Further information on sensitive areas in Wisconsin is found in section 2.2.*

2.1.4.2. Emissions and the Carbon Cycle

Greenhouse gases are gases in the atmosphere that absorb and emit thermal radiation in processes known as the *greenhouse effect* (Figure 2.2, "Human Enhanced Greenhouse Effect"). [For more information on global warming and climate change see: http://www.epa.gov/climatechange]

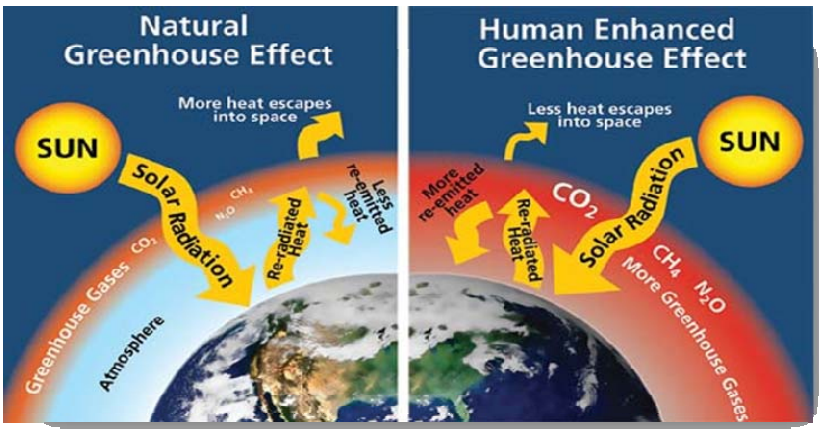

Figure2-2. The greenhouse effect is the primary mechanism by which solar radiation is captured by earth's atmosphere. Human activity has enhanced the warming ability of this mechanism. (Will Elder, U.S. National Park Service.)

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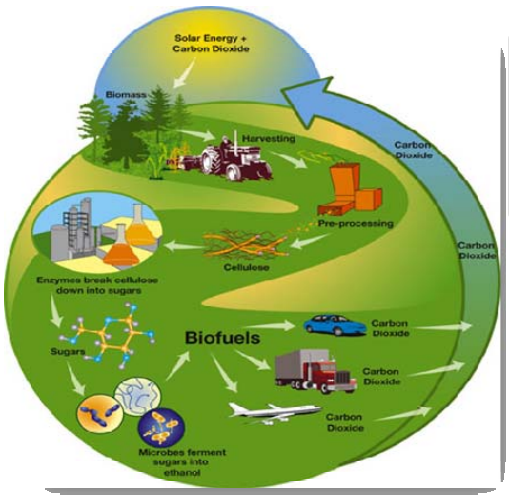
Biomass has the potential to be *carbon-neutral* by balancing the amount of carbon released in use of bioenergy products with an equivalent amount put into and stored in soils and plant tissues. Biomass bioenergy is part of a global carbon cycle, in which plants take up atmospheric carbon dioxide and convert it into plant tissue (i.e., they *sequester* carbon) which is released back to the atmosphere when the plant biomass is burned directly or after it has been converted into a fuel and used (i.e., carbon emissions) and from there it is available again for plant up-take (i.e., sequestration).However, when taking a life-cycle assessment approach, bioenergy from biomass may or may not be carbon neutral. At issue is feedstock production, land use and land use change (LUC).



Q: How is burning biomass different than burning fossil fuels?

A: Biomass is already part of the carbon cycle whereas the carbon in fossil fuels wassequestered, or taken out of the cycle, millennia ago.

Figure2-3 The carbon cycle and biofuel: carbon dioxide (CO2) from the atmosphere is taken up by plants and converted into plant tissues. Plants are harvested and converted into fuels, which are burned, releasing CO2 into the atmosphere where it becomes available again for plants. However, instead of a "closed loop", as depicted here, emissions of CO2 from conversion of untilled soil and emissions from use of fossil fuels in fertilizer production and diesel use in farm equipment can increase the amount of atmospheric carbon dioxide from bioenergy systems rather reduce it. (Source: US DOE)

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Land use, and more specifically land use change (LUC), affects the flux of GHGs between the atmosphere, soils, water, and tissues of living things (Figure 2.3).Converting native prairies to cropland, for example, releases carbon dioxide (CO_2)to the atmosphere from burning vegetation for land clearing or microbial decomposition of organic carbon stored in plant biomass and soils after plant materials have been cut or mowed. In the case of clearing of new land (i.e. native habitat) for biomass production, the amount of GHG emissions depends on the ecosystem being converted. In some cases, the amount of CO_2 emitted will be large and required decades if not hundreds of years to be sequestered again by bioenergy feedstock crops.During this lag between release of $CO_2$and eventual sequestration, carbon emissions will have contributed to global climate change. Carbon sequestering potential of some bioenergy feedstock systems, then, is much less than some native ecosystems at the same location. The reverse can also be true though, where some biomass crop systems are capable of sequestering more carbon than a native ecosystem at the same location. The global net effect of change in carbon balance at local and regional levels due to LUC associated with bioenergy is unknown.

In addition to LUC, net GHG emissions of biomass production systems also depends on the type and amounts of agricultural inputs used and the amount of transportation fuel used in planting, management and harvest activities. Fertilizer inputs result in emission of $CO_2$and carbon monoxide in their manufacture, and emission of nitrous oxide through their application to soils. Fossil fuels used to manufacture pesticides also results in GHG emissions. Therefore, to understand whether or not bioenergy increases or decreases GHG emissions and climate change, it is vital to make a completely account for all pathways through which various GHGs may be sequestered or released, and to do so throughout the life cycle of bioenergy production and use.

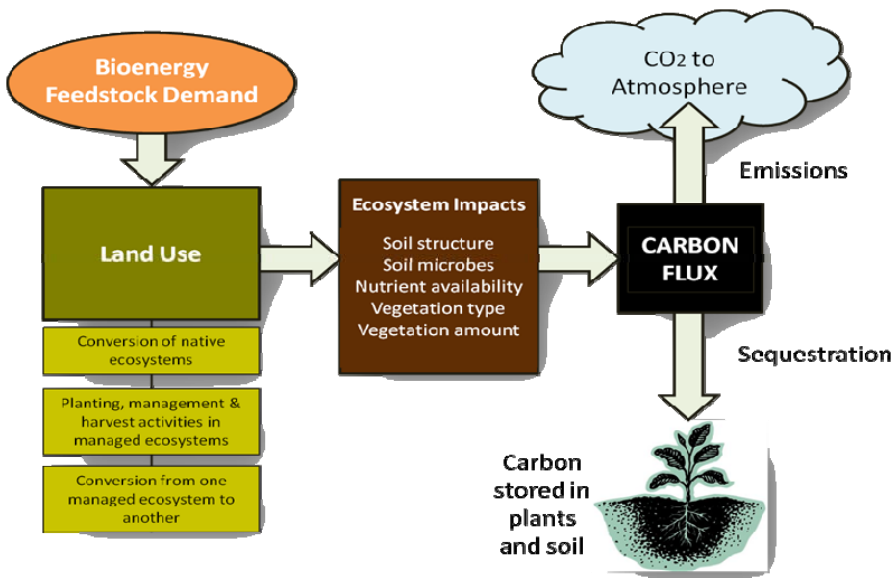

Figure 2-4 Land use impacts on carbon flux and the ecosystem mechanisms that regulate carbon emissions and sequestration. (CL Williams, 2011.)

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To-date, from the life-cycle assessment perspective there is no scientific consensus on whether bioenergy as a whole contributes to or abates global climate change. Rather, scientific evidence appears to indicate that "it depends". First generation biofuel systems, such as ethanol made from corn grain, tend to emit more GHGs than cellulosic ethanol systems, particularly CO_2.Compared to perennial biomass production, corn cropping requires more fertilizer and pesticide inputs, and results in greater soil disturbance leading to land use- induced carbon emissions. Moreover, when agricultural commodity prices are high, marginal lands and lands set-aside for conservation purposes tend to be converted into row crops such as corn and thus lead to LUC-induced CO_2emissions. In comparison, second and third generation biofuels offer greater potential for GHG mitigation through use of cellulosic feedstocks which originate from production systems that tend to have less land-use related GHG emissions. Additionally, biochar – the co-product of pyrolysis, is carbon rich and stable, and when added to soil it serves as a long-term carbon bank. While second, third, and even fourth generation biofuel systems potentially reduce GHGs they are not yet widely available at commercial scales and future demand is uncertain.

2.1.5. WATER QUANTITY AND QUALITY IMPACTS

Production of non-forest biomass in accordance with these guidelines should have positive to neutral impacts on groundwater and surface water quantity compared to conventional crop production systems. Perennial biomass systems typically improve infiltration of precipitation over annual cropping systems, thereby improving groundwater recharge and providing greater base-flows to groundwater fed surface waters.

Harvesting of crop residues from annual cropping systems for biomass energy should not appreciably decrease infiltration nor increase runoff if the guidelines in chapter 3 are followed. The guidelines limit the amount of crop residue removed for biomass to preserve organic carbon in soils and provide adequate ground cover to promote infiltration and reduce runoff. However, over-harvesting of crop residues from annual crops will actually increase surface runoff, decrease infiltration, and likely lead to reduced base-flows in surface waters.

Likewise, production of non-forest biomass should have positive to neutral impacts on water quality compared to conventional cropping systems. Perennial vegetation systems tend to have less soil disturbance and greater soil coverage than conventional crop production systems which will reduce runoff and thus the delivery mechanism for sediment, nutrients, and pesticides to surface waters.

Any biomass production system will require some level of fertilization to maintain productivity. Over-fertilization must be minimized to prevent subsequent nutrient losses to either surface water or groundwater. Typically, excess levels of soil phosphorus and inadequate runoff control results in eutrophication of surface waters. Over application of nitrogen on cropping systems leads to excessive leaching of nitrogen through the soil profile resulting in elevated nitrate concentrations in groundwater which could pose human health and environmental risks. Sound nutrient management practices can minimize both groundwater and surface water quality impacts from cropping systems. See University of Wisconsin research results on nutrient management and water quality impacts at:
http://www.soils.wisc.edu/extension/nonpoint/runoff.php

A recent study, "Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin" by the USDA- NRCS concluded that runoff from agricultural fields accounts for significant nutrient losses to the river and that increasing the adoption and implementation of nutrient management plans on agricultural lands is needed to mitigate nutrient loadings to the Mississippi River Basin (see http://www.nrcs.usda.gov/technical/nri/ceap/umrb/index.html). Nutrient management planning for biomass productions systems will similarly reduce the amount of nutrient losses to surface and groundwater resources. For more information regarding nutrient management planning requirements for Wisconsin, see the NRCS 590 NM Standard for WI.

2.1.6. SOIL QUALITY IMPACTS

Biomass production has the potential to benefit or degrade soil quality. Maintaining soil health is integral to ensuring that lands can continue to be productive.Healthy soil is a mixture of water, air, minerals, and organic matter. *Soil organic matter*consists of plant and animal material that is in process of decomposing, is a

primary indicator of soil quality, and is an important factor in*carbon sequestration*. Biomass crop choice and management techniques can be selected to reduce impacts and improve quality.

Figure2-5. Aerial view of contour strip cropping in central Wisconsin. Photo: Ron Nichols NRCS database

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Erosion can drastically reduce the life and productivity of land. Many factors increase the incidence of soil loss including weather, slope, tillage, crop choice, and planting design. Perennial biomass crops that remain on the landscape year round, creating sod or dense root structure can reduce erosion. Limiting soil surface disturbance, for example employing no-till planting will also reduce soil (and carbon) loss. Other mechanisms for reducing soil loss include planting on the contour (Figure 2.6) and planting perennial crops.

Soil compaction also reduces soil health. Soil compaction occurs when soil particles are pressed together and the pore space between them is reduced.Compaction results in reduced movement of water, air, and soil fauna through soil, which therefore reduces its functionality. In addition, soil compaction impedes root growth of plants. Hydric soils are especially susceptible to compaction, making wetlands highly sensitive to soil compaction.Deep soil compactions (greater than 24") may be irreversible and should be avoided (Muckel 2004).

Decreasing the potential for soil compaction during field operations can be done by reducing weight on the soil, reducing amount of traffic, and harvesting during dry periods or when the ground is frozen (DeJong-Hughes, *et al*. 2001). Lighter equipment lessens the amount of compaction. Decreasing the amount of equipment used in harvest operations and number of passes a single piece of equipment makes can also reduce soil compaction.Because the depth of soil compaction increases with the amount of moisture in the soil, harvesting during dry periods or when the ground is frozen can reduce soil compaction. There is also potential for using modified equipment with tracks designed to lower pressure on soil.

Soils have tremendous potential to sequester carbon. Most soils in agricultural use have soil carbon content substantially below equivalent undisturbed soils due to oxidation of carbon during tillage and other farming operations. Many scientists consider increasing soil carbon as a viable option for capturing atmospheric CO_2.

In addition to reducing greenhouse gas emission, some biomass production systems may actually increase the amount of CO_2 stored in soils. Carbon sequestration - capture of carbon by plants and long term storage as soil organic matter – is touted as a means to reduce atmospheric CO_2. However, if agronomic prac-

tices deplete carbon currently stored in soil or result in more labile (decomposable) forms, we only partially capture this value. The cycling of carbon in the soil depends on numerous endogenous factors including soil properties, moisture, and temperature; factors influenced by management practices over the long term such as soil microbial populations and forms of organic carbon; and factors with a relatively rapid influence such as tillage operations (aeration and mixing that accelerates decomposition of organic matter), carbon additions such as manure, cover crop, and residue incorporation, and removals such as crop harvests. Detailed, quantitative understanding is just emerging.

Research has not matured to the point of being able to provide specific numeric standards or guidelines, other than measuring general indicators such as soil organic matter content, and with much more effort, the type of organic matter. We can point in the directions that will enhance sequestration, for example, less tillage is better than more, less residue removal is better than more, permanent cover (particularly sod-forming cover) is better than row cropping, etc.

For our guidelines, we have used the Soil Conditioning Index (SCI) developed by USDA Natural Resources Conservation Service. SCI is a relative measure of the likely direction of soil organic matter accumulation (gain or loss over time) under specified conditions including crops, rotations, fertility, soil types, and topography.

2.1.7. Wildlife and Natural Area Impacts

The maintenance and restoration of Wisconsin's natural areas and the improvement of habitat for both game and non-game wildlife is important for Wisconsin's health and economy.Dedicated biomass crops have the potential to provide additional wildlife habitat throughout Wisconsin, which could lead to increased recreational opportunities for Wisconsin citizens.However, like any habitat management program, crop selection and management will play a huge role in determining the extent to which wildlife benefit.

Wildlife as a Public Trust

Conservation of Wisconsin's wildlife follows the North American Model of Wildlife Conservation. This model was developed in the late 19th century as a consequence of severe declines in game animals due to market hunting. A central tenet of the North American model is that wildlife is a public trust. This idea was the result of a Supreme Court decision in 1841 which declared that natural resources such as wildlife and fish cannot be privately owned. The development of the North American Model has resulted in the establishment of federal and state natural resource agencies whose charge is to manage wildlife for the public as a whole. Because wildlife lives on the lands we also are actively using, any changes to land management has the potential to impact our state's wildlife resources. It is incumbent on the state's natural resource managers to use the best information to predict and mitigate practices that might result in the decline of our state's wildlife resources.

To read more about the North American Model for Wildlife Conservation see The Wildlife Professional Fall 2010 special issue at http://issuu.com/the-wildlife-professional/docs/twpfall2010

For maximizing wildlife benefits associated with biomass crops, harvest times should be scheduled to avoid local nesting and brood-rearing seasons of bird species and fawning/calving of big game species that might use these blocks of habitat by either harvesting before nesting/fawning activity begins or waiting until after

young birds have fledged and young animals are capable of leaving area during harvest activity. The peak of nesting season for grassland birds in Wisconsin is approximately May 15 – August 1 (similar dates for forest species).Fields harvested during that time or multiple times during that period will result in destruction or abandonment of nests.Limiting or avoiding management actions during the peak nesting period is important to maintain grassland wildlife populations in the State.Further expanding the limited management window (e.g. April 15 – Oct 15th) will allow for successful nesting of early (e.g. Ring-necked pheasants) and late nesting species and also provide refuge for reptiles and amphibians that utilize biomass habitats for portions of their life cycles.Delaying or limiting biomass harvests and other management actions until August 1 or later will benefit a variety of wildlife.Biomass cropping systems that include multiple harvests during the summer months will provide little benefit to wildlife.Multiple harvest events during the growing season may also have negative consequences on yield and stand longevity depending upon the crop. These are examples of benefit tradeoffs and are discussed in more depth later in this chapter and chapter three.

Taller stubble heights when harvesting herbaceous vegetation result in better wildlife habitat and can improve soil moisture by catching snow and increasing soil shading which reduces evaporative loss. Increasing stubble heights improvesstand usefulness by providing winter cover and spring nesting habitat for a variety of waterfowl, game birds, and grassland songbirds. Recommended harvest heights from the USDAare typically set for the minimum height needed to ensure plant survival; those heights should be lengthened based upon regional wildlife needs.

