Project Narrative

Special Research Grant
USDA/CSREES Grants for Agricultural Research

Sun Grant Initiative - Industrial Ecology Assessment of Sustainable Biomass Feedstock Production and Utilization

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Introduction

The Sun Grant Initiative (SGI) is a federally authorized program under the Farm Security and Rural Investment Act of 2002. The program builds on the ability of land grant universities to conduct research, teaching and outreach activities that focus on agricultural-based renewable energy and products. Special grants through the USDA/CSREES were used to help plan and build the Sun Grant network and garner stakeholder input on sustainable biomass production. The mission of the Sun Grant Initiative is to:

- ► Enhance America's national energy security through development, distribution and implementation of biobased energy technologies.
- ► Promote diversification and environmental sustainability of America's agriculture
- ► Promote opportunities for biobased economic diversification in America's rural communities

One key point emphasized by our stakeholders is that biomass production must be developed on a regional, and sometime local, level because environmental conditions vary greatly across the nation. The structure of the Sun Grant Initiative allows us to addresses this need by developing regionally relevant projects that address our national issues. This regional approach also facilitates the coordination and leveraging of state and federal efforts. Since authorization the Sun Grant initiative has received programmatic funding from the US department of Energy and US Department of Transportation. A summary of Sun Grant activity can be found on our web page (www.sungrant.org).

The Sun Grant Initiative authorization identifies five land-grant universities as Regional Sun Grant Centers to serve the land-grant universities in their respective regions: Oregon State University, South Dakota State University, Oklahoma State University, the University of Tennessee, and Cornell University (figure 1). These regional centers emphasize research, extension, and educational programs on renewable energy technologies and promotion of biobased industries in rural communities. Each center is also responsible for facilitating a federally funded competitive grant program for their region. The current program is support by US Department of Transportation funding. The programs are to embrace the multi-state, multi-functional, multi-disciplinary integrated approach that is at the heart of the land-grant method of addressing national problems.

A non-profit organization called the Sun Grant Association (SGA) was founded soon after the Regional Sun Grant Centers were established. The SGA provides national coordination and communication of the Sun Grant Initiative and facilitates communication and coordination among the Regional Centers. Non-land-grant entities are encouraged to partner with a land-grant institution and join the Sun Grant Initiative.

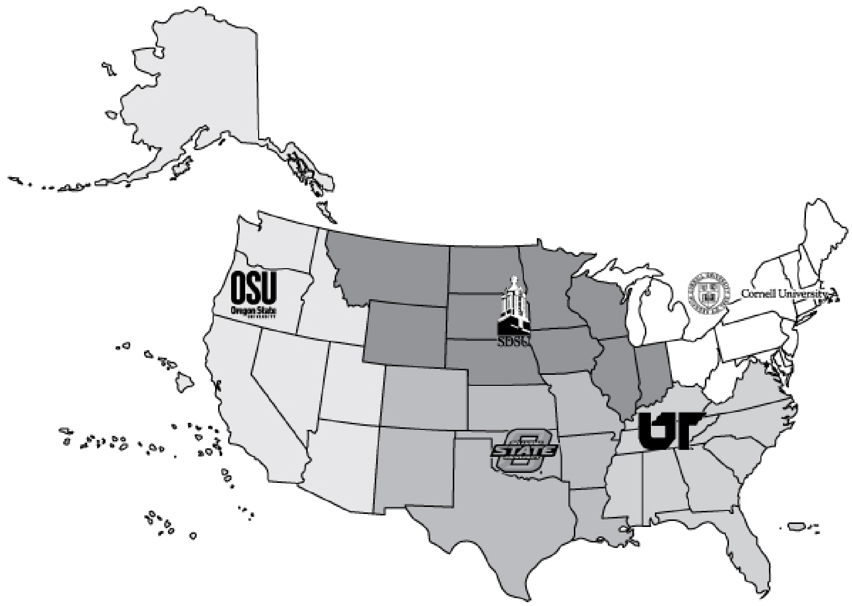

Figure 1: Five Regional Sun Grant Centers and the areas they serve

Project Background and Literature Review

Agricultural-based biofuels and bioproducts systems are very complex and highly integrated systems. There systems are tightly coupled to even more complex and intricate biosphere systems and subsystem such as carbon and water systems (Dornburg et al., 2004; Munksgaard et al., 2005). Identifying and managing the material and energy flows is essential for sustainable development of agricultural-based biofuels and bioproducts systems (Koening and Cantlon, 2000). Thus, it is important that the Sun Grant Regional Centers play a leadership role in developing system science and engineering tools that will help the nation develop sustainable biofuels and bioproducts systems, and that can be deployed for important life cycle analyses of these systems.