Maximum wildlife benefits will be achieved if portions of biomass crop fields are left unharvested.From a wildlife standpoint, leaving a portion of the field unharvested, called*habitat refugia,*each year provides winter and nesting cover for species requiring taller cover than stubble would provide on fully-harvested fields. Alternating harvested areas on fields will help maintain wildlife benefitsand can serve as a biomass reserve in time of drought or other emergency. Leaving vegetation resistant to lodging (blow-down) during winter months can provide valuable winter cover for wildlife as well as result in an economical way to stockpile biomass for harvest and use the following spring.

2.1.8. Invasive Species Impacts

Invasive species are an expanding problem that has resulted in a tremendous increase in social and economic costs, as well as ecological stresses to native species and natural communities. The expansion of biomass planting and harvesting in WI poses both a potential danger for increasing invasive species on the landscape and the hope of a new market available to drive restoration and suppression efforts.

A risk of all agricultural endeavors is possible escape of introduced novel crops (biomass or otherwise) into landscapes where they could potentially become invasive.Such is the case with Miscanthus, a warm-season grass with high potential for biomass feedstock utilization.*Miscanthus x gigantius*, the variety most likely used

Reed Canary Grass: Case Study

Reed canary grass (*Phalarisarundinacea*) is a drought-tolerant, tall, perennial grass common inwetlands and moist areas. Although a native ecotype exists, Eurasian varieties were brought to the U.S. as a forage and hay crop. The aggressive nature of non-native varieties haveresulted in its invasionof native systems across much of theMidwestU.S. It is under consideration as a bioenergy feedstock source, particularly for combustion. However, in highly disturbed areas with little probability of restoration, harvest of reed canary grass has a potential benefit not only as a bioenergy feedstock, but for removing excess nutrients from agricultural run-off (Jakubowski et al., 2010).

in bioenergy production, is a sterile cross of two known invasive Miscanthus parents.However, visual differentiation of the sterile *Miscanthus x gigantius* from its invasive parents is difficult and certified sterility of tubers is lacking. While risk of invasion of novel species and crops is a possibility associated with bioenergy, so is expansion of current invaders that have bioenergy feedstock potential. Greater risk comes from the unintentional spreading of invasive species via seed or plant materials transported by machinery, especially if existing fields or conservation areas are harvested. Steps to reduce these risks include rinsing/removing plant material from machinery before leaving each biomass site.

Biomass operations can support the removal of invasive species from the landscape by providing a market for biomass removed during habitat restoration efforts. For example, a common practice in prairie or savannah restorations is the removal of encroaching trees and shrubs, which commonly are piled and burned onsite. A biomass market could help subsidize the costs of restoration through the sale of the collected woody material.

2.1.9. Economic and Commercial Impacts

At present, economic choices and trade-off decisions are complicated because markets for biomass and bioenergy products are immature.Simply put, willingnesstopay for biomass and bioenergy by end-users is uncertain.It is possible to look at current prices of traditional energy sources such as liquid transportation fuels, natural gas, and coal for comparison.However, if externalities of GHG emissions and other pollutants are not counted, natural gas and coal still appear to be relatively inexpensive energy sources, given current trends in energy prices. Under such circumstances, it would seem unlikely that biomass energy will be economically competitive in the near-term.

Despite these economic issues, numerous advantages to increasing use of renewable energy (national security, cleaner environment, local jobs) have already been articulated (citations).Therefore, economic and operational feasibility studies also need to account for the opportunity costs of NOT increasing renewable energy use.

Realistically, the current relatively low value of biomass means that without policy that provides economic incentives it is unlikely to replace traditional food production on better quality land.Whether and how biomass crops can be profitably grown on either marginal or prime agricultural lands is still an open question.Marginal lands are likely to have lower-than-average yields and higher-than-average production costs compared to lands with fewer limitations on row cropping.Over time, analysis and trials will be necessary to compare the return on investment to individual landowners to that of public investment in improved ecological and environmental performance.Particularly before public funds are used to develop biomass markets, such analyses should be done to protect land owners, growers, and investors (whether public or private).

2.1.10. Social Impacts

A broad community of people are potentially affected by conversion of land to biomass production.This includes land owners and managers directly involved in production, neighbors and communities within ar-

eas undergoing land use changes, regulators intending to maintain public interests, entrepreneurs building components of biomass supply systems, and end-users of biomass such as operators of power plants or liquid fuel production facilities.Choices of entrepreneurs and end-users may be motivated primarily by economic considerations, while others may have a broader set of criteria that enter into their choices.Guidelines provide a basis for mediating the differences in perspectives between these groups.

In addition to the externalities of production that directly affect nearby lands, individual choices about bioenergy crop production may have ripple effects on local and regional economies. Because biomass for energy is generally large volume, low value material, many believe that it will require collective action and investments to create viable collection and transportation systems. Thus, when we think about the impacts and economics of biofuels, it's also useful to think about community perspectives; this is a human analog to the landscape perspective and landscape multi-functionality discussed in the next section.

Land owners, managers, entrepreneurs, and representatives of public agencies all need tools and methods to evaluate the environmental, economic, and social tradeoffs involved in decisions about biomass systems. These Guidelines mostly focuses on the environmental tradeoffs, as this is the purview of the agencies involved and the expertise of the authors. Although it is beyond the scope of this document to detail how to assess social and economic impacts, the following provides a description of the kinds of analyses that may be necessary for a complete understanding of biomass systems, particularly those on marginal lands.

Operational Feasibility: access to land cannot be taken for granted, particularly marginal land; it is typically located on high, steep parts of the landscape or low, wet areas. Feasibility assessment should include evaluation of type and cost of road and trail construction, equipment-limiting slopes or waterways along access routes, need for and cost of easements to access remote fields, and other improvements that may be necessary to get production and harvest equipment into fields and onto all-season roads.

Opportunity Costs: As noted in ecosystem services discussions, marginal lands are currently providing public benefits. Readily quantified services that clearly will be adversely affected by conversion to cropland should be estimated. These could include loss of non-crop products such as gathering of wild plants, hunting, and other recreational opportunities. Although the focus herein is on conversion of marginal open lands to cropland, the opportunity cost assessment might also include evaluation of potential benefits of afforestation (particularly if carbon crediting is set up in a way that favors this kind of land use conversion).

Yield potential: Initially, yield predictions will be based on models which extrapolate from production on better quality land adjusted by soil properties. Over time, these can be refined based on actual yields similar to the "proven yield" information currently collected by FSA and incorporated in soil property data. Public and private investors can then make appropriate assumptions about transportation and energy production costs, the costs of alternative fuels, and so forth to decide whether an appropriate return on investment is feasible. Although not adapted to Wisconsin, North Dakota State University Extension conducted a detailed analysis of bioenergy crop yield potentials:
http://www.ag.ndsu.edu/energy/documents/BiomassCompare031309.xls.

Demand and crop prices: Under current market conditions, bioenergy cannot compete with fossil fuels if only the fuel value is considered. It is and will be cheaper to burn coal and petroleum for the foreseeable future if the negative externalities are not accounted. However, public policies and programs at state and federal levels are directed toward increasing production of liquid biofuels for transportation and for direct conversion of bioenergy crops to heat, steam, and electricity for numerous environmental and energy security reasons. The amount and duration of these supports and incentives will continue to evolve. Moreover,

the infrastructure for aggregating, processing, and using bioenergy feedstocks is just emerging. As such, we are in a period of uncertainty about "farm gate" prices for bioenergy crops. For farmers to make an investment in bioenergy crops, we will need some way to predict likely levels and potential range of demand over at least a five to ten year period, and the economic tools to understand returns on investment over this kind of time period. Work currently underway in the UW-Madison Department of Agricultural and Applied Economics is aimed at providing demand and crop price assessments for switchgrass in Wisconsin, and should be available some time in 2011.

Community considerations: Evaluation of the sustainability of bioenergy crop production will need to consider the type and extent of investments made in regions larger than single farms. As noted above, the value of bioenergy crops will depend on having an infrastructure capable of moving materials from farms to processors and end users. Because a substantial portion of cost is associated with handling and transporting relatively low value, high volume material, this must be done as efficiently as possible, including spatial aggregation of production. Regions (e.g., towns, watersheds, farm associations or cooperatives) working collectively may be able to provide a "critical mass" to justify investment and provide a stable market for the participants.

2.1.11. Conclusion

Pressure is increasing on renewable energy sources to meet energy demands while providing economic development and limiting environmental impacts.Whether and to what degree biomass projects deliver on the simultaneous demands for energy and sustainability depends on the assessment of all potential effects from "cradle to grave".Greenhouse gas emissions, wildlife and natural area impacts, impacts to soil and water quantity and quality, and invasive species impacts are concerns regarding biomass bioenergy and its sustainability.Environmental costs and benefits and the management of trade-offs are key conceptual issues in creating sustainability bioenergy.It will likely be necessary, for example, for stakeholders to assess the potential benefits and costs associated with the various components of bioenergy systems including biomass production, conversion technologies, distribution and use; but moreover, stakeholders will need to make decisions regarding what costs are associated with each benefit and which costs comprise tolerable tradeoffs.

2.2. Wisconsin regional considerations when assessing biomass production

HOW TO USE THIS SECTION: In the previous section, we described the major impacts of biomass production and how to maximize environmental benefits through crop choice and land selection. In this section, we take a closer look at Wisconsin's regional geography and natural environments where extra caution or additional consideration is needed when de-

Chapter 2: Section 2

- State Geography and Ecological Areas
- Habitat Restoration Areas and Major Conservation Opportunity Areas
- Sensitive Geography
  - Karst areas
  - Highly erodible lands
  - Water quality management areas

ciding whether to plant a biomass crop or harvest existing material.

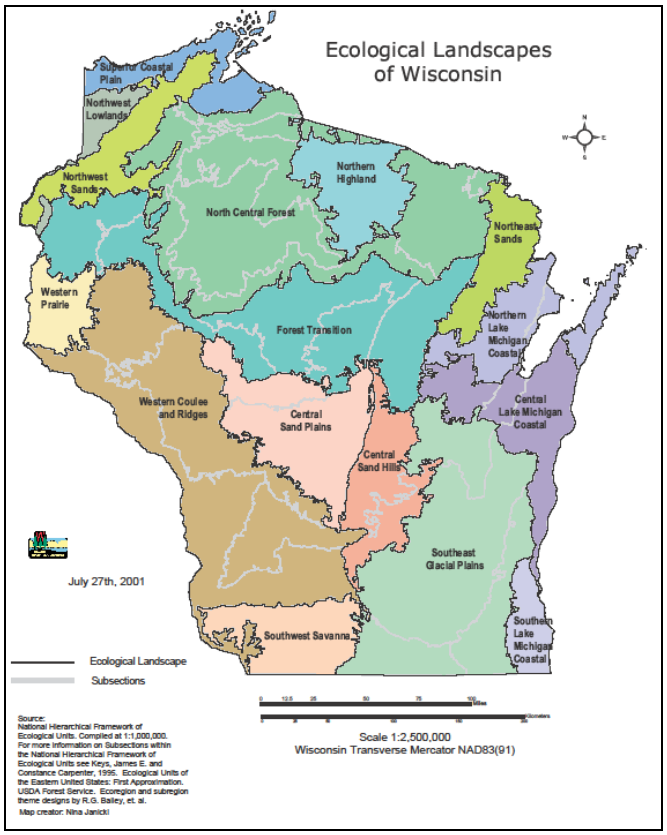

Figure2-6. Ecological landscapes of Wisconsin.

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Wisconsin is geographically and ecologically diverse. The variation in Wisconsin's natural areas is a major tourism driver and part of what makes our state so beautiful. Because of this diversity, not all regions are well-suited for biomass production or harvest. As discussed in the preceding section, environmental benefits can be gained from considering the predominant vegetation of land surrounding a biomass crop. For example, in the North Central Forest (Figure 2.6) woody biomass may provide more benefits than monoculture switchgrass because it more closely mimics the original land cover. Several areas in Wisconsin need to be given further considerations based upon their geography or sensitive environments.

Where to expand biomass and what to plant is an important conversation to have as Wisconsin's bioenergy market emerges as they could have profound impacts on Wisconsin ecosystems and citizens.These difficult conversations need to be held to create effective policy and healthy economies.We present a number of land considerations that should be included in this discussion.

2.2.1. Sensitive Areas

There are many sensitive geographical areas in Wisconsin; we highlight a few types in depth here. You should contact your county agronomist or xxxxxxxx to see if your potential biomass production area has special geologic, environmental, or soil considerations.

2.2.1.1. Habitat Restoration Areas and Major Conservation Opportunity Areas

The Wisconsin Department of Natural Resources in collaboration with many federal, state and local partners has developed multiple Habitat Restoration Areas throughout Wisconsin (Figure 2.7).The stated goal of these restoration areas is to protect, restore, and create permanent (grassland and wetland) habitats. In addition, the Wisconsin State Wildlife Action Plan, 2005-2015 Implementation Plan (WDNR 2005) identifies a number of specific grassland communities that are of significant statewide ecological importance (Figure 2.7).Lands dedicated to crop production within these landscapes have relatively low value to the more sensitive grassland species, but they can help maintain the open aspect of a treeless landscape and potentially increase the effective conservation area for some species (Sample *et al*. 2003).Grassland fragmentation and woody encroachment have a negative impact on grassland bird productivity in these landscapes (Sample and Mossman 1997).Dedicated grassland crops grown on working lands in these landscapes could be part of the multi-organization effort in these restoration areas. Wisconsin Grassland Habitat Restoration Areas and Major Conservation Opportunity Areas are identified in the 2005-2015 Implementation Plan for the Wisconsin Wildlife Action Plan (WDNR 2005).

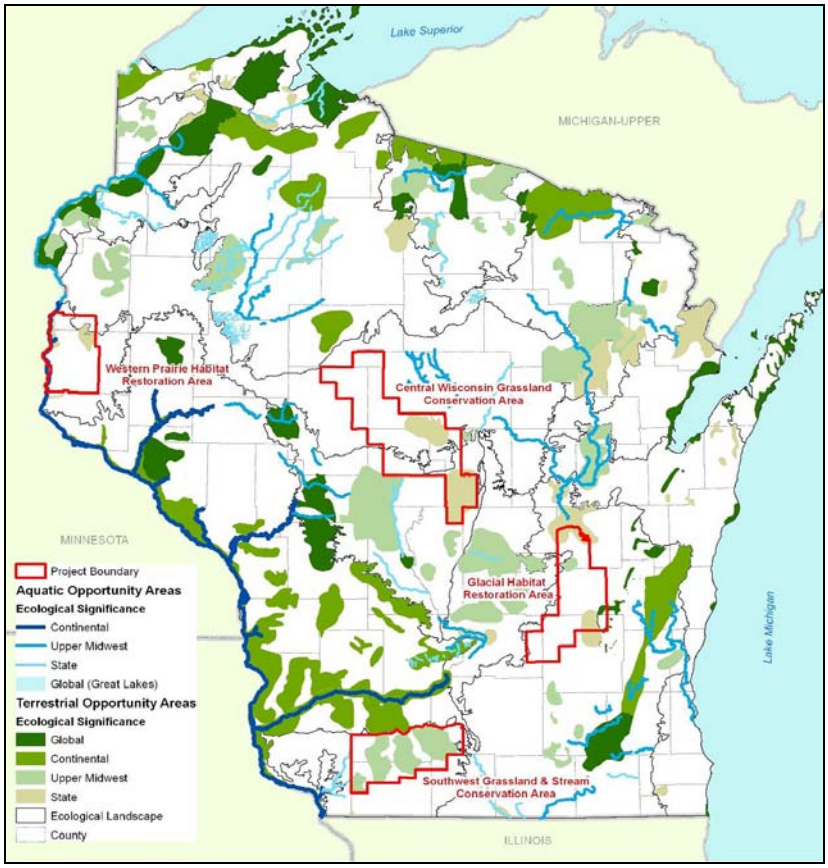

Figure2-7. Wisconsin Grassland Habitat Restoration Areas and Major Conservation Opportunity Areas identified in the 2005-2015 Implementation Plan for the Wisconsin Wildlife Action Plan (WDNR 2005)

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2.2.1.2. Karst Areas

Additional cautions needs to be taken when considering biomass production in *Karst* areas. "Karst" is the term used by geologists to describe areas where the bedrock, usually limestone or dolomite, has been (or has the potential to be) easily dissolved by surface water or groundwater. Karst landscapes may have deep bedrock fractures, caves, disappearing streams, springs, or sinkholes (Figure 2.8). These features can be isolated or occur in clusters, and may be open, covered, buried, or partially filled with soil, field stones, vegetation, water or other miscellaneous debris. Karst features can act as direct conduits for pollutants to enter groundwater, wells, springs, and streams; some endangered species live exclusively in karst features or landscapes; bedrock in these landscapes, especially around sinkholes, may be weak and prone to collapse, raising safety and liability issues.

Table 2-1. A large sinkhole in Eagle, Wisconsin (photo courtesy of WI Geological Survey).