Agricultural-based biofuels and bioproducts systems can be divided in three core subsystems: feedstock production, feedstock logistics and feedstock conversion. Each of these subsystems are composed of a number biological, chemical, and physical processes that can be interconnected to a multitude of ways to generate the essential material and energy flows for the production of biofuels and bioproducts. In many respects, these complex subsystems and systems behave as "ecological systems operate through a web of connections in that organisms live and consume each other and each other's waste" (Frosch, 1992). Thus, the SGI Regional Centers are seeking to bring an industrial ecology framework to the development of agricultural-based biofuels and bioproducts systems. The following definition of industrial ecology captures the spirit in which SGI centers would bring to the challenge of developing sustainable agricultural-based biofuels and bioproducts systems:

> "The definition of industrial ecology is to integrate an entire industrial process to determine maximal beneficial use of resources, optimize the utilization of the resource, minimize waste generation during the obtaining and processing of the resource, minimize waste during manufacturing, maximize destruction or

reuse of waste resulting from manufacture, maximize the ultimate recycling or disposal of the product, and minimize consumption of energy throughout the process. In all parts, environmental impact must be considered." (Frosch, 1992)

Project Objectives

One objective of this project is to develop a database of "technology coefficients" (simple constants for relating inputs and byproducts to the principal material that is being processed or produced: Koenig and Tummala, 1972; Walker, 1984), and capital, operating, and energy cost functions that capture the non-linear behavior of capacity in three core subsystems of biomass utilization: feedstock production, feedstock logistics and feedstock conversion. The second objective is to develop an interactive input/output modeling method for structuring and analyzing agricultural-based biofuels and bioproducts systems.

Project Approach

To meet the challenge of creating sustainable agricultural-based biofuels and bioproducts systems we need to develop system models and analytical tools that not only consider process optimization, but also allow the designers of integrated energy and product systems to consider the impact of introducing alternative means of production, alternative energy, and alternative management practices on the global system (Walker, 1984). Many of these concepts need to be explored from a quantitative system perspective in order for us to measure the effectiveness of our system design effort. As noted by Koeing and Cantlon (2000), "industrial ecosystems are defined, not as natural ecology for industrial application, but as bounded networks of engineered ecological processes that are interdependent in a measurable mass, energy, and information sense." Thus, we propose to develop an interactive input/output modeling method for structuring and analyzing agricultural-based biofuels and bioproducts systems.

Our modeling effort will not be an attempt to develop sophisticated models of individual processes. Instead, we are proposing to use simple generic models of material transformation, transport and storage processes to represent the components of industrial systems and focus on how these processes are linked together to create an industrial ecology (Koening and Tummala, 1972). An important component in the development of this approach is the creation of a database of "technology coefficients" (simple constants for relating inputs and byproducts to the principal material that is being processed or produced), and capital, operating, and energy cost functions that capture the non-linear behavior of capacity.

This approach is consistent with the *Strategic Energy Science Plan for Research, Education and Extension* mission area recently published by the US Department of Agriculture (http://www.ree.usda.gov). The database and model we develop will be an important step in realizing the vision of a fully integrated, systems approach to our nations energy needs. Each of the regional Sun Grant projects will collect detailed information on various aspects of the three subsystems of an agricultural-based biofuels and bioproducts value chain. This information is necessary to conduct whole life-cycle analysis of various production systems in the different regions of the country. These data and model will also help the USDA/REE achieve its first goal of "Sustainable Agriculture and Natural Resources Based Energy Production" by 2012. Plus the students involved in this university-based research will be available to populate the bioeconomy workforce by 2012 as outlined in goal 4 of the strategic plan.