Include more specific section on what the concerns are and how to avoid them

Wisconsin counties that may contain noticeable karst features include Brown, Buffalo, Crawford, Dane, Dodge, Door, Grant, Green, Iowa, Jefferson, Kewaunee, La Crosse, Lafayette, Monroe, Pepin, Pierce, Richland, Saint Croix, Sauk, Trempealeau, Vernon, and Waukesha. Learn more about karst and shallow carbonate bedrock in Wisconsin athttp://www.uwex.edu/wgnhs/karst.htm

2.2.1.3. Highly Erodible Lands (HEL)

Highly Erodible Lands are land areas that have an erodibility index of eight or more. The soil erodibility index (EI) provides a numerical expression of the potential for a soil to erode considering the physical and chemical properties of the soil and the climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped. Factors that contribute to erodibility include slope, soil type, and land management. Additional caution and consideration needs to be given to HEL areas.

Federal law requires that all persons that produce agriculture commodities must protect all cropland classified as being highly erodible from excessive erosion. For compliance, conservation systems must result in a "substantial reduction" in cropland soil loss, defined as 2T or less, with T being the tolerable soil loss level. HEL are located throughout WI.

Corn production for grain and/or stover on certain marginal or HEL lands is not sustainable in regard to yield and soil fertility (Varvel *et al*. 2008).Wilhelm *et al*. (2004) cautions that crop production on highly erodible land (HEL) must occur while maintaining adequate crop or residue cover to protect against erosion, thereby limiting the suitability of HEL lands for biomass harvest.

2.2.1.3.1. Additional resources

- Wisconsin USDA HEL websitehttp://www.wi.nrcs.usda.gov/programs/comp.html
- Joe Lauer, Corn Agronomist article "Managing Corn Silage on Highly Erodible Land" *http://corn.agronomy.wisc.edu/WCM/W105.aspx*
- UW Soil Science Extension Websitehttp://www.soils.wisc.edu/extension/water.php

2.2.1.4. Important Watershed Areas

Additional considerations and greater caution needs to be taken when biomass production is considered on lands surrounding surface water sources including rivers, lakes, streams, ponds, and wetlands. Consult an expert, such as your county XXXXX, before beginning a biomass production project.

2.2.1.4.1. Additional resources

- USDA Publication "Wetlands and Conservation Compliance, What every Wisconsin farmer needs to know."ftp://ftp-fc.sc.egov.usda.gov/WI/Pubs/wetland_compliance_08.pdf

2.2.2. Summary

Wisconsin possesses a wide range of geography and natural environments. This variety makes our state beautiful and keeps our economy and environment healthy. Some areas are more sensitive to land change and should be given further consideration and caution when biomass planting or harvest is being considered; this includes but is not limited to: habitat restorations areas, Karst areas, highly erodible lands, and watershed areas.. Contact a regional expert to determine if your biomass production location falls within sensitive geology.

2.3. Maximizing Environmental Benefits

HOW TO USE THIS SECTION: Sections 1 and 2 of this chapter described the environmental impacts and sensitive areas of WI, this section will cover how to maximize benefits through crop and land selection. To be added in the next draft: Included is a case study describing the decision process taken by one switchgrass project in 200X in XXXXXX county that includes environmental and economic considerations.

Chapter 2: Section 3

- Biomass Crop Selection
- Land Selection
- Case Study: Switchgrass in X county
- Conclusion/Summary

2.3.1. Biomass Crop Selection

Cropping systems must be productive to meet the provisioning services needs of growers (James et al. 2010). This will be a moving target as the bioeconomy emerges and evolves. However, such productivity should not be driven by inputs of inorganic nutrients alone, as this will negatively affect air and water quality. While innumerable benefits are provided by the natural world, research and experience shows that particular cropping systems have characteristics that tend to increase overall environmental benefits, namely, **perenniality** and **diversity**.

A biofuel industry utilizing a range of *perennial* biomass crops in mixture or monoculture can enable land-use systems that better optimize production of food, biofuel and bio-products, and potentially increase the total productivity and efficiency of land, water, and nutrient use (Wilson 2007, Gopalakrishnan *et al*. 2009,

Spiertz and Ewert 2009). Such systems can also potentially improve conservation of biodiversity, wildlife habitat, and soil and water quality *(Robertson and Swinton 2005, Robertson et al*. 2010, Foster et al. 2009, Tilman *et al*. 2009, Jordan and Warner 2010). Production costs could also be lower for perennial crops than for annual crops due to less herbicide, pesticide, fertilizer and petro-fuel consumption, which equates to cleaner air and water for public use and aquatic species. Hence, increasing the range of ecosystem services and creating new revenue streams for landowners (Robertson and Swinton 2005, Jordan *et al*. 2007, Swinton *et al*. 2007). A significant barrier to development of widespread perennial biofuel production systems is inadequate understanding of their environmental performance (Boody *et al*. 2005, Oquist *et al*. 2007, Cruse and Herndl 2009, Fargione *et al*. 2009, Scheffran and BenDor 2009, Webster *et al*. 2010).

Diverse mixtures are cropping systems with more than one species grown in an area at the same time, typically thought of as stands containing 10 to 100 species within 1- to 100-m^2. Improved technology to produce biofuel from diverse mixtures of grasses and forbs or trees and shrubs can better mimic natural landscapes and provide for wildlife. Monocultures could be improved by incorporating practices that add diversity in the form of management rotations or inter-seeding. For example, benefits could be increased in grass biofuel monoculture by inter-seeding with forbs or legumes to supply necessary wildlife food and brood cover and providing a natural source of nitrogen.

Selecting crops that will enhance the diversity of the surrounding areas (i.e. where each field is not the same in the neighborhood) will also increase benefits. There is mounting evidence that landscape mosaics, where a diversity of cropping systems are present within small watersheds, support natural enemies of plant pests and minimize the need for energy-intensive pest control compared to cropping systems in homogeneous landscapes (Tscharntke *et al*. 2005).About $3 billion is spent annually on insecticides for control of insect pests and over $15.7 billion annually in crop yields is lost to crop pests (Losey and Vaughan 2006) indicating that pest pressure on crops is not trivial and needs to be considered in models predicting biomass and ecosystem services. Similarly, pathogen pressure in diversified landscapes is expected to be lower than in spatially homogeneous monocultures. These issues of landscape structure are likely critical to implementing a large-scale biofuel agriculture since the scale-dependent processes, including the associated with buildup of insects and pathogens, may vary with changes in landscape structure and both small (e.g., within-farm) and large spatial scales (e.g., among-farms, and watersheds).

2.3.2. Land Selection

Add section describing the positive benefits that could be achieved by establishing perennial biomass crop systems on marginal lands that are currently in traditional rowcrop production.

It is important to consider the surrounding vegetation and geography of lands surrounding a potential biomass site. Converting a row crop field to forested or woody biomass would be ecologically advisable set amidst a larger forested landscape. Here, reducing open edges will benefit the forest ecosystem and forest birds, plants, amphibians, etc. adapted to it.However, when set within a larger open grassland landscape, such conversion of open cropland to woody biomass would fragment the open landscape, and challenge the plant and animal species that require it (e.g., those adapted to the native prairie landscape).

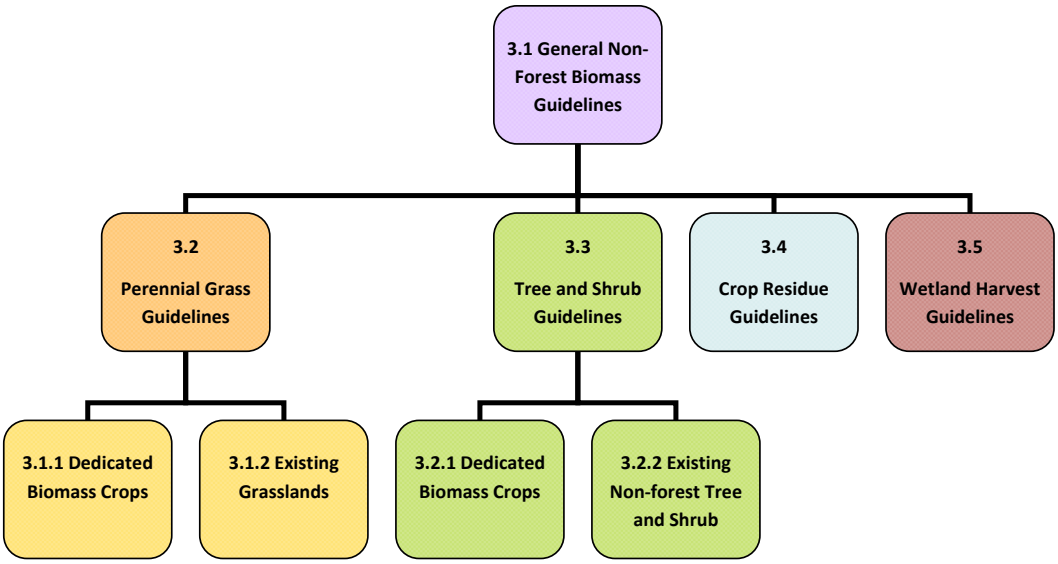
2.3.3. Case Study

To be added in next Draft: Switchgrass economics in SW Wi

2.3.4. Conclusion/Summary

3. Considerations for how to plant, grow and harvest biomass feedstocks

HOW TO USE THIS CHAPTER: This chapter begins with a set of general guidelines applicable for all non-forest biomass operations with references to discussions in chapter 2. These guidelines should be used in making broad decisions about biomass selection.Specific recommendations for planting, managing, and harvesting biomass from grasslands, woodlands, wetlands and row-crop systems follow in the order outlined in the figure below and apply in addition to the general biomass guidelines. Each section is accompanied by a discussion of the science behind and additional resources for each biomass category.



3.1. Guidelines – All Biomass Crops

Applies to any biomass type considered for production or harvest for bioenergy

3.1.1. Site Selection

- Where possible, established grasslands, wetlands and forestlands should be maintained to sustain positive environmental benefits.
- To ensure preservation and enhancement of environmental benefits, plant selection, establishment and management options should be carefully matched to site conditions and overall land use goals.
- Marginal lands currently in perennial cover (such as grassy steep hillsides) are preferred to remain in perennial cover. If converted to perennial bioenergy crops, caution should be taken to ensure that increased erosion and nutrient loss does not occur, especially during establishment period.

3.1.2. Crop Selection

- Choose perennial and diverse cropping systems when possible, to maintain a diverse suite of environmental benefits, especially on marginal lands
- Multiple positive environmental benefits (soil, water, wildlife, yield) can be achieved by planting perennial crops on marginal or sensitive lands
- Diversify clone types and species planted, to improve disease resistance and diversity
- Measures should be taken to prevent the spread of invasive species.
- If invasive species are used for biomass production the industry and producer must make every effort to ensure only infertile varieties are approved for biomass production.
- Prevent spreading seeds of unwanted plants to other areas. Inspect for and remove all plants found on equipment before leaving site. Wash all equipment after use in wet areas to avoid spreading seeds.
- Consider surrounding vegetation and geography when selecting a bioenergy crop.
- Generally, environmental benefits are highest when biomass systems mimic surrounding natural vegetation. For example, the consideration of perennial grassland systems is encouraged in core grassland habitat restoration areas throughout Wisconsin such as the Southwest Grassland Conservation Area(refer to figure 2.7) and in key grassland conservation opportunity areas that were identified as part of the Wisconsin Wildlife Action Plan. Whereas, short-rotation woody cropping systems are discouraged in those same areas due to negative effects on grassland wildlife species of greatest conservation need.

3.1.3. Wildlife

- Limit management activities (e.g., planting, harvesting) to the extent practicable during the primary bird nesting season (May 15 – August 1).A wider window (April 15 – October 15) is pre-

ferred, particularly on public lands or conservation grasslands, to avoid adverse impacts to birds and most reptiles, amphibians, and small mammals, including rare species.

- Before establishing a new biomass crop on uncropped land or harvesting existing biomass sources, determine the presence of and potential impacts on key resources.Manage properly for these resources with the help of specialists (see bullet bellow)

  Key Resources here include:

- Species listed at the federal or state level as Endangered or Threatened
- State Special Concern Species and Species of Greatest Conservation Need underthe State's Wildlife Action Plan (i.e., rare or declining, but not listed as Federal or State Endangered or Threatened)
- Element Occurrences (EO) of Wisconsin Natural Heritage Inventory (WNHI) Community Types (see below).
- Consult specialists, management guides, and databases to assess occurrence, habitat requirements, community characteristics, potential impacts of proposed management activities, and management alternatives and recommendations

3.1.4. Crop Management

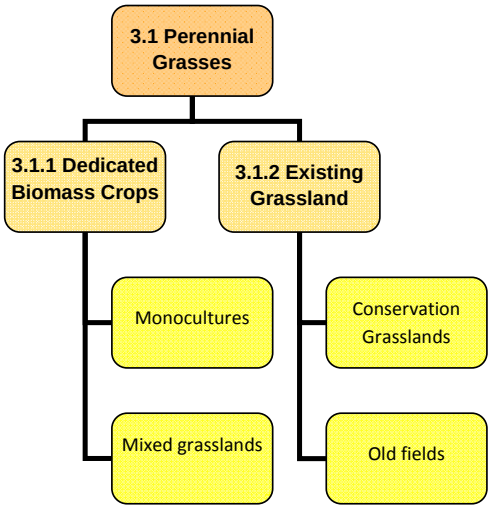
- Construct and maintain harvest roads, stream crossings, and other improvements needed for field access using best management practices that minimize erosion, water quality degradation,and habitat damage (see [forestry BMPs]).
- Avoid or minimize fertilizers and pesticides to optimize economic yields.Avoid use of agricultural chemicals in situations where these threaten environmental resources.As appropriate or required, incorporate biomass production into nutrient management plans.
- Control noxious weeds and undesirable species. (For example: leafy spurge, Canada thistle, cheatgrass, wild parsnip). If chemical control is necessary in wetlands or riparian areas, use a formulation labeled for use in these areas.
- Use insecticides/fungicides only as specified within Integrated Pest Management (IPM) plan, not preemptively.
- Minimize chemicals that reduce earthworm or other microfauna populations that promote tilth and move carbon to deeper soil layers.
- Where available, crop management practices should conform to the specifications determined by the following three conservation plan types:
- A farm- specific nutrient management plan that is compliant with the NRCS 590 Standard for Wisconsin as specified by state statutes ATCP 50 and NR 151.
- Soil erosion calculations that do not exceed the tolerable soil loss level for the critical soil type present in the field.Soil erosion calculations must be determined using the Revised Universal Soil Loss Equation 2 (RUSLE2).

- Soil Conditioning Index values must be greater than 0.05. Soil Conditioning Index values are a relative measure of the soil organic matter content trend for given soils, cropping, and management practices. Positive numbers (above 0.05) represent an increase in soil carbon content over time and are a surrogate for carbon sequestration trends.
- Reminder: The NRCS 590 Nutrient management practice standard restricts applications of nutrients in the fall, in water quality management areas, and near direct conduits to groundwater such as drinking wells.
- Limit harvest actions that damage soil including skidding/scraping of the duff layer, rutting, and soil compaction.Options for reducing damage include; avoiding operations on wet soils, distributing vehicle weight, minimizing tractor and equipment weight, adding organic matter, and where possible harvesting on frozen soil.
- Considerperforming life cycle cost analyses (see section 2.1) of the cropping system and production process on a given site.

3.2. Perennial Grass

This section examines biomass production from perennial grasslands. General guidelines and descriptions for grass systems are included within two categories: *dedicated grassland crops*, defined as areas planted specifically for biomass harvest, and *existing grasslands*, defined as grasslands already established that may support periodic biomass harvest.

In addition to the general guidelines, further discussions and guidelines are included for specific approaches/crops within those categories that have arisen as options for WI biomass grass sources.



3.2.1. Guidelines

3.2.1.1. All Grasslands - General Guidelines

Applies to all grassland being considered for biomass production or harvest, including dedicated and existing biomass resources

- Retain a minimum of 6-inch grass stubble and sufficient surface residue (at least 75% residue) as of April 1 to improve water infiltration, reduce erosion, and maintain grass health.
- Harvest a maximum of once per year after senescence (browning) to minimize harvesting of nutrients and avoid most wildlife breeding seasons. An earlier harvest (pre senescence) may be necessary if harvesting for ethanol production (add citation to discussion)
- Consider leaving a part of the field unharvested to serve as habitat for beneficial insects and wildlife and consider harvesting in early spring to leave cover for wildlife overwinter.

3.2.1.2.Dedicated Grassland Crops - General Guidelines

Applies to grasslands specifically planted for biomass including switchgrass, Miscanthus, and diverse grasslands.

3.2.1.2.1. Site Selection and Planting Guidelines

- Target land that would be most improved by long-term coverage of perennial plants.
- Steeply sloped cultivated land
- Low/wet areas currently in cultivation
- Sensitive lands currently in cultivation (e.g. Karst* areas or highly erodible land)
- Pick a grass variety that is appropriate for your region and site. Use native ecotypes to the extent possible. ConsultNRCS, county agronomist, or other specialists to ensure crop selection suitability.
- When possible, choose diverse species mixes (including forbs) over monoculturesto increase the number of environmental benefits (see chapter 2)
- To minimize weedy competition avoid nitrogen fertilizer application during the establishment year
- Replant stand when stand frequency (i.e. ground cover) is less than 50% by year 2or3??ask RENZ(Consult Appendix E in full document for methods to measuring frequency)

3.2.1.2.2. Weed management

- Use low-impact herbicides, only as needed to rejuvenate stands.
- Weed control during establishment may improve stand productivity, but results are site specific (see Renz et al. report to *Focus on Energy* Final Report)
- Explore cultural and mechanical control methods (burning, mowing, etc) before performing chemical controls after establishment.