Each Sun Grant Regional Center will be generating a subset of the technology coefficients database, and capital, operating, and energy cost functions. The Western Regional Sun Grant

Center at Oregon State University will focus their efforts on the production and pre-treatment processing of grass and cereal grain straws. The South-Central Regional Sun Grant Center at Oklahoma State University will be provide data on production, handling logistics, and conversion of the four feedstocks indentified in their Regional Feedstock Workshop of which sorghum and switchgrass were the top candidates. The Southeastern Regional Sun Grant Center at the University of Tennessee will collect data on the conversion of 750 acres of land from its current use to switchgrass biomass production. The data set will include production inputs and a detailed account of carbon. The North Central Regional Sun Grant Center at South Dakota State University will focus it efforts on the feedstock conversion subsystem and the impacts of the end use of biochar on the carbon status of biofuels and bioproducts. The Northeast Regional Sun Grant Center at Cornell University will develop the simulation framework and input/output modeling. They will also collect data for technology coefficients and energy/monetary cost functions associated with aqueous pretreatments.

MATLAB will be the computational framework for managing the combined database, developing the interconnected system models, and for generating material and energy flows for different industrial ecology system configurations. Professor Larry Walker (NE Regional Center, Cornell University) will serve as the advisor and coordinator for the modeling effort. Jim Doolittle (NC Regional Sun Grant Center) will serve as the overall project director.

The expected outcomes from the first year of this project are (1) the development of the database; and (2) complete a series of energy and carbon analysis of three systems that are representative of potential biofuels and bioproducts systems.

Justification

This modeling approach is well suited represent a compromise between a full-blown and intricate ASPEN simulation and the poorly structured and simplistic Excel spread sheet system models. Energy and monetary flows are explicitly identified; new processes can be easily introduced into the system network and their impact on overall system performance can be assessed. The information generated can easily be used for different types of economic, environmental and life cycle analyses.

Current Work

Input-output modeling methods are used to explore the use of the industrial ecology perspective for the design and analysis of sustainable bio-based industries in a course developed and taught by Prof. Walker at Cornell University. The graduate level course, “Industrial Ecology of Agriculturally Based Bioindustries” was originally developed through funding from the USDA MGET (Multidisciplinary Graduate Education Traineeships) program.

Activities of North Central Regional Sun Grant Center at South Dakota State University

One of the greatest challenges in the utilization of lignocelluosic biomass for biofuels and bioproducts is the high costs associated with collection, handling, transportation, conversion, and utilization of biofuels and bioproducts. One of the conversion techniques that holds great promise is the production of syngas (synthetic natural gas) and bio-oil from lignocelluosic biomass using pyrolysis reactions. Along with syngas and bio-oil, the other byproduct formed is biochar.

Biochar is a form of charcoal produced by heating biomass in the absence of air. Biochar is carbon rich and is being proposed as a soil amendment. Because it is derived from vegetative sources and carbon rich, adding biochar to soil is also being considered as a form of carbon sequestration in the mitigation of global warming. If the mineralization rate of biochar is slow, then the industries that produce biochar as a co-product of biofuel production will have a small carbon footprint and be considered carbon neutral. The impact of soil applied biochar on the carbon footprint of bio-energy and bio-product industries as well as material and energy flows will be critical for evaluating the sustainability of bio-fuels and bio-products systems. Biochar is highly reactive in soils. Studies from Arkansas showed that burning rice stubble to reduce disease incidence resulted in nonperformance of several herbicides that should have had residual activity. Monsanto and other manufacturers have recognized that preemergence residual herbicides are important and needed in the weed management system. Biochar application could stop or reduce herbicide efficacy. If biochar is highly reactive and affects pesticide efficacy, then general field application may be undesirable but these materials could play an important role in filter strips. Biochar could be added in filter strips and waterways to clean water running off fields.

Computer simulations to model and predict the costs of production have been used with success for many industrial processes. They provide the ability to estimate the effect of increasing costs of raw materials or utilities, variations in material composition, and the incorporation of new technologies. Beginning with a base-case scenario and designing the model to simulate those conditions effectively allows the user to estimate results of alternative processes with confidence. These models are full-blown and intricate, such as ASPEN simulation. Sun Grant Center proposed to use simple generic models of material transformation, transport and storage processes to represent the components of industrial systems and focus on how these processes are linked together to create an industrial ecology. NC Sun Grant Center is proposed to create an interactive input/output process and cost model with consideration of impacts of the end use of the biochar on the carbon status of the fuels or products made in the pyrolysis process. The objective of this 2 year proposal is to explore several aspects of research to develop the coefficients for the input/output process and cost model.