3.2.1.2.3. Harvest Guidelines

- Retain as much crop residue as possible on the surface after harvesting.
- Minimize tillage at the end of stand life and other soil disturbances that speed decomposition.
- Minimize tilling unless required for planting/reestablishing.

3.2.1.2.4. Giant Miscanthus Specific Guidelines

- Giant Miscanthus *(Miscanthus* x *giganteus)* should only be considered if an expert or supplier has certified the rhizomes as infertile; many of the fertile varieties are considered invasive.

3.2.1.2.5. Diverse Mix Specific Guidelines

Applies to plantings with two or more of the following, warm-season grass, cool season grass, and forbs

- Eliminate noxious weeds and undesirable species. Examples include: leafy spurge, Canada thistle, cheatgrass, and wild parsnip.
- Nitrogen fertilizer has no demonstrated effect on diverse prairie stands, so should be avoided.

3.2.2. Existing Grassland Guidelines

Applies to existing diverse mix grasslands, including prairie and switchgrass mixed stands.

- Minimal or no-till methods are preferred to establish or replenish conservation grasslands on marginal land enrolled in a bioenergy program (if being reinvigorated or replenished-one time tillage may be necessary.)
- Consider the no-fertilizer option to maximize environmental benefits; if choosing to fertilize, consider non-chemical fertilizer options (e.g. manure application or legume inter-seeding) before chemical options on conservation grasslands.
- Consider longer harvest rotations (i.e. harvesting every 3 or 5 years) on grasslands that were originally established for wildlife habitat, soil quality or water quality purposes. (Exception: if more frequent harvest has been demonstrated to maintain/improve services)
- Do not harvest from sites where Federal or state endangered species are known to exist or are discovered during operations. (Exception: if harvest has been demonstrated to maintain/improve habitat for species present, then follow appropriate management guidelines to sustain occurrence or condition.)
- Landowners with expiring CRP contracts are encouraged to consider enrollment into bioenergy programs instead of conversion back to annual row-crop agriculture to ensure that ecosystem services are maintained.

EVALUATING STAND SUCCESS

Warm-season grasses can be difficult to establish due to weed competition and winter damage to rhizomes.Stand success in grasslands has been assessed using stand frequency measurements since the 1950's (Schmer*et al.* 2006).A threshold frequency is the value at which increased establishment frequency no longer affects the frequency in the following year.Consult Appendix E for methods for measuring frequency. Vogel and Masters (2001) reported thresholds of 50% for a successful stand, 25% for a marginal stand and 0-25% frequency for a partial or unsuccessful warm-season grass stand.A study by Schmer*et al.* (2006) in the northern Great Plains using Vogel and Masters' frequency grid indicated a frequency threshold of 40% for switchgrass grown for biomass, and a 25% or greater frequency as adequate for conservation stands that would not be harvested for several years.

3.2.3. Science Discussion and Guideline Implementation notes – Perennial Grasses

3.2.3.1. All Grasslands

Grasslands are a diverse group of systems and potentially an environmentally beneficial biomass crop. The fundamental basis for encouraging use of grassland/prairie species for biomass production aside from yield, lies in the fact that native plants have extensive root systems that improve the ability of water to infiltrate the soil and withstand wet or erosive conditions. Native prairie plants often have greater biomass below the surface than above. In this illustration (Figure 3.1), note the Kentucky bluegrass shown on the far left, which, when compared to native grass and forb species, exhibits a shallower root system.

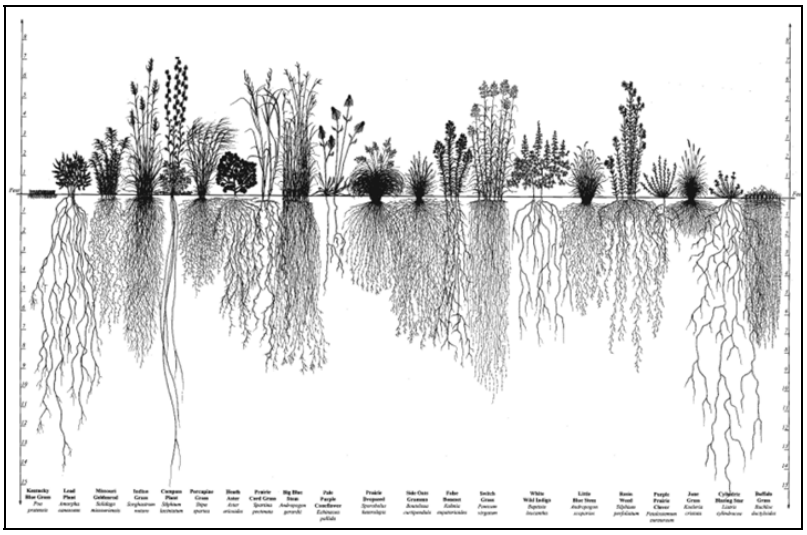


Figure 3.1.Illustration by Heidi Natura of the Conservation Research Institute

3.2.3.2. Harvest frequency

The guideline of harvesting no more than once per year supports stand longevity and keeps costs down. Switchgrass and other perennial grasses grown for biomass do not follow the same rules as forage crops like alfalfa, which are cut more than once per year to maximize yield. Tall-grass species do not typically display the same recovery. Most research has shown greater long-term yields with a single switchgrass harvest than with the combined yields of two or three annual harvests. (for a review see Parrish and Fike 2005). In only a few studies, twice-annual harvesting produced similar or slightly higher yields as single harvests (Thomason *et al.* 2004, Reynolds *et al.* 2000, and Vogel *et al.* 2002). A trial by Roth *et al.* (2005) in southwestern Wisconsin, observed no vegetation re-growth immediately following an August (pre-senescent) harvest.Multiple harvests may overtax rhizomes and soil nutrients, decreasing future yields. Multiple harvests also greatly increase the operating costs with double the fuel, labor, and nutrient replacement.

3.2.3.3. Harvest Timing

The guideline of harvesting after grasses have senesced in the fall was reached by balancing considerations of soil nutrients, biomass quality and yield, and wildlife.

3.2.3.4. Nutrient Considerations

The nutrient cycle in warm season grasses directs the harvest schedule (Figure 3.2).As plants die back in the fall nutrients are moved into the below-ground plant tissues and remain there for the plant's use the following growing season. Harvesting biomass before the plants senesce increases the amount of nutrients in the harvested plant tissues and increases the need for supplemental fertilization (Adler *et al*. 2006; Haque *et al*. 2009; Heaton *et al*. 2009). Field trials have shown that nitrogen removal decreased by more than 50 percent in harvests delayed until after senescence (Varvel *et al*. 2008).

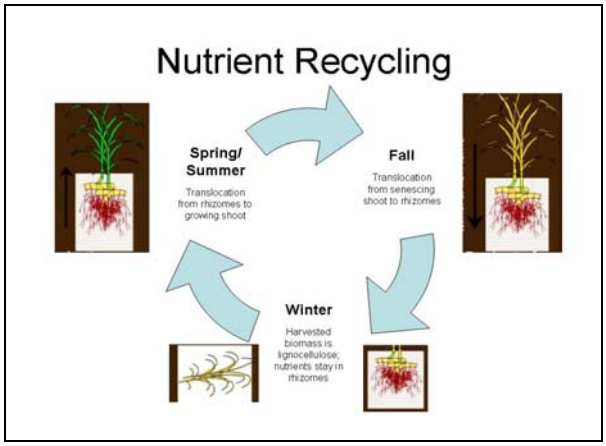


Figure 3.2: Nutrient cycle in warm-season grasses, adapted from Heaton et al. 2009

3.2.3.5. Biomass Quality and Yield Considerations

The quality of grasses used in biomass energy conversion systems is influence by the composition of elements in the grass, which change with the seasons. Thus, the timing of harvest can be an important factor in obtaining high quality biomass. Two factors that affect the quality of harvested biomass are chemical composition and moisture content. Elements found in perennial grasses that can be harmful to biomass combustion boilers are potassium, chlorine, magnesium, and phosphorous. Perennial grasses harvested before senescence (spring/summer) possess the highest levels of combustion contaminants, which decrease as harvest is delayed and crops are allowed to senesce (fall/winter) (Adler *et al*. 2006; Sanderson *et al*. 2006). Further aboveground contaminates are leached by rain and snow after senescence (Heaton *et al*. 2009).

In contrast to grasses harvested for use in biomass combustion boilers, grasses harvested for use in ethanol bio-refineries may benefit from earlier harvest in the fall. High fermentability and lignocellulose yield (*i.e.*,

quantity) defines biomass quality for ethanol bio-refineries. Field trials have recorded up to 25% fermentability declines in crops left overwinter and harvested in spring rather than fall harvests (Adler *et al*. 2006).

Moisture content also can affect the quality of harvested materials for use as biofuel feedstock. Moisture affects the stable storage, stable transportation, and combustion efficiency of harvested materials. If the moisture content of harvested biomass is too high it may need to be dried before processing, therefore creating logistical concerns. Moisture content decreases with time after the first frost with the lowest moisture content occurring in early spring (Adler *et al*. 2006).

Biomass yields from warm-season grasses are highest just before senescence at the R3 to R5 stage of maturity. Yields decline as the grass becomes dormant in fall, generally from August to November with a smaller percentile loss if harvest is delayed overwinter (Adler *et al*. 2006).Peak yield is traded for improved health and longevity of the stand and soil.

3.2.3.6. Wildlife Considerations

There are more than 50 grassland dependent wildlife Species of Greatest Conservation Need (SGCN) in Wisconsin (WDNR 2005).The habitats and management regimes required to benefit these species are well understood in Wisconsin (Sample and Mossman 1997).A widespread grassland biomass program in Wisconsin could have dramatic positive impacts on grassland wildlife populations similar to the Conservation Reserve Program (NRCS 2009, Meehan et al. 2010, Robertson et al. 2010).However, the local impact of grassland biomass programs on grassland-dependent wildlife species will largely depend on the type of grasses planted, their configuration across the landscape (Sample and Mossman 1997), and the timing and extent of harvesting. Some grassland birds prefer shorter more sparse vegetation and may respond positively to annually harvested grassland crops. Other bird species prefer taller, denser vegetation and may benefit from tall dense stands of grassland vegetation that is harvested late in the fall or portions of fields that go unharvested and serve as refugia.For example, Roth et al. (2005) found that a variety of grassland bird species utilized harvested switchgrass fields in Wisconsin because of the resulting mosaic of vegetative heights post-harvest. They also found that harvesting switchgrass fields in mid-August changed the grassland bird composition the following nesting year due to the changes in vegetative height and density.

Certain harvest management strategies could benefit grassland wildlife. For example, strip harvesting where residual nesting material remains available for wildlife could be beneficial for ground nesting birds like Northern Harriers and ring-necked Pheasants (Murray and Best 2005).Roth et al. (2005) suggested that leaving portions of fields unharvested would provide critical habitat for some grassland wildlife preferring taller dense vegetation.

Beneficial insects may also be influenced by the biomass cropping systems. Landis and Werling (2010) predicted that biofuel cropping systems have the potential of altering arthropod communities on the landscape thereby altering pollination and pest control services. They concluded that perennial grass systems provide the best opportunity to favor a variety of beneficial arthropods when compared to annual cropping systems.

The peak of nesting season for grassland birds in Wisconsin is approximately May 15 to August 1.Fields harvested during that time or multiple times during that period will result in destruction or abandonment of nests. Avoiding management actions during the peak nesting period is important to maintain grassland wildlife populations. Widening the “no-management” window, (e.g. April 15 to Oct 15) will allow for success-

ful nesting of early and late nesting species and will provide refugia for reptiles and amphibians that utilize grassland habitats for portions of their life cycles. Therefore, delaying biomass harvests or other management actions until at least August 1 or even later will benefit a variety of grassland dependent wildlife.

3.2.3.7. Dedicated Grassland Crops

Dedicated grassland crops have received considerable attention as bioenergy sources because they provide both long-term yield potential and many ecosystem services (Mitchell *et al*. 2010, Webster et al. 2010). When managed effectively, perennial grasslands (warm- and/or cool-season grasses and forbs) can be maintained in long-term rotations for 10 years or longer, offering many advantages over annual crops (Mitchell *et al*. 2010; Culman *et al*. 2010; see Chapter 2).Cool-season (C_3 photosynthetic pathway) grasses, such as smoothbrome, orchardgrass, timothy, Kentucky bluegrass are prominent livestock forages, but not generally recommended for bioenergy harvest because of their high nutrient content. Perennial, warm-season tall-grasses (C_4 photosynthetic pathway) offer the most potential as biomass crops since they are very productive and efficient with water and nutrients (Lewandowski *et al*. 2003; Parrish and Fike 2005).

The two primary dedicated biomass approaches discussed are warm-season grass monocultures and multi-functional group mixes. Multi-functional group mixtures (grass and forbs) are gaining recognition after several small scale trials recorded similar or greater yields with diverse stands than monoculture stands (Tilman *et al*. 2009; DeHaan *et al*. 2010; Weigelt *et al*. 2009, but see Adler et al. 2010…maybe 2009). Full field level experiments are needed to compare systems accurately.Add Wisconsin relative results

Perennial, warm-season tall-grasses demonstrate the most promise for yield and biomass combustion quality of all grassland groups. Switchgrass (*Panicum virgatum* L.) emerged as the lead perennial herbaceous candidate from a study funded by the US Department of Energy (McLaughlin and Kszos 2005; Parrish and Fike 2005; Vogel *et al*. 2002). As a result, it has been the focus of agricultural and genomic research for herbaceous biofuel. Much less is known about the biomass crop potential for other warm-season grasses. For these guidelines, the assumption was made that much of the information regarding switchgrass management will be applicable to other warm-season grass monocultures.

Warm-season grasses are slow to establish; peak yields are usually achieved 3 to 5 years after planting. Even with slow establishment, overall operating costs may be lower than traditional row crops since fields do not need to be planted and fertilized every year, reducing fuel and labor expenses (McLaughlin *et al*. 2002; James *et al*. 2010).

3.2.3.8. Switchgrass

Switchgrass (*Panicum virgatum* L.) is a perennial North American prairie grass capable of growing across a wide geographic range and in many soil conditions.Switchgrass is planted in the US as forage, for soil restoration, for wildlife habitat, and increasingly for biomass (Parish and Fike 2005; McLauphlin and Kszos 2005; Sanderson *et al*. 2006; Mitchell *et al*. 2010). Switchgrass emerged as the lead perennial herbaceous candidate from a research program in the 1990's funded by the US Department of Energy (McLaughlin and Kszos 2005; Parrish and Fike 2005; Vogel et al. 2002). Agronomic traits that promoted its use over other (equally productive) native tall grasses including big bluestem and indiangrass include the ease of seed harvest, cleaning, and planting (McLauphlin and Kszos 2005). The long history of cultivation and involvement

by the DOE has produced many varieties on the market and prompted research into hybrid and genetically modified strains for improved biomass production.

There are two ecotypes of switchgrass, upland and lowland, defined principally by soil type and historic vegetation (Casler *et al*. 2004; Casler *et al*. 2007).Both native and 'improved' varieties have been recommended as possible biomass crops. Switchgrass is a small seeded species and yields only 33-66% of its biomass potential in the initial and second years, reaching full potential yields during year three (McLaughlin and Kszos 2005).Generally, the perennial long life and production of the stand overshadow initial yield shortfalls. In the establishment years, the roots and rhizomes are utilizing the majority of nutrients, forming a base for longevity of the stand. In the US, yields as high as 7 to 9 tons/acre have been reported (McLaughlin and Kszos 2005). However, in Wisconsin test yields have reached only 4.7 tons/acre (Renz 2010 unpublished data; Table 3.1).

Table 3.1. Average yield (tons/acre) of switchgrass varieties from various field plot studies in Wisconsin(adapted from Renz 2010 unpublished data).

	Location			
Variety	Lancaster	Arlington	Marshfield	Spooner
Blackwell	4.02	3.35	4.23	4.54
Cave-in-Rock	4.54	3.54	4.45	4.39
Pathfinder	3.89	2.91	4.13	4.33
Sunburst	4.28	3.51	4.57	4.74

Producers should choose a switchgrass variety based upon both ecotype (upland or lowland) and the latitude or plant hardiness zone of origin. Research has shown that cultivars are not as successful when planted more than 300 miles or one plant hardiness zone north or south of their origin (McLaughlin and Kszos 2005, Casler *et al.* 2004 and 2007). Wilsey (2010) found no difference in biomass production between cultivars and non-cultivars over the first two years of establishment, so local seed sources may be viable alternatives. Check with your local Natural Resources Conservation Service (NRCS) or extension office for varieties adapted to your area. Newly harvested seed generally has high percentage dormancy (Shen *et al*. 2001). Verify that the seed selected has an adequate pure live seed (PLS) rating.

3.2.3.9. Other native warm-season grasses

Other native, warm-season grass species are promising as dedicated biomass crops, especially when grown in mixtures or in areas that are very dry or very wet. Little research has been conducted regarding their potential as dedicated biomass crops (Gonzalez-Hernandez *et al*. 2009).

3.2.3.10. Indiangrass

Indiangrass (*Sorghastrum nutans* L.) is a native perennial tall-grass that is dominant in tall-grass prairies. It achieves similar yields to unimproved switchgrass varieties or slightly lower yields than improved switch-

grass (Wilsey 2010). Indian grass is a chaffy-seeded species, making seed collection, cleaning and planting more difficult than switchgrass (Gonzalez-Hernandez *et al*. 2009).

3.2.3.11. Big bluestem

Big bluestem (*Andropogon gerardii* Vitman) is a native perennial that was dominant in tall-grass prairies. It achieves similar yields to unimproved switchgrass varieties or slightly lower yields than improved switchgrass (Wilsey 2010). Big bluestem is a chaffy-seeded species, making seed collection, cleaning and planting more difficult than switchgrass (Gonzalez-Hernandez *et al*. 2009).

3.2.3.12. Little bluestem

Little bluestem (*Schizachyrium scoparium*) is a native North American prairie grass adapted to dry and shallow soils. While it does not produce as much biomass as other biomass crops (Wilsey 2010), it can grow on land not suitable for larger species and is very adaptable to fluctuating climate conditions (Gonzalez-Hernandez *et al.* 2009).

3.2.3.13. Prairie cordgrass

Prairie cordgrass (*Spartina pectinata*) is a native North American species with a wide geographic range, notably adapted to soils that are too wet for other tall grass species like switchgrass (Gonzales-Hernandez *et al.* 2009).

3.2.3.14. Planting

In general, the best time to plant native grasses is in the spring when the soil has thawed. Planting methods include drilling or broadcasting into either tilled or untilled firm seedbeds, although some studies in WI have shown mixed results (citation). Research shows switchgrass produces similar yields across a range of planting rates and row spacing (cite).Planting density does affect the speed of establishment not necessarily the maximum biomass achieved. Planting density affects weed encroachment and wildlife habitat suitability, both positively related to size of spacing.

3.2.3.15. Pest/Weed Control

Warm-season grasses germinate later than cool-season grasses and forbs and are easily outcompeted. Thorough weed control is necessary for warm-season grasses to be successfully established. Weed control options need to tailor to individual field conditions. In Wisconsin, the best establishment results have come from using chemical weed control(Miesel et al., submitted).

Weeds are not reported to be problematic in established dedicated warm-season grass stands. Leaf litter and canopy closure act as natural deterrents in healthy stands. After establishment, weeds have been managed

using cultural and mechanical methods. To maximize environmental benefits, nonchemical methods are favored after a successful establishment. Grazing fields in early spring when cool-season and weedy species are growing diminishes competition but may damage warm-season plants as well. Sanderson *et al*. (2004) found that switchgrass and big bluestem biomass yields did not decline when burned before the grass crop had 25 cm of new growth.

3.2.3.16. Soil and Nutrient Management

As with any crop, soils should be tested and phosphorous and potassium deficiencies corrected before planting. Warm-season prairie grasses are efficient users of soil nutrients (see figure 3.2).The field history, soil type, application timing, and perhaps most importantly, harvest cycle will affect nutrient requirements and success. A nutrient management plan taking the harvest considerations for each field should be established.

Native warm-season grass trials have not clearly defined a best management practice for nitrogen application (Parrish and Fike 2005; Lewandowski *et al.* 2003; Heaton *et al.* 2009; Heggenstaller *et al.* 2009; Renz et al. 2009, Table 3.2). Ruark *et al.* (2009) conducted a switchgrass trial in Wisconsin and reported reduced returns when applying greater than 100 lbs N/acre. At some point, the cost of application also surpasses the profit gained from additional productivity or quality.

Table 3-1. Switchgrass nitrogen application research summaries

Location	Results	Source
Michigan	125 lbs/acre Highest productivity 50 lbs/acre Highest economic return	Parrish and Fike 2005
Wisconsin	reduced returns when applying greater than 100 lbs N/ acre	Renz *et al*. 2009

3.2.3.17. Giant Miscanthus

A naturally occurring, sterile hybrid grass originating in Asia, Giant Miscanthus can grow in a wide geographic range in temperate regions. Field trials show that Miscanthus is best suited for areas with well-drained soils and at least 30 inches of rain a year, with higher productivity as rainfall increases (UW extension document, Iowa extension doc).

The use of Giant Miscanthusas a biomass crop is attractive because of its high biomass yields documented in field trials in Europe and the United States. Field trials in Illinois and Iowa indicate that *Miscanthus* can yield dry mass 2 to 4 times the dry mass of traditional switchgrass varieties (12 to 24 tons/acre vs. X-X tons/acre, respectively; Heaton *et al.* 2008; Dohleman and Long 2009).

Giant Miscanthusreaches full yield potential by year 3 or 4 and can only be propagated vegetatively (no viable seeds).Winter die-off has been reported in northern latitudes (Farell *et al*. 2006; Lewandowski and

Heinz 2003). The UW Extension reported that planting material currently could cost $1000-5000 per acre. However, Heaton *et al.* (2004) reported that over a ten-year period, Giant Miscanthuscould be more profitable than corn/soybean rotation in the Midwestern US; however no long term trials have been published from Wisconsin.

The largest point of contention is the possibility of the plant to become invasive. The same qualities that make Giant Miscanthusa promising biomass crop are often qualities of an invasive species. Giant Miscanthus, as an infertile plant, propagated only by rhizomes or plantlets (no viable seeds) is not much of a threat. There is doubt over the certainty that only triploid Giant Miscanthuswould be planted, since it is in short supply and easily mistaken for its invasive relatives. The parent species of Giant Miscanthus, *Miscanthus sinensis* and *Miscanthus sacchariflorus* are listed with the National Biological Information Infrastructure (NBII) & IUCN/SSC Invasive Species Specialist Group (ISSG).Proponents report that only plant material with a known genetic triploid background *i.e.*, a sterile variety will be used and that Giant Miscanthushas been cultivated for biomass and fodder in Europe since the 1980s without any reported invasive escapes (Lewandowski *et al.* 2000).Whether or not seed propagation would become possible in the future is a concern that has also been raised (Raghu *et al*. 2006). Faced with this uncertainty, only consider planting if the stock material (rhizomes) can be certified as the infertile Giant Miscanthus by an expert.

3.2.3.18. Pest/Weed Control

Generally, the same weed control issues apply for *Miscanthus* as for native Wisconsin warm-season grasses. *Miscanthus*, as a relatively new crop in the US does not currently have herbicides labeled for its use.

3.2.3.19. Soil and Nutrient Management

As with any crop, soils should be tested and phosphorous and potassium deficiencies corrected before planting. *Miscanthus* is also an efficient user of soil nutrients (see figure 3.2). *Miscanthus* seems to require smaller amounts of N than switchgrass. While *Miscanthus* in new to the US, it has been grown in Europe for over 30 years. In a review of 31 *Miscanthus* trials across Europe by Lewandowski *et al.* 2003 it was reported that some N application is required to replace nutrients taken off the field with harvest to retain maximum yields.

3.2.3.20. Diverse Mixed Plantings

The authors originally wanted to provide specific guidelines for a variety of mixed species stands (e.g., C3 mixes, C4/C3 mixes, etc.).However, there was little science available for making these types of distinctions, at least compared to the science available for monocultures like switchgrass.Therefore, all grass "mixes" are covered within a diverse mixed group category. When more science becomes available,further specific recommendations for mixed grass stands will be drafted.

Diverse mixed plantings define a wide range of grassland species blends, which contain at least one tall warm-season grass and one forbs.Mixtures appear to have greater disturbance resistance or productivity if plantings include species from several functional groups that grow at different times of the year; mixtures within a particular class, such as switchgrass and big bluestem, may provide some habitat variation but do

not confer the same benefits (Wilsey 2010).Mixed stands are also likely to provide additional ecosystem services compared to monocultures (see Chapter 2 and Figure 7).

Increasing the percentage of forbs improves ecosystem services, especially for wildlife. Increasing the percent coverage of legume/nitrogen fixing species, improves the nutrient cycling in the soil and decreases or negates the need for supplemental fertilization. Both low-input high diversity blends and the combination of tall-grass and a legume, have gained credence in recent years for improved yields, reduced inputs and improved ecosystem services.

Low input, high diversity mixtures provide the greatest ecosystem services and diversity of all dedicated grassland crops. Low input, high diversity mixtures are defined as mixtures incorporating 2-3 functional groups, warm-season grass and a combination of cool season grasses and/or forbs (flowering forbs, nitrogen-fixing legume, etc.) with little to no supplementary applications of fertilizer once established. The exact species mixture and establishment method should be selected with the assistance of a specialist.DeHaan *et al.* (2010) found that yields of warm-season tall-grass and legume bi-cultures were as productive as 16-species (maximum diversity tested) plots containing both tall-grass and legume, both of which were over 200% more productive than the average for low input monoculture (need to define low input monoculture and review for accuracy)

With the exception of seed mixture composition, specific biomass establishment and management methods for mixed species planting are not distinguishable from the recommendations for other grasslands. There are many resources available for prairie and conservation grassland establishment and management. Our guidelines complement those best management practices already available for establishing and maintaining prairie and conservation grasslands.

3.2.3.20.1. Additional establishment and management resources for switchgrass and native grasses

- Consult your county NRCS, agronomist, or UW-Extension office for detailed planting and establishment assistance.
- Prairie Establishment/Restoration Seeding Recommendations – NRCS WI Agronomy Tech Note 5.
- How to Establish and maintain Native Grasses, Forbs, and Legumes – NRCS Wisconsin Job Sheet 135.
- Establishing and Managing Switchgrass-UW Extension. Renz, Undersander, Casler (http://www.uwex.edu/ces/forage/pubs/switchgrass.pdf).

3.2.3.20.2. High-diversity establishment resources:

- Incorporating prairies into multifunctional landscapes: establishing and managing prairies for enhanced environmental quality, livestock grazing and hay production, bioenergy production, and carbon sequestration (Iowa State University Extension, 2010).
- A practical guide to Prairie Reconstruction by Carl Kurtz 2001
- USDA Plants database; http://plants.usda.gov

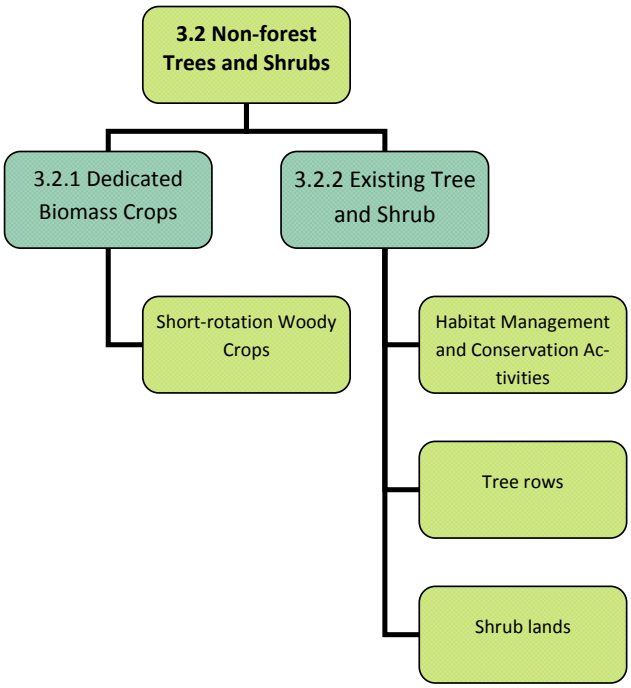
- Wisconsin native seed sources and restoration consultants- distributed by WDNR; **http://clean-water.uwex.edu/pubs/pdf/nativeplants.pdf**
- Plant species composition of Wisconsin prairies: an aid to selecting species for plantings and restorations based upon University of Wisconsin-Madison plant ecology laboratory data. 1995. Richard A. Henderson

3.2.3.21. Existing Grasslands

Wisconsin has over 4million acres of prairie, hay, pasture and grassland habitat including over 400,000 acres enrolled in the Conservation Reserve Program (CRP) and an additional 111,000 acres of WDNR public lands that are managed primary for wildlife habitat (Alan Crossley, pers. comm.).While not all of that land would be suitable for biomass production and harvest, it identifies the potential acreage of established grassland that could be harvested for biomass in Wisconsin.

Several scenarios and harvest goals for established grasslands need to be considered. For conservation grasslands, publicly or privately owned, biomass collection may be integrated as part of a regular maintenance activity such as biannual mowing to prevent encroachment of woody species or invasive species removal efforts. For pastures or hayfields, a late season harvest might be sold for biomass rather than forage. Harvests of timothy, rye, and other cool-season forages may need to have an altered harvest schedule based upon biomass quality issues. The extent and occurrence of these harvests will largely be determined by the requirements and locations of processing plants.

In general, the grassland guidelines outlined at the beginning of Chapter 3 apply for existing biomass as well. Conservation guidelines are more conservative because they typically have other primary goals (*e.g.*, wildlife, water, and soil conservation).Therefore, harvesting guidelines on these types of lands should follow careful consideration of the primary conservation intent of the land. For instance, timing and extent of biomass harvests on public wildlife areas should only occur if the resulting management action will benefit current of future wildlife species of interest that utilize the area, the habitat itself, and/or the constituents that utilize the property.



3.3. Non-forest Trees and Shrubs

This section includes guidelines for managing woody biomass sources not included in

Wisconsin's Forestland Woody Biomass Harvesting Guidelines (Herrick *et al*. 2009). Herrick et *al*. defined forest as "an ecosystem characterized by a more or less dense and extensive tree cover, often consisting of stands varying in characteristics such as species composition, structure, age class, and associated processes", typically with a canopy cover of greater than 50%. Non-forest woody biomass materials come from two major categories: dedicated biomass crops (short-rotation woody crops) and existing nonforest trees and shrubs.

General guidelines and descriptions are provided for woody biomass harvest from existing resources and a more detailed set of guidelines for short-rotation woody crop establishment and harvest. The authors acknowledge that not all possible woody sources are covered in detail, however these recommendations will be revised as new information becomes available.

These guidelines do not apply to management of any forest cover types that are included in the Silviculture Handbook (WDNR Handbook 2431.5).

DEFINITIONS

Short-rotation woody crops (SRWC) are fast growing tree species that are intensively managed, specifically for biomass production in a manner similar to agricultural crops and typically harvested in short-term cycles. Guidelines specifically focus on willow and poplar SRWC because of the availability of information for those species; there are other softwood species that may be used as SRWC.

Existing non-Forest Woody Resources are trees or shrubs that were grown for another purpose or voluntarily arose, including but not limited to:

- Naturally occurring shrublands that are managed for habitat conservation purposes and could, in some cases, be maintained in a rotation for biomass production. Shrublands are upland or lowland areas where the cover of shrubs and trees is greater than about 33% (but tree cover would be less than 50%- Otherwise this would be forestland). These habitats are typically early successional and require periodic disturbance for their maintenance. Shrublands on lowland or peat soils are relatively stable by comparison.
- Woody biomass incidentally generated from activities whose goal is primarily habitat conservation and restoration (including the removal of invasive species), such as oak savanna and oak woodland restoration and management; these are usually one-time or very infrequent harvests.
- Miscellaneous unmanaged woody biomass such as tree- and hedge-rows (both planted and volunteer) in agricultural areas, urban trees, Christmas tree plantations, orchards, shelterbelts, stream- or ditch-bank trees, and right-of-ways.

Coppice:a management technique where the aboveground biomass is cut, encouraging sprout regrowth originating from the cut stem or root of a cut tree.

3.3.1. GUIDELINES

3.3.1.1. All non-forest woody biomass – general guidelines

Applies to any tree/shrub system considered for biomass production or harvest including dedicated and existing woody resources and meant to be used in cooperation with recommendations of the seedling supplier

- Use practices that maintain or enhance habitat for wildlife, including diversity in native tree or shrub species, cultivars, age classes, and stand structures.
- For example, rotate harvests so that multiple age classes exist on property

3.3.1.2. Short Rotation Woody Crops (SRWC) - general guidelines

Applies to both willow and poplar SRWC coppiced or grown for general bioenergy purposes.

**It should be noted that this is a very new initiative in Wisconsin, with little production experience and almost no research. The guidelines are based primarily on reports developed in New York and Ontario, which have similar general conditions but may have different specific issues, such as insect and disease pressure and cultivar response to local soil and climate conditions.*

3.3.1.2.1. SITE SELECTION AND PLANTING

- *Reminder: We strongly encourage growing SRWC in landscapes where it fits with and enhances the natural surrounding vegetation types (see chapter 2)*
- Once established, biomass crops can be productive for decades, so design of fields should be carefully planned. For example, plan access wide enough for machinery to turn around.
- Use erosion control practices such as planting on the contour or cover crops or mulch on bare soils wherever appropriate. Avoid bare soil planting on slopes greater than 8 to 10% when not employing further erosion control practices.

3.3.1.2.2. NUTRIENT MANAGEMENT FOR ALL SRWC

Adhere to all biomass guidelines found on page X in addition to the following specific guidelines.

- Nitrogen fertilization is not recommended during the establishment year to minimize weed competition. If fertilizer is required, minimize application or use slow-release products.
- Only apply fertilizer in spring when trees are actively growing (typically mid to late June).
- Fertilize to maximize economic return on nitrogen (not maximum yield), which is generally less than 100 lbs. N/acre

- Soil and foliar analyses recommended after harvest to diagnose nutrient deficiencies, compare with pre-establishment soil analyses, and guide replacement applications.