Task 1. Conversion process data collection from different sources: there are many feedstocks being proposed for the pyrolysis process. These include woodchips, switchgrass, and corn stover. Drs. H. Lei, J. Julson, K. Muthukumarappan and V. Kelley of SDSU Agriculture and Biosystems Engineering will set up and develop the needed processes to create syngas, bio-oil, and biochar from different materials under different conditions.The main processing parameters are power input and control, temperature, pressure, residence time, and condensation control. In Year 1 and 2, a microwave-aided pyrolysis process will be assembled and compositional data of raw materials and biofuels and biochars, mass and energy flow data will be collected to provide quantitative assessments of various processing variables. These assessments will be used to guide process optimization and improvement and development of cost-effective production of synthesis gas and biofuels and biochars from biomass.

Task 2. Dr. S.A. Clay, Plant Science Department, will be in charge of laboratory studies to determine effect of reactivity of biochar from different sources, at different rates, and in different soils. This will be quantified by measuring the sorption of two common herbicides, an acid herbicide, typically not sorbed to soil, and a weakly basic herbicide. Results from these tests will be used to help determine the suitability of biochar as a common soil amendment or as a specialty product with target application in areas such as filter strips to sorb contaminants in runoff. The stability of biochar in soils will be tested in other mineralization studies to determine its role in carbon sequestration and carbon credit assessment.

Task 3. Dr. G. Warmann, Economics Department, will analyze the economics of using bio char as a soil amendment. Handling, transportation and land application cost analysis will provide needed data for full bioprocessing and carbon footprint analysis of cellulose pyrolysis processing. Agricultural and other uses and markets for bio char will be explored.

Activities of Western Central Regional Sun Grant Center
Sub-Award to Oregon State University

Cellulosic feedstocks arising from crop residues (such as grass seed straw, wheat straw, and corn stover), crops grown solely for biomass (such as switchgrass and reed canarygrass), and various hard and softwoods (including Douglas fir, hybrid poplar, and oak) from biomass-intended forests or from forest thinnings, sawmill residues, and other waste wood have been proposed as sources of cellulosic ethanol. These cellulosic sources have potential to displace fossil fuel use, reduce greenhouse gas emissions, and limit the use of grain crops for ethanol production. Productivity of these crops varies widely depending on the climate, soil conditions, and agricultural management practices, thereby significantly affecting profitability. Production costs are not only a function of labor but more importantly a function of transportation of low density cellulosic feedstocks with respect to fuel-yield to fuel-use ratios. These ratios are dependent on such factors as farm acreage to be harvested and subsequent yield, proximity to roads, rail, and water transportation systems, and distance to processing facilities and final markets.

The vision document released by the Nation Renewable Energy Laboratory (NREL, 2002) identified the need to attain at least 10% of our chemical building blocks from renewable resources by 2020, and reach 50% by 2050. To accomplish this objective it will be necessary to establish plant-based systems for producing renewable feedstocks with efficient conversion processes. This will require building partnerships among industrial stakeholders, growers, producers, universities, and federal and state governments leading to commercial applications. Recently, a report from Iowa State University (Tokgoz et al., 2007) analyzed the effects of the emerging biofuel industry on US grain, oilseed, and livestock markets. The researchers concluded that cellulosic ethanol from corn stover or switchgrass would not be economically viable in the Corn Belt due to due to high cost of collection and transportation over large distances.

While many economic studies have been conducted on processing technologies and crop production potential, there is currently no integrated system to analyze the profitability of cellulosic ethanol production considering both agro-climatic conditions and processing technologies. Development of such an integrated tool, similar to the web-based species suitability mapping tool for grass species (Hannaway et al., 2005) would address the needs in this critical area of interest to researchers, policy makers, entrepreneurs, and farmers.

Project Objectives: The overall goal of this four year project is the development of an integrated, web-based mapping system to evaluate the potential profitability and sustainability of using cellulosic feedstuffs in the production of ethanol. This knowledge based system will include spatial analysis of field and tree crop production capabilities related to climatic, edaphic, and management-affected activities. Processing technologies will be evaluated with respect to conversion efficiencies, and siting strategies will include proximity to roads, rail, and water transport systems and distance to final market. The integration of the crop productivity model and the process model would support decision making by growers, biofuel producers, and policy makers. The necessary objectives to achieve the overall project goal are:

- Development of a model for cellulosic feedstock potential productivity based on climatic and edaphic factors to estimate farm gate prices for cellulosic feedstocks.
- Development of a transportation and process model for cellulosic ethanol production.
- Integration of the production and processing models to generate profitability and sustainability maps for different cellulosic feedstocks for the US.