3.3.1.2.3. Pest/Weed management for all SRWC

- Use low-impact herbicides, only as needed to rejuvenate stands. During the establishment years, chemical herbicides may be necessary.
- Explore cultural and mechanical control methods (e.g., graze, burn, mow, disc, or cultivate) before chemical control.
- Consult with experts to determine effects of weed control on long-term health of area.
- Monitor weed growth after crop canopy closure. Good stand establishment should result in conditions that no longer need herbicides.
- Explore cultural and mechanical control methods (e.g., burn, mow, disc, cultivate, or graze) before chemical control.

3.3.1.2.4. Harvest

- Time harvest to minimize transport of nutrients offsite (e.g. after leaf fall).
- Harvest late, after the breeding season , to aid nesting birds
- Manage to promote re-sprouting.
- Maintain erosion rates less than T and positive SCI values.

3.3.1.2.5. Specific Recommendations for Willow Biomass Plantations

Applies to willow coppice plantations

- Consider planting willow in areas of low productivity from agronomic and forestry perspectives, such as relatively wet or seasonally saturated portions of the landscape.
- Recognize that phosphorus movement and de-nitrification will be important considerations in low, wet areas, and use appropriate nutrient management practices.
- Year 1 Coppice recommendations:
- Coppice can occur between leaf fall (senescence) and when buds begin to swell in spring. Exact timing will be site and condition-dependent. Leave coppiced material on ground to improve survival after first coppice.
- Manage to maximize re-sprouting.

3.3.2. EXISTING NON-FOREST WOODY HARVEST RECOMMENDATIONS

3.3.2.1. Harvest from restoration and management of oak savanna, oak woodland, barrens communities, and shrublands

- If the harvest is part of habitat restoration activities, ensure that harvest procedures do not compromise the ecological goals of the restoration.
- Protect and manage *Species of Greatest Conservation Need* and sensitive ecosystems.
- Do not harvest from sites where Federal or state endangered or threatened species are known to exist or are discovered during harvest operations. Exception: if harvest has been demonstrated to maintain/improve habitat for species present, then follow appropriate management guidelines to sustain occurrence or condition.
- Retain some snags and fallen logs (CWD) to improve habitat quality for wildlife (not applicable for shrublands).

3.3.2.2. Harvest of miscellaneous unmanaged woody biomass

- Follow guidelines to protect statewide forest health. For example,
- Oak clearing should follow established timing and methods to limit spread of oak wilt - see http://dnr.wi.gov/forestry/Fh/oakWilt/).
- Take steps to limit spread of emerald ash borer, gypsy moth, and other diseases and insect pests. Comply with quarantines on movement of wood products(http://www.emeraldashborer.wi.gov/, http://www.datcp.state.wi.us/arm/environment/insects/gypsy-moth/quarantine_regs.jsp).
- Manage against invasive herbaceous and woody species
- For information on how to address concerns with invasive species, consult Wisconsin's Forestry Best Management Practices for Invasive Spe-cieshttp://council.wisconsinforestry.org/invasives/forestry.php

3.3.2.2.1. SOIL RESOURCE CONSERVATION

- Replace nutrients if needed for restoration and habitat management purposes through fertilization.

3.3.2.2.2. Habitat conservation and restoration

- Where possible, use techniques and equipment that minimize or eliminate damage to limbs of remaining oaks and other desirable species, thus avoiding increased vulnerability to fire, disease, and pests.

3.3.3. Science Discussion – Non-forest trees and shrubs

3.3.3.1. Short-Rotation Woody Crops – All Types

Poplar and Willow varieties are currently the focus of Short Rotation Woody Crops (SRWC) in the United States. They can be clonally propagated, easily propagated (e.g., can be frozen then planted), have high nutrient use efficiency (e.g., leaves recycle nutrients), and possess a low ash content when burned (pers. comm. W. Berguson).

One to two years after planting date, SRWCs produce less runoff because of higher levels of increased evapotranspiration and soil cover. Also the forest floor, while intensely managed during establishment, is not tilled as often as row crops systems and promotes more rainfall interception and retention comparatively.

Carbon Sequestration: Add something here about sequestering more carbon than row-crops? Consult publications by Berguson's group and Ray Miller

3.3.3.1.1. Wildlife considerations

The impact of SRWC on wildlife populations is likely scale dependent. At a larger scale, SRWC could provide important habitat for early successional species and some interior forest species by connecting fragmented forests or creating corridors (Shepard and Tolbert 1997). Surveys of species compositions within willow and poplar SRWC show mixtures of open land (crop and grassland) and fringe forest species (Christian et al. 1997; Christian et al. 1998). The plantation's surrounding vegetation and geography play a role in how wildlife uses SRWC (see chapter 2).The conversion of open grasslands, which in Wisconsin most often support unique assemblages of grassland bird species (e.g. upland sandpiper, meadowlark) could increase grassland fragmentation and a reduction in those rare species, in some portions of the state.

At plot or field scale, research has consistently shown several differences in avian abundance between SRWC plantations and traditional row crops. Avian abundance and species richness were greater in SRWC plantations than row crops sampled in the US and UK (Christian et al. 1997, Hanowski et al. 1997 and Rowe et al. 2011).However, most of the observed birds were habitat generalists, widespread species capable of utilizing a wide variety of habitats (Christian et al. 1997; Dhondt et al. 2004). The usefulness of SRWC to different wildlife groups also varies with crop choice. For example, willow varieties with more branching growth structures were found to be better able to support and hide nests promoting the use of plantations by breeding birds (Dhondt et al. 2004).

Small to medium sized mammals such as voles, rabbits, and tree squirrels were not found to use SRWC plantations in the winter (Christian 1997) or show a discernable preference for plantations over row-crop land (Christian et al. 1997). Other studies found winter deer use of plantations overall variable; in some plantations, especially in the Northwestern US, deer browsing has been reported as a major source of young tree mortality (Christian et a. 1998).

Creating habitat heterogeneity is a management strategy that could promote wildlife utilization of a SRWC. Maintaining a diversity of SRWC ages within a planting offers greater variety of habitat and food sources and will attract different species (Hanowski et al. 1997).

3.3.3.1.2. SITE SELECTION AND ESTABLISHMENT

Field preparation for the establishment of short-rotation woody biomass crops should be tailored to the intended crop, soil conditions, and cropping history of the field. Once established biomass crops can be productive for long periods. Site selection and field design need to be planned carefully to prevent difficulties or avoidable work in the future. Soil requirements for healthy willow and poplar stands are given in table 3.2. The field design, regardless of the crop should include breaks wide enough for equipment to get on and off the field and room at the end of rows for machinery to turn around. Wildlife friendly grasses or cover crops can be used in these access rows. Other universal steps towards the successful establishment of poplar or willow include intensive weed control in the planting year and second growth season and minimizing nitrogen fertilization in year one to help decrease weedy competition. Work with the supplier and other specialists to create management plans.

Table 3-2. Soil characteristics to consider when selecting SRWC location.

	Willow		Poplar	
Soil Characteristic	**Suitable**	**Unsuitable**	**Suitable**	**Unsuitable**
Texture	loams, sandy loams, loamy sands, clay loams and silt loams	course sand, clay soils	loams, sandy loams to clay loams	hardpan
Structure	well-developed to single grain structure	massive or lacking structure		
Drainage	imperfectly to moderately well drained	excessively wet or very poorly drained	imperfectly to moderately well drained	excessively wet or very poorly drained

3.3.3.1.3. Coppice

Cutting aboveground material and allowing it to regenerate from the roots is called coppicing. Coppicing promotes multiple sprout formation and results in rapid canopy closure the second year (Abrahamson et al. 2002).Care needs to be taken with mowing equipment, ensuring clean cuts and no uprooting. The cut material can be left on the field or used as additional planting material. Trees should be coppiced at the end of the growing season after leaves have fallen and nutrients transported belowground. Coppice can be completed anytime between leaf fall and when buds begin to swell in spring.

3.3.3.2. Poplar SRWC

Poplars (*Populus* spp.) consist of 25-35 deciduous woody flowering plant species that are members of the willow family and native to the Northern Hemisphere. They are fast-growing, early successional species with a clonal growth habit. Poplar is a geographically widespread genus and an economically important wood and fiber resource (Villar, *et al*. 1996).Poplars have been cultivated for centuries in Europe, and since European settlement in the Midwestern US (Stoffel 20xx); Yemshanov and McKenney 2008).Research on developing hybrid poplar clones specifically for bioenergy production has been ongoing in the upper Midwest for 25 years (Stoffel 20xx).Hybrid poplars are particularly fast growing and suited for biomass production (http://bioenergy.ornl.gov/misc/poplars.html)

Hybrid poplar has been identified as a key feedstock for biofuel production throughout much of the U.S., including the Great Lakes Region (U.S. DOE 2006).The trees produce large quantities of aboveground biomass in 5-y cycles. Poplar provides several advantages relative to traditional row crops: it requires less fertilizer, can be grown on marginally productive soils, and provides structural and biological diversity within a landscape. Moreover, it provides growers with multiple market opportunities (ethanol, pulp/paper, solid wood products).Poplar also affords advantages in terms of genetic manipulation for the purpose of biofuel production. Major research initiatives are now underway at multiple locations in the U.S., Canada, and Europe to enhance poplar production for use as a biofuel.

Add negative aspects that should be discussed Potential for hybridizing w/ native strains and swamping their gene pool? Comparisons to natural forest (less diverse, more fertilizer/herbicide/cultivation).Consult Glen Stanoz at UW

3.3.3.2.1. Establishment

Poplar planting may be done in spring as soon as sites are workable, late spring frost or freezes may lead to diebacks, mid-April to early June planting dates are recommended. Poplar planting material consists of unrooted hardwood cuttings and poles, cut back rooted cuttings, bareroot stock, greenwood cuttings, container stock and balled and burlaped stock. The majority of plantings are unrooted hardwood cuttings and poles or bareroot stock due to cost and availability. Larger stock and bareroot stock grow faster which may deter deer browse in the first planting year. Planting unrooted cuttings can be done by hand or by machine. Unrooted cuttings should be planted upright with one or two buds exposed.

3.3.3.2.2. Additional Resources

3.3.3.3. Willow SRWC

Willows (*Salix* spp.) are deciduous woody flowering plants that include about 450 species worldwide, distributed predominantly in the temperate and arctic zones of the Northern Hemisphere (Kuzovkina and Martin 2005).As a group, willows are fast-growing, early successional plants that typically are found in riparian zones or wetland soils, which is important mainly for good seed germination (Kuzovkina and Martin 2005).Characteristics of Willow that make it well-suited for biomass production include high yields produced in a few years, resprouting ability, a brief breeding period, ease of vegetative propagation (clonal growth habit), and a broad genetic base (Volk *et al*. 2004). Willows have been grown and used in North America for centuries, first by Native Americans, and later by European immigrants, in the 1840's (Volk, *et al*. 2006).Cultivation of willow expressly as a biomass crop began in the 1980's in New York State (Volk, et al. 2006).The species of willow used in SRWC are taken from the 125 species in the subgenus *Caprisalix* (Vetrix).While similar in many ways, the species in this subgenus vary in their growth patterns, resistance to pests and diseases, and life history traits; this variation is key for development of improved varieties. There are intensive willow breeding programs in Europe and North America.

3.3.3.3.1. Establishment

Willow planting is done by hand or machine in early spring as soon as sites are workable, and within days of cultimulching. Willow planting material consists of either unrooted dormant stem cuttings, eight to ten inches long or dormant stem whips, greater than four feet to seven feet long both with diameters of 3/8 to ¾inches (Abrahamson *et al*.2002) Cuttings should produce roots and shoots one to two weeks after planting.

3.3.3.3.2. Additional Resources

- "Willow Producer's Handbook" produced by the State University of New York,www.esf.edu/willow/pdf/2001%20finalhandbook.pdf.

3.3.4. Existing Non-forest Woody Resources

Existing Non-forest woody resources include any pre-existing tree/shrub cover on the landscape that does not fit under the definition of forest. However, these guidelines focus on the three sources identified at the start of this section, (a) woody biomass from naturally occurring shrublands, (b) woody biomass incidentally generated from activities whose primarily goal is habitat conservation and restoration and (c) miscellaneous unmanaged woody biomass such as tree- and hedge-rows in agricultural areas, woody ditch- and streambanks, urban trees, Christmas tree plantations, orchards, shelterbelts, and right-of-ways (not originally planted for biomass). Initially, the authors wanted to provide specific harvest guidelines for each of these categories, however little more than anecdotal information exists for their use as biomass, therefore we limit our discussion to their potential as biomass sources and will revisit guidelines in future editions.

3.3.4.1. Shrubland harvests

Both upland and lowland shrublands occur in Wisconsin. Some large acreages of upland brush are managed with fire as brush prairie (dominated by oak grubs) in the northwest and northeastern sands regions, generally on publically owned properties. Many of these properties are managed specifically for wildlife, for example Sharp-tailed Grouse. Throughout many parts of the state, habitats such as retired pastures and old-fields revert to a brush stage when the grazing or agricultural disturbance ceases. This brush stage is ephemeral, as without management it succeeds into forest types eventually. While in the shrub stage, these habitats support a unique mixture of bird species, including a good number of Species of Greatest Conservation Need. These include shrub-dependent species such as Brown Thrasher, Bell's Vireo, Field Sparrow, and Willow Flycatcher. However, especially in cases where retired pastures include unplowed native prairie sod, brush removal is a standard management practice to promote the rejuvenation of the native prairie vegetation. Regular management is needed to keep brush out of these areas.

Patches of lowland shrubs, both small and very large (hundreds of acres) exist in wet or lowland soils in many parts of the state; very little of this type is found in the Driftless Area, however. Many of the most extensive concentrations of lowland shrubs, or shrub carr, occur on publicly owned lands, especially in central and northern Wisconsin. Species of Greatest Conservation Need that inhabit lowland shrub habitats include Golden-winged Warbler and Willow Flycatcher. Under the right conditions, lowland shrub occurs as a climax vegetation community, and can maintain itself for decades. As such, many areas of lowland shrubs do not require regular management, unless habitat goals call for their removal.

In the Midwest, Minnesota is the state that utilizes shrublands for biomass to the greatest extent (see Additional Resources, below).

3.3.4.2. Additional resources

For a thorough summary of brush and shrubland harvest guidelines from MN, consult:
http://www.frc.state.mn.us/documents/council/site-level/MFRC_brushland_BHG_2007-12-01.pdf

3.3.4.3. Habitat conservation and restoration

The restoration and management of oak savanna, oak woodlands, and barrens can produce significant amounts of biomass from harvest of trees, saplings, and brush. Currently, the biomass resulting from restoration and management activities is rarely used for energy production. Typically the large logs are used for firewood or lumber, burned on site, or sold when possible (e.g., walnut). Slash is usually burned on site.

There are conservation benefits to leaving snags in oak savanna, barrens, and oak woodland management. Wildlife species that benefit from this practice include Red-headed Woodpecker, Eastern Bluebird, and several bat species. Leaving some Coarse Woody Debris – fallen logs - provides habitat for invertebrates, reptiles, amphibians, and mammals, as well as promoting nutrient cycling.

The removal of trees (e.g., box elders, willows) from southern Wisconsin stream banks is occurring in southwest Wisconsin as part of stream restoration projects. Typically, these trees are either burned up in piles or taken for firewood.Ditch districts sometimes enforce tree removal along ditchbanks.There is a sig-

nificant amount of this type of biomass in the state. Additionally, Red cedar removal in prairies and barrens results in considerable quantities of wood that has a significant potential as a bioenergy source.

3.3.4.4. Additional resources

3.3.5. Miscellaneous unmanaged woody biomass

The removal of wooded fencerows that separate fields in open agricultural areas – specifically in those landscapes with significant acreages of grassland habitats (CRP, CREP, pasture, prairie remnants) - can improve habitat for wildlife, most importantly for obligate grassland birds. Removal of linear woody vegetation along stream and ditch banks can also have a beneficial effect in similar landscapes. Some woody-dependent wildlife (e.g., raccoons) will lose habitat as a result of this tree removal activity, but most of these wildlife species are abundant and not of conservation concern.

3.3.5.1. Additional resources

3.4. Crop Residues

Row crop agriculture is extensive in Wisconsin. The potential exists for organic residues from several crop types to be used in bioenergy production. Crop residues considered for bioenergy production mainly focus on corn stover, wheat straw, and soybean stubble. In Wisconsin, approximately 4 million acres of corn are grown each year, while approximately 1.6 million and 250,000 acres of soybeans and wheat (respectively) are planted annually. For the purposes of this report, guidelines focus primarily on corn stover harvesting, however the principles outlined below can, in many cases, be used for harvesting soybean stubble and wheat straw as well.

3.4.1. GUIDELINES

3.4.1.1. General Guidelines

Applies to all crop residue harvesting scenarios.