RATIONALE AND SIGNIFICANCE: Economies of scale are an important factor when considering the size of cellulosic ethanol plants (Aden et al., 2002). The scale of plants is in turn determined by the availability of feedstocks. Since crop productivities vary according to location, development of a decision support system to choose appropriate crops, processing plant sizes, and the process technologies to be used must include factors such as climate, soil conditions, crop productivity, transportation costs, and efficiency of processing technologies.

Aden et al. conducted a detailed study of the economics for the production of ethanol using corn stover biomass. Feedstock costs contributed 31% of total ethanol production cost. Transportation costs (23%), baling and staging costs (47%), and farmer's premium (18%) were included in the feedstock costs. Transportation costs were estimated based on a simple model assuming the plant to be at the center of the collection area. A recent Government Accountability Office (GAO) published study (GAO, 2007) concluded that the Department of Energy (DOE) does not have a strategic approach to coordinate increasing production of cellulosic feedstocks with infrastructure development needs (highways, railroads, and shipping).

A strategic approach to infrastructure development requires tools that can predict the profitability and sustainability of cellulosic ethanol production. Production and processing of cellulosic ethanol depends on many factors such as type of feedstock, climate and management practices, transportation costs, and processing technology. A decision support system that integrates all these factors to suggest suitability of cellulosic ethanol production can be a very valuable to government entities, industry and farmers. Such a decision support system would aid in the decision making process for infrastructure development at local, state, and national levels.

<u>Materials and Methods-Crop production model:</u> The crop production model will incorporate climate, edaphic, and management practices such as fertilizer application, irrigation, and pesticide use to determine productivities of cellulosic feedstocks. Regional cellulosic feedstock crops that will be considered to generate cost per dry ton of various cellulosic feedstocks in US are cereals and grass straw and oilseeds, and possibly forest residues. The crop production model will be used to generate cost and availability maps for the Western region. This model will also be tested with corn stover and switchgrass data.

<u>Process model:</u> Process models will be developed for three pretreatment technologies: (1) dilute acid pretreatment, (2) hot water treatment, and (3) the ammonia fiber explosion process. Variable pretreatment process efficiencies for different cellulosic feedstocks will be incorporated into the model. This model will be used to estimate fixed and variable capital costs for different process technologies and the ethanol production cost. The process model will be developed using C++ with a graphical user interface to change the model parameters dynamically.

<u>Integrated economic analysis model:</u> Using the crop production model and process model and incorporating transportation costs using rail, road, and waterways, a profitability forecast will be made for two different scenarios. The integrated model will then be used to generate profitability maps for different feedstocks for production of cellulosic ethanol around the region and the US.

PROJECT MILESTONES-<u>Year 1:</u>

- Western Governors Association infrastructural data layer acquired for decision model.

- Crop production model for forecast production of one cellulosic (straw) feedstock across the Western region.
- Process model to forecast unit cost of production for cellulosic ethanol from straw begun

Year 2

- Test ability of crop production model to forecast production of one additional cellulosic feedstock across the region and the U.S.
- Complete process model for straw
- Communication of results to stakeholders (including professional, business, growers, and other interested audiences) through peer reviewed publications, national conference presentations, posters, popular press, websites, and College of Agriculture newsletters.

Year 3/4 (if additional funding were obtained)

- Use of integrated model (including transportation costs) to generate profitability maps for US cellulosic ethanol production.
- Creation of web segment as part of western region Sun Grant Initiative site.
- Communication of results to stakeholders (including professional, business, growers, and other interested audiences) through peer reviewed publications, national conference presentations, posters, popular press, websites, and College of Agriculture newsletters.

Activities of South Central Regional Sun Grant Center
Sub-Award to Oklahoma State University

As the South Central Center for the Sun Grant Initiative, Oklahoma State University will provide input/output data to the industrial ecology framework as outlined in the following objectives which reflect the three core subsystems. As is appropriate, all data will be generated in concert with research being conducted by the other four SGI Centers.

Objective 1-Feedstock Production: Identify at least four different feedstocks with associated production practices. Numerous feedstocks were identified at the South Central Regional Feedstock Partnership meeting held last fall in Tulsa, OK. For this assessment, at least four different feedstocks will be identified as to their existing and potential production potential. The consensus of the workshop participants was to concentrate on sorghums (grain, high-yielding forage, and sweet) and switchgrass, i.e. a perennial grass, because of their liquid fuel production potential. Other likely candidates include an oilseed crop and animal waste. All standard production practices will be assessed for each feedstock selected.