3.4.1.1.1. SITE SELECTION AND ESTABLISHMENT

- Row crop systems produce the highest yields on soil types designated as prime farmland and/or soil capability classes I and II.Row crops that will be utilized for bioenergy production should not be grown on marginal lands due to increased risk of soil erosion and subsequent soil and water quality impacts.
- Use the following agronomic practices whenever possible to reduce soil and nutrient losses from the field:
- No-till or conservation tillage planting
- Plant on the contours on all slopes greater than 2%
- Utilize a cover crop or companion crop to reduce erosion pre- and post-harvest
- Rotate crops, using grasses and other continuous cover crops to the extent practicable

3.4.1.1.2. HARVEST

- Do not harvest crop residues from Highly Erodible or marginal lands.
- Site specific stubble height, residual cover and stover removal rates should be determined using RUSLE 2 and SCI.
- Without specific field-based assessment, remove only 25% of stover to maintain soil organic carbon levels and structural stability.

3.4.2. Science Discussion – Crop Residues

Crop residues are a potential feedstock source for direct combustion, as well as bio-refineries using lignocellulosic conversion to produce ethanol (Graham *et al*. 2007; Sanderson 2006).Corn stover is an agricultural residue defined as the portions of the corn plant aside from corn kernels that remain on the soil surface following grain harvest (Haddad and Anderson 2008).Corn stover makes up more than half of all crop residues in the US and is by far the most ubiquitous (Perlack *et al*. 2005).

Harvesting crop residues has been associated with declining soil quality and productivity (Lal 2005; Moebius-Clune *et al*. 2008).Tradeoffs exist among beneficial effects of residue harvest, such as faster warming of soils in spring, better seed germination and less favorable habitat for plant-pathogens, and the potential adverse effects, such as organic matter (OM) declines, higher soil temperature fluctuations and faster losses of stored soil moisture (Mann *et al*. 2002;Wilhelm *et al*. 2004).Corn stover is an important reservoir of several elements (e.g., C, K, Ca, N, and P), thus its return to the soil after harvest is essential to element recycling and sustaining grain and biomass yields (Blanco-Canqui and Lal 2009).The economic benefit of harvesting crop residues must therefore be weighed against the potentially negative effects that such management may have on soil quality (Moebius-Cline *et al*. 2008).

Mann *et al*. (2002) identify two main areas in which there are potential environmental impacts associated with removal of stover: erosion and soil organic carbon (SOC) dynamics. Higher erosion rates associated with corn stover removal results in lower corn yields. Therefore, adequate residue must be left in place to prevent erosion losses.SOC in the surface layer has the biggest effect on tilth, soil workability, nitrogen dynamics, water retention, and other factors important to corn production and soil resistance to erosion (Mann *et al*. 2002)(Cruse and Herndl 2009) (Graham *et al*. 2007).Refer to chapter 2.1 for further explanation of environmental costs and benefits.

3.4.2.1. Soil Organic Carbon (SOC)

Although SOC and crop productivity are important considerations, the knowledge base for quantitatively assessing the amount of stover that needs to remain on the field to maintain SOC or crop productivity is limited (Wilhelm *et al*. 2004; Linden *et al*. 2000).Blanco-Canqui and Lal (2007) showed that systematic stover removal decreased SOC concentrations, increased the soil's susceptibility to compaction, and reduced crop yields, but the effects were soil specific. The USDA Soil Conditioning Index can be used to assess the effect of stover removal rates on soil organic carbon (Graham *et al*. 2007).

3.4.2.2. Stover Removal Threshold

Some estimate that no more than 30 to 50% of stover should be removed for biofuel production (Nelson 2002; Kim and Dale 2004; Graham *et al*. 2007). These threshold estimates are principally based on the requirements to control soil erosion below the tolerable limit (T) but not specifically on the need to maintain soil fertility and productivity (Blanco-Canqui and Lal 2009).Blanco-Canqui and Lal (2009) concluded that only about 25% of stover might be available for removal, based on the need to maintain SOC levels and structural stability, which were reduced with removal rates as low as 25% and 50%, respectively.

3.4.2.3. Soil Erosion

Biomass removal accelerates the soil erosion process, especially for row crops such as corn (Nelson 2002).Stover removal impacts are greater in sloping soils than flat, glaciated soils (Blanco-Canqui and Lal 2009).The exponential relationship between residue cover and soil erosion developed by Laflen and Covlin (1981) illustrates that reducing residue cover on a given slope increases soil erosion and that changes in residue cover have a greater impact as residue cover decreases (Cruse and Herndl 2009).Although T is commonly assumed to be an acceptable erosion rate, it may not be sustainable (Mann *et al*. 2002).

Recent literature suggests that the residue quantities required to maintain soil organic matter are greater than the residue quantities required for soil erosion control (Wilhelm *et al*. 2007).Restricting residue harvest to insure that soil organic matter is maintained will constrain corn residue harvest beyond that for soil erosion control in many landscape positions (Cruse and Herndl 2009).If harvest recommendations insure that soil organic matters is maintained, the soil erosion will also be addressed.

Predicted changes in rainfall intensity and duration as a function of climate change also argues for careful consideration of soil surface cover removal for any purpose (Groisman *et al*. 2005; IPCC 2007).To keep soil loss, water runoff, and associated nutrient loss at an acceptable level as rainfall intensity increases, innovative cropping practices integrating, for example, cover crops and/or perennial species with row crops in areas sensitive to soil and water loss must be implemented (Cruse and Herndl 2009).

3.4.2.4. Tillage

The importance of maintaining or improving SOC via minimum and no-till farming systems is viewed as essential in maintaining the productivity of agricultural lands (Jarecki and Lal 2003; Lal 2004).No-till was used or recommended to improve the long term sustainability of biomass harvest in studies by Mann *et al*. (2002), Blanco-Canqui and Lal (2009), Varvel *et al*. (2008), and Thelen et al. (2010).Graham et al. (2007) suggested that if farmers chose to convert universally to no-till and total stover production did not change the sustainable supply for biomass would almost double.

3.5. Wetlands

This section examines wetland biomass collection in Wisconsin as a means to remove and control invasive species and improve wetland ecosystem services. Harvesting existing invasive, wetland species has the potential to help fund wetland restoration efforts and could lead to improved ecosystem and cultural services through the removal of excess nutrients and ground litter.

General guidelines applicable to any wetland harvest activity are provided followed by guidelines specific to the two leading candidates for harvest: cattails (*Typha* spp.) and reed canary grass (Phalaris arundinacea). Other possible biomass sources on wetland soils, including common reed (*Phragmites)* and cup plant (*Silphium perfoliatum*) are not included in this document due to a lack of research and data available at the time this document was drafted.

WETLAND PERMITTING

The WI State Legislature defined wetlands in 1978 as "an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophilic (water-loving) vegetation and which has soils indicative of wet conditions."

Wetlands are sensitive ecosystems that provide important services across the state.They create habitat for a diversity of wildlife, help alleviate flooding, reduce soil erosion, cleanse polluted waters, and contribute to regular water flow in streams and rivers (Thompson and Luthin 2004).Detailed information about the functional values of wetlands can be found on WDNR wetlands website (http://dnr.wi.gov/wetlands/function.html/).

More than half of Wisconsin's historic wetlands have been drained or filled to make way for farms, cities, roads and factories.Wisconsin has taken the protection of its remaining wetlands very seriously. Wetlands are protected by state and federal rules and in some places, by local regulations or ordinances.Landowners and developers are required to avoid disturbing wetlands from development projects; if wetlands cannot be avoided, appropriate permits must be supplied to affect wetlands.Further information regarding permitting processes can be found within: Overview of Wisconsin's Regulatory Program [PDF 61KB]andTemplate to Reasoned Environmental Planning [PDF 91KB].

If you are planning any operation that proposes wetland impacts, including biomass collection, you will need to obtain a wetland water quality certification (permit) from the WDNR approving the proposed wetland impact before you may proceed with the project.As part of the certification process, you will be required to explore various project alternatives that would avoid and /or minimize wetland impacts.

These guidelines discourage any planting or promotion (*i.e.* weed control, fertilizer) of cattail species and reed canary grass (RCG) due to the invasive nature of these species. Ideally, the guidelines recommend biomass harvest as a tool to suppress and eliminate cattail and RCG with the end goal of restoration to diverse native vegetation. The guidelines below include Information regarding suppression and restoration.

3.5.1. GUIDELINES

3.5.1.1. 3.4 Guidelines - All wetland harvests

- Leave a buffer of vegetation along edge of wetland areas. Buffer width guidelines are as follows (adapted from NR 151):
- For degraded, wet crop areas, and monotypic wetlands (less susceptible wetlands), a buffer is not required. Please check with a specialist to ensure the area can be classified as degraded, wet crop or monotypic
- For highly susceptible wetlands (fens, sedge meadows, bogs, low prairies, conifer swamps, shrub swamps, fresh wet meadows, shallow marshes, deep marshes and seasonally flooded basins), a buffer width of50 feet.

- For Outstanding Resource Waters (ORW), Exceptional Resource Waters (ERW) and wetlands in areas of special natural resource interest: 75 feet.
- Where water control structures currently exist and drawdown is needed to facilitate harvest, do not initiate drawdown from October 1 - April 30 to avoid harm to over-wintering amphibians and reptiles.

WETLAND BUFFERS

Generally speaking, wetland buffers should be comprised of the upland plants surrounding the wetland to be harvested, a strip of unharvested plant material within the wetland, or a combination of both.

For additional information on the types of vegetation to use in a buffer strip and addition width suggestions, consult the NRCS Field Office Technical Guide (Code 393-Filter Strips).

3.5.1.2. Recommendations for Harvesting Undesirable Cattail

The recommendations listed above for all wetland harvests should be performed. Additional specific guidelines for cattail include the following.

- Harvest during winter to decrease the need for drying of harvested materials and to minimize soil compaction and rutting.
- If suppression of cattails is desired, cutting cattails below the high water mark and at multiple times each year may provide additional suppression success.

3.5.1.3. Recommendations for Reed Canary Grass (RCG)

The recommendations listed above for all wetland harvests should be performed. Additional specific guidelines for reed canary grass include the following.

- Harvest from late summer/early fall until early spring. This avoids harm to nesting birds and creates favorable spring habitat for marsh birds. Some studies suggest harvest during this time will also provide the greatest yield. Harvesting during early spring (material from the last growing season, before new green shoots are seen) may provide a higher quality bioenergy crop (less unwanted elements) and may be considered.
- If harvesting for suppression, Use of herbicides in conjunction with mowing is recommended. Mowing of RCG alone may not be sufficient to suppress it
- Reed canary grass grown on soils with high clay content may produce biomass with high ash levels making it unprofitable for combustion.

3.5.2. Science Discussion and Guideline Implementation notes- Wetlands

3.5.2.1. All Wetland Harvests

Wetlands serve many important functions. They create habitat for a diversity of wildlife, help alleviate flooding, reduce soil erosion, cleanse polluted waters, and contribute to regular water flow in streams and rivers (Thompson and Luthin 2004).Because of their importance to Wisconsin's watersheds and greater ecosystems it is essential to protect wetlands from potentially harmful activities. Biomass harvests need to be considered carefully and planned with state and federal permitting processes understood.

3.5.2.1.1. Soil compaction

A danger associated with the harvesting of wetlands for biomass is soil compaction. Soil compaction occurs when soil particles are pressed together and the pore space between them is reduced (Muckel 2004).Compaction results in reduced movement of water, air, and soil fauna through soil, which therefore reduces the function of a wetland. In addition, soil compaction impedes root growth of wetland plants (Muckel 2004). Hydric soils are especially susceptible to compaction, making wetlands highly sensitive to soil compaction (Muckel 2004).Deep soil compactions (greater than 24") may be irreversible and should be avoided (Muckel 2004).

Decreasing the potential for soil compaction during harvesting of wetland biofuels can be done in by reducing weight on the soil, reducing amount of traffic, and harvesting during dry periods (DeJong- Hughes, *et al*. 2001). Lighter equipment lessens the amount of compaction, by using smaller equipment or decreasing the load per axle, the amount of soil compaction can be reduced. Decreasing the amount of equipment used in harvest operations and number of passes a single piece of equipment makes can also reduce soil compaction. Because the depth of soil compaction increases with the amount of moisture in the soil, harvesting during dry periods or when the ground is frozen can reduce soil compaction. There is also potential for using modified equipment with tracks designed to lower pressure on soil.

3.5.2.1.2. Buffers

A number of pollutants threaten water resources. One of the top pollutants to aquatic ecosystems, as recognized by the U.S. Environmental Protection Agency (EPA), is nitrogen. Nitrogen in excess can be harmful to both the ecosystem and human health. Riparian buffers (vegetative zones adjacent to streams and wetlands) are thought to be an effective, sustainable way to control nutrient stressors (such as nitrogen) from entering aquatic ecosystems and considered a best management practice by many state and federal resource agencies (EPA 2005).

The effectiveness of a buffer strip depends on a number of factors including buffer width, vegetation type, soil characteristics, water flow, and topography. Buffer width has been shown to be the most important factor in determining buffer effectiveness (Phillips 1989).However, research in this area is expansive, variable, and conflicting. One aspect complicating buffer width guidelines is that the relationship between buffer width and buffer effectiveness is non-linear (*i.e.*, a wider buffer strip does not necessarily equate to a more effective buffer) (Mayer *et al*. 2007).This suggests there are other important factors which play into the equation. Other factors which may be equally or more important in determining buffer effectiveness are: vegetation type, depth of roots, total root area, and presence of soil conditions which promote denitrifying bacteria (EPA 2005).Therefore, narrow buffers may be just as effective as wide buffers if other factors are at optimum levels. However, in scientific literature it is generally agreed that buffer width is an important determining factor of buffer effectiveness and it has been demonstrated that wider buffers tend to be more effective at removing nitrogen across a variety of conditions (Mayer *et al*. 2007).

Because of the variety of factors influencing buffer effectiveness, it is difficult to recommend a minimum buffer width for protecting water resources. Some research suggests a minimum of 15m (50ft) is sufficient to remove nitrogen (Castelle et al. 1994), while other sources indicate the need for a 149m (~490ft) to be 90% effective in removing nitrogen (Mayer *et al*. 2007). To be consistent with current Wisconsin state standards, guidelines for buffers are borrowed from NR 151.For other information on types of vegetation to use in a buffer strip and additional width guidelines consult NRCS personnel.

3.5.2.2. Wetland Wildlife Considerations

Where water control structures currently exist and a drawdown is desired to facilitate harvest, do not initiate drawdown after October 1 to avoid harm to reptiles and amphibians over-wintering in the wetland.

3.5.2.2.1. Cattails

Cattails are a common plant found in wet soil types across North America. Several species of cattails exist in Wisconsin: the native broadleafed cattail (*Typha latifolia*), the European-introduced narrowleaf cattail (*Typha angustifolia*), and a hybrid of the two (*typha x glauca*).Cattails perform important functions in wetland systems such as stabilizing substrates, providing cover and food for wildlife, and removing nitrogen and phosphorus. Cattails, however, can invade an area and create dense monocultures that displace other important native wetland vegetation. The hybrid variety of cattails seems to be the most aggressive invader of wetland systems (Hall and Zedler 2009).Because cattails grow densely in many wet areas which are not suitable for farming, they may be an ideal candidate for biomass harvest in addition to harvest for ethanol production (Dubbe *et al*. 1989).Cattails' biomass yields have been recorded from 3.4 to 5.3 tons/acre (Woo and Zedler 2002, Dubbe *et al* 1989) although research is lacking and variable in this area.

3.5.2.2.2. Harvest Timing

Harvesting when the ground is frozen may be the best option for harvesting cattails. In addition to reducing soil compaction and potentially increasing accessibility to cattails, winter harvest may also produce higher quality biomass because of lower moisture content in harvested materials. Moisture affects the stable storage, stable transportation, and combustion efficiency of harvested materials. If the moisture content of harvested cattails is too high it may need to be dried before processing, creating space and time concerns. Thus, harvesting during winter may be beneficial because cattails are retaining less moisture. It is unknown how harvest during the winter affects yields of cattail biomass.

3.5.2.2.3. For suppression/native restoration

Cutting cattails below current water level or below high water marks, so that cut cattails submerge during high water periods, has been shown to improve suppression (Hall *et al*. 2008).Other studies have shown multiple harvests per year may be necessary for suppression (Hall and Zedler 2009). If suppression is primary goal, than harvesting during nesting periods may be an option with consultation with a specialist. If suppression is successful, planting of suitable native vegetation is encouraged and may be necessary, as areas invaded by cattails have demonstrated poor underlying seed bank quality (Frieswyk and Zedler 2006).For restoration ideas and tips consult:

- NRCS guidelines; **http://www.nrcs.usda.gov/feature/backyard/bakwet.html**
- WDNR's Wetland Restoration handbook; **http://dnr.wi.gov/wetlands/handbook.html**

3.5.2.3. Reed Canary Grass (RCG)

Reed canary grass (*Phalaris arundinacea*) is a cool season grass found in wet soil types throughout North America. Reed canary grass was originally planted in North America as a forage crop for livestock. There are many varieties of RCG found in Wisconsin and the extent of RCG varies across Wisconsin (Figure 9).These varieties are extremely difficult to distinguish and presumably interbreed with one another. Reed canary grass is a very aggressive grass that can outcompete a variety of other wetland vegetation types and form monotypic stands. This seems to be true particularly after disturbance events (Wisconsin Reed Canary Grass Management Working Group 2009).Reed canary grass has been a successful biomass crop in Northern Europe, specifically Sweden, so there is reason to believe RCG could be a useful biomass crop in North America as well (Venendaal *et al*. 1997).Yields have been reported from 3.03 to 7.64 tons/acre in North America (Jakubowski *et al*. 2010).

3.5.2.3.1. Placement in the Landscape

Reed canary grass can have high ash content, which is undesirable for direct combustion biofuel production. High ash content appears to be largely due to the soil type where the RCG is grown (Burnvall 1997).Reed canary grass on soils with high clay content creates the highest ash percentage (10.1%) in harvested material while RCG on humic soils produced the least ash (2.2%) (Burnvall 1997).

3.5.2.3.2. Harvest Timing

The composition of elements in plants change with the seasons, thus timing of harvest can influence the quality of the biomass obtained for use in biomass energy conversion systems. Two factors that affect the quality of harvested biomass are chemical composition and moisture content. Elements found in perennial grasses (including RCG) that can be harmful to biomass combustion boilers are potassium, chlorine, magnesium, and phosphorous. Perennial grasses harvested before senescence possess the highest levels of combustion contaminants, which decrease as harvest is delayed and crops are allowed to senesce (Adler et al. 2006; Sanderson et al. 2006) Further aboveground contaminates are leached by rain and snow after senescence (Heaton *et al*. 2009).

Moisture content also can affect the quality of harvested materials for use as biofuel.Moisture affects the stable storage, stable transportation, and combustion efficiency of harvested materials. If the moisture content of harvested biomass is too high it may need to be dried before processing, therefore creating space and time concerns. Moisture content decreases with time after the first frost with the lowest moisture content occurring in early spring (Adler *et al*. 2006).

Considering yield and biomass quality factors there are two suggested times for harvest of RCG in the scientific literature: late summer/early fall and early spring. The traditional harvest period is considered to be late summer/early fall after senescence. Because of combustion contaminates discussed above, RCG which is harvested in the late summer/early fall may need to be left in the field after cutting to leach chemicals back into the soil (Cornell Extension 2005).

If RCG is harvested once a year during the fall, the spring re-growth is beneficial to a number of wetland birds (Epperson *et al*. 1999). Fall harvests pose little to no risk to nesting birds.

Finally, fall harvested RCG has been shown to have a higher yield in older stands (Olsson 1999).One study showed on average of 4.46 tons/acre for fall harvest compared to 3.57 tons/acre for spring harvest (Olsson 1999).

However, debate has arisen around the quality fall yields. Harvest of RCG during early spring has been used in Sweden and sometimes depicted as a superior method. Early spring harvest or "delayed harvest" is the harvesting of material from the previous growing season before the new grass shoots appear. This timing may produce higher quality yields because there are lower levels of chlorine and potassium in harvested materials (Landstrom *et al*. 1996; Burnvall 1997) in addition to lower moisture content (Adler *et al*. 2006). Landstrom et al (1996) reported yields of 1.1 tons/acre (dry matter) for spring harvest compared to 1.4 tons/acre (dry matter) during fall harvest. However, both chlorine and potassium concentrations were 6 times lower in the spring harvested crops making it a higher quality fuel for use in combustion machines (Landstrom et al. 1996).Harvesting during the driest period is also recommended to avoid harmful soil compaction as mentioned in the 'general' scientific discussion section.

3.5.2.3.3. Wildlife Considerations

Harvesting RCG once a year after in late summer or fall may benefit marshland birds. During spring migration, cranes and waterfowl depend on green plant shoots and invertebrates to provide nutrients for migration. A study in California demonstrated that haying during late summer/fall increased the number of individual birds on a property in addition to increasing the number of species on a property when compared to non-hayed sites (Epperson *et al*. 1999).Haying in late summer/fall allows more sunlight to reach soil and

promoted early spring plant growth. The removal of the old plant material allows birds to easily access new green plant shoots as well as improving their ability to spot predators.

3.5.2.3.4. HARVEST FOR SUPPRESSION/RESTORATION

Mowing of RCG may not be sufficient to suppress it. Because RCG is a grass that thrives on high light, mowing alone may not be harmful to RCG's growth and survival. Therefore, the use of herbicides in conjunction with mowing is recommended to achieve suppression/elimination (Reed Canary Grass Management Guide 2009).

For restoration ideas and tips consult:

- NRCS guidelines; **http://www.nrcs.usda.gov/feature/backyard/bakwet.html**
- WDNR's Wetland Restoration handbook; **http://dnr.wi.gov/wetlands/handbook .html**
- Reed Canary Grass Management Guide (PUB-FR-428); **ftp://ftp-fc.sc.egov.usda.gov/WA/Tech/RCG_management_0509.pdf**

4. Conclusion and Summary

The guidelines in this document are a key first step in helping to expand and develop Wisconsin's burgeoning biomass and bioenergy market while also protecting our treasured natural resources. This document and the guidelines within it are only the beginning. They should notbe viewed as the definitive approach to non-forest biomass harvest in Wisconsin but rather the beginning of an iterative process that refines these guidelines as our knowledge continues to grow. The authors recognize that this document does not cover all potential biomass crop types or all potential scenarios for Wisconsin producers. The intent is to revise these guidelines regularly as new research information becomes available, as new potential biomass crops become available, as bioenergy markets evolve, and as sustainability goals are revised and refined over time.

The guidelines and accompanying discussions were designed to provide information to producers, managers, and conservationists about three important questions:1) *What biomass crop should I grow or harvest? 2) Where should I grow or harvest this biomass? and 3) What practices are necessary for sustainable production?*

In answering those questions, the authors purposely chose not to repeat or rehash established agronomic principles. For example, establishment guidelines for switchgrass are well known and are readily available in other places (e.g., UW extension and NRCS publications).Rather, the guidelines and discussion chapters take a more holistic and multi-scale approach in answering the questions by focusing on field level, farm level and landscape level concerns. When warranted, specific and prescriptive site-level guidelines for planting and harvesting biomasswere provided. However, focusing on multiple-scales allowed us to address the impacts of biomass programs on a variety of ecosystem services and within various system dynamics while acknowledging that our understanding at broader spatial and temporal scales is limited in some respects.

4.1. What was learned?

There are clear ecosystem service advantages in choosing low input-high diversity biomass cropping systems over high input-low diversity crops (see Chapter 2).However, it is very clear that no single strategy is "correct" for Wisconsin as a whole.Nor should there necessarily be one. Rather, the best approach is utilization of the concept of multi-functional landscapes, and commitment to development and deployment of a suite of diverse biomass crops in diverse cropping systems across the landscape, as introduced in Chapter 2.A diversity of biomass cropping systems among farms and across the Wisconsin landscape has the best potential to provide or enhance a variety of ecosystem services, including yield. A producer in southwestern Wisconsin, for example, may be harvesting corn stover, growing switchgrass, and harvesting woody crop materials to supply his/her local biomass/bioenergy producer, while a land manager in central Wisconsin may be periodically harvesting invasive woody materials in routine maintenance of grassland wildlife habitat and supplying this material to local bioenergy interests. This is perhaps the best way to leverage the inherent diversity of biomass resource types and agricultural systems within Wisconsin while contributing to a value-added approach to biomass and agricultural sector development in Wisconsin.

4.2. Future Steps and Research Needs (1 paragraph/section)

A number of information gaps exist in our understanding of potential biomass cropping systems in Wisconsin. Filling in these gaps will lead to more refined and ultimately a better set of user guidelines for Wisconsin that ultimately meet socio-economic and sustainability needs. Below are a number of priority research needs as identified by this working group.

4.2.1. Landscapes

Research is currently underway at UW-Madison to help us further understand the concept of multi-functional landscapes…Randy/Carol/Chris/Cathy

4.2.2. Grasslands

Randy/Carol/Dave/Chris/Cathy

4.2.3. Trees/Shrubs

Dave?

4.2.4. Wetlands

Wetland biomass harvest would benefit from further research in a number of areas. More research is needed on impacts to wetland ecosystems from large-scale harvest. Additional research on cattails as biofuel is needed, on feasibility as well as information on yields. Advances in equipment to harvest in wetlands in a manner that lessens the amount of soil compaction and furthers feasibility without negatively affecting wetlands would also be beneficial to the future of wetland biomass harvest.

4.2.5. Crop Residue

Although the guidelines recommend the use of the soil conditioning index (SCI) as an acceptable surrogate for assessing the amount of stover that needs to remain on the field to maintain soil organic carbon, additional research that quantitatively measures the amount of stover required to remain on the field to maintain SOC or crop productivity is needed.

4.2.6. Economics

Steve/Gary Maybe this is the place for Steve's economic considerations section that is currently in the Appendix?

5. Case Studies or Scenarios – Next iteration or stand alone extension type publication

- Illustrate an example of scenario of sustainable biomass systems across Wisconsin. What would a sustainable biomass operation look like at a farm scale and landscape scale?
    - See this example of case study from the NWF Bioenergy document

NWF Example.doc

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7. Literature Cited

We will edit and simplify the citation style in the document for draft 4 (i.e. consider footnotes and subscript numbers in text).

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8. APPENDICES

8.1. Glossary

Bioenergy Advisory Council:Governor Jim Doyle created the Bioenergy Advisory Council by signing Act 401 in 2010. The Council is part of a broad strategy to advance clean, renewable sources of energy here in Wisconsin.The Bioenergy Advisory Council will advise agencies and other stakeholders on best practices for sustainable production of biomass feedstocks

Bioenergy : renewable energy derived from recently living biological material, or biomass.Fossil carbon sources of energy such as coal and petroleum are not sources of bioenergy since these materials are the result of geological processes that transformed plants living many thousands of years ago.Bioenergy includes power and fuels derived from biomass.

Biopower : electricity generated from combustion of biomass.Heat and steam, or a combination of both, may also be produced through combustion of biomass, and may be produced in co-generation with electricity.

Biofuel : commonly used to refer to biomass-derived liquid fuels and gases most typically used in transportation.

British Thermal Unit (Btu):The quantity of heat required to raise the temperature of 1pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit). *See heat content*

Heat Content:The amount of heat energy available to be released by the transformation or use of a specifiedphysical unit of an energy form (e.g., a ton of coal, a barrel of oil, a kilowatthour of electricity, a cubic foot of natural gas, or a pound of steam). The amount of heat energy is commonly expressed in *British thermal units (Btu).Note*: Heat content of combustible energy forms can be expressed in terms of either gross heat content (higher or upper heating value) or net heat content (lower heating value), depending upon whether or not the available heat energy includes or excludes the energy used to vaporize water (contained in the original energy form or createdduring the combustion process).

Carbon sequestration: storage of carbon

Clone: Individuals reproduced asexually from a common mother plant either naturally of by human propagatin; therefore genetically identical.For example: aspen clones naturally sprouting from the roots of the mother plant. Some clones are manmade from cuttings or grafts.

Conservation grassland:A grassland habitat type that was established, restored, protected or managed for the primary purpose of wildlife, water or soil conservation. (e.g. public wildlife area, conservation reserve program field).

Coppice: Sprout regrowth originating from the cut stem or root of a cut tree.

Cultivar: Abbreviation of cultivated variety. Plants with distinctive characteristics; usually given a specific English name. A cultivar can be a clone or a seedling. Similar to variety.

Dedicated Biomass Crops:Crops that are grown for the primary, but not necessarily exclusive, purpose of producing biomass that can for direct combustion or converted to fuel.

Ecosystem Services: a collective term that includes the diverse benefits and services that people obtain from healthy ecosystems.These services include 4 main categories:provisioning services, regulating services, supporting services and cultural services.

Exsisting Biomass:Existing herbaceous or woody materials that have been planted or grown for a purpose other than biomass production but that could support periodic harvesting for bioenergy production.

Habitat refugia: areas left unharvested within a field

Hybrid: Hybrids are offspring of cross breeding of parents of different genetic makeup irrespective of taxonomy (SAF 1958). Hybrids can be within the same species i.e. hybrid corn, or between two species.

Invasive species: non-native plants, animals and pathogens whose introduction causes or is likely to cause economic, or environmental harm or harm to human health, usually refers to species that did not occur in an area prior to European settlement.

Landscape:refers to land areas larger than individual fields, farms or woods – those smaller units of land use and land cover that impact and are impacted by processes within and beyond the landscape(s) with which they are associated.

Low impact herbicide:Herbicides that are less harmful to the environment than other herbicides, due to their low dose and low environmental impact.

Marginal Lands:Sensitive or marginal lands are lands that have one or more of the following characteristics and are generally not conducive to annual crop production:Steep slopes greater than about 12%, shallow soils (less than 12-24" to bedrock), wet (5-30 days of seasonal saturation in root zone) or drought-prone (less than 10 mm per 100 mm water holding capacity)..)

Nonforest Biomass: non-woody cellulosic plant materials including leaves, stems and stalks of native and non-native perennial and annual grasses, forbs and legumes (e.g., switchgrass, cattails, orchard grass, reed canary grass, and native prairie plants);woody material from nonforested systems such as shrublands, non-merchantable woody material (e.g., materials removed in savanna management); woody material harvested from short-rotation hybrid poplar, willow, and other plantations; and crop residues (e.g., corn stover, wheat straw).

Noxious weeds: plants legally considered harmful to the public health environment, natural areas, crops and livestock (e.g. Canadian thistle).

Phytoremediation: The use of plants to clean up and/orremediate sites by removing contaminates from soil and water.

Precautionary principle: Guidelines will follow the "precautionary principle" as used in Wisconsin's Forestland Woody Biomass Harvesting Guidelines. That is when there is scientific uncertainty we will be conservative in protecting resources.

Riparian buffers: streamside plantings of trees, shrubs, and grasses designed to intercept sediment, nutrients and/or contaminates from surface water runoff, wastewater or groundwater before they reach the stream.

Shelterbelt: Single or multiple rows of trees and/or shrubs planted for environmental purposes surrounding fields of agricultural crops.

Soil Conditioning Index (SCI): a tool that can predict the consequences of cropping systems and tillage practices on soil organic matter. Organic matter is a primary indicator of soil quality and an important factor in carbon sequestration and global climate change.

Soil organic matter

Sustainability: The stewardship of lands and resources dedicated to nonforest biomass production in ways that are environmentally, socially and economically sound across a broad range of scales, that does not negatively impact other ecosystems, and that can meet societal needs both now and into the future.

Variety: a subdivision of a species produced by selective breeding with distinctive characteristics and maintained by cultivations.

8.2. Food and Fuel

In 2007-08 global agricultural commodity prices spiked causing millions of people in poor and *lesser* developed countries to suffer food shortages.Subsequent analyses have identified a complex and interconnected set of factors contributing to the crisis, including most notably, futures trading, increased petroleum prices, agricultural price supports and subsidies in developed nations, low grain reserves, increased demand among a growing human global population, and diversion of food crops for making ethanol (Dorelien 2008; Food and Water Watch, 2009; Global Food Markets Group, 2010; Pfuderer *et al*., 2010; Surowiecki 2008; UNCTAD, 2008).That is to say, although industrial large-scale agricultural production and world trade have many benefits, fundamentally the 2007-08 was an unfortunate consequence of a complex globalized food and fuel commodity system.A complete analysis of the crisis and potential future similar crises is beyond the scope of this document.However, here it is important to acknowledge that during the 2007-08 crisis much attention was directed toward the use of food crops for production of biofuel as a driver of increased food prices.This attention emerged through the popularized phrase, "Food v. Fuel."

Conventional row crops like corn, sugar cane and soybean can be used for food, feed or to make biofuels.Use of arable farmland for production of biofuels does present some risk of impact to food supply on the global scale (Pfuderer *et al*. 2010, Rosegrant 2008).There is much debate about how best to respond to this dilemma, but responses can be characterized in general as supply-focused or demand-focused.Supply-focused approaches emphasize increases in global agricultural productivity and efficiency, and commercial development of second generation biofuels utilizing non-food crops; demand-focused approaches emphasize such things as reduced per capita consumption of food and energy in developed countries through increased efficiencies and lifestyle changes.Despite much debate over which approach is best, solutions to competing land uses serving increasingly globalized commodity markets may not be in the form of a "silver bullet" – a single remedy,but rather "silver BBs," that of a multi-tactic approach.To fulfill increased demand for food, feed, fiber, fuel and power in Wisconsin and beyond, it may be necessary to embrace a "food *and* fuel" mentality - no mere platitude.

8.3. Soil Conditioning Index

SCI.pdf

8.4. Measuring grassland establishment success

Stand frequency is a percentage of focal plants in a given area. A simple frequency grid tool, composed of a 0.75 x 0.75m grid subdivided into 25 (15x15 cm) cells, developed by Vogel and Masters (2001), is a simple, inexpensive way to measure stand success. Frequency is measured by recording the presence or absence of a focal grass in each cell for a total sample of 100 cells.

Frequency = #cells with focal plant/100

Plants/ m^2 = Frequency x 0.4

x o	o		x	xx
xx		x		xxxx o
	xx		xxx	
	o	x	ooo	
oo	xx			xxx

Frequency grid example: x=grass and o=forbs/legume. In the above example 12 cells have the grass of interest and 6 have the forb/legume of interest. The grid should be flipped 3 times to get a total of 100 cells. If the next three 'flips' show 13, 15, and 10 cells positive for the grass of interest than the grass frequency is 50% which corresponds to 0.2 Plants/ m^2