Objective 2-Feedstock Logistics Identify appropriate existing technologies to harvest, handle, store, and transport each feedstock identified in Objective 1. Existing resources and methods of packaging and moving the chosen feedstock from field to biorefinery plant gate will be evaluated. Unconventional technologies and methodologies, including on-farm preprocessing of the feedstocks, will be explored.

Objective 3-Feedstock Conversion Identify the appropriate enabling technologies for conversion of the feedstocks identified in Obj. 1 into value-added bioproducts. The South Central region has expertise in a wide range of enabling technologies including chemical hydrolysis, extraction, fermentation, gasification, and microbial digestion. Several of these technologies were highlighted in the regional DOT Biobased Transportation Research Competitive Grants Program. Each technology that is appropriate in converting feedstocks into a marketable product(s) will be evaluated.

Objective 4-Systems assessment: Assess energy, carbon, environmental, and economic consequences associated with each core subsystem._All inputs and outputs will be assessed for each set of variables within a core subsystem. These will be incorporated into the overall systems model(s) developed under the leadership of the Northeast Regional Center.

Activities of South Eastern Regional Sun Grant Center
Sub-Award to the University of Tennessee

The Intergovernmental Panel on Climate Change (IPCC) has reported that concentrations of greenhouse gases (GHG) in the atmosphere have been rising at an increasing rate since 1861 and the beginning of the industrial revolution (IPCC, 2007). Although there is still debate over the consequences of atmospheric CO2 growth and warming, there is growing interest in taking action to curb GHG growth and even reduce their concentrations in the atmosphere. In the recently introduced and highly touted America's Climate Security Act of 2007, soil carbon sequestration is listed as an eligible offset mechanism (S.2191). If the U.S. chooses to unilaterally initiate reductions in GHS emissions, it is likely that soil sequestration will be used as an offset mechanism under a larger GHG emission program. In order for soil sequestration to gain credibility as a valid mechanism for abating emissions, it is essential to have accurate estimation of the carbon abatement potential of crop management practices upon U.S agricultural lands.

The recently passed Energy Independence and Security Act of 2007 requires 16 billion gallons of ethanol to be produced from cellulosic feedstocks such as switchgrass by 2022 (EISA, 2007). Cellulosic energy crops will likely be grown upon newly converted pasturelands. Due to lack of empirical evidence, there is debate over whether conversion of pasturelands to perennial energy crops will increase or decrease soil organic carbon levels. If the amount of carbon entering the soil can exceed that lost through soil respiration, then net gains in soil organic carbon can be made. On the one hand, conversion of pastureland may increase soil respiration through light tillage and lead to soil carbon losses. On the other hand, increases in root biomass from dense stands of high yield perennial grasses may increase soil carbon levels. The production of cellulosic feedstocks will likely lead to changes in other variables such as nutrient levels, soil moisture, soil compaction, and soil temperature which impact the dynamics of soil organic carbon formation and retention. Empirical data on the soil organic carbon impacts of conversion of pasturelands to perennial energy crops is essential in carbon lifecycle analyses of cellulosic ethanol. Additionally, it will be instrumental in determining whether perennial energy acreage would be eligible for offset payments under potential climate change legislation.

PROJECT DESCRIPTION AND OBJECTIVE 1:In three months or less, 725 acres in East Tennessee will be converted from their current land use to switchgrass. Much of the land was in soybeans, corn, wheat, or green beans last year. Some was in switchgrass, hay, pasture, or warm season grass mixture. Questions regarding carbon emissions and sequestration continue to surface with regard to land conversion and the benefits that a perennial deliver in sequestering carbon. It is the intent of this project to measure carbon content prior to conversion and during the following two years.

METHODOLOGY: The perimeters of the contracted fields, approximately 700 acres, will be globally positioned and accurate areas of each field will be determined. The GPS coordinates will then be used to overlay each field over the Natural Resource Service published soil survey. The soil survey will show the presence and extent of soil mapping units, which are a combination of slope range, degree of erosion, and soil series, in each field. The soil series name denotes a number of soil variables including soil texture, drainage, and effective rooting depth. Within each mapping unit, a predetermined number of soil sampling points will be determined and GPS coordinates assigned prior to field sampling. These globally positioned points will be located in each field, marked and soil sampled. These fields will also be mapped using real-time kinematic GPS to get accurate elevation maps.

Since most soil carbon changes are usually most evident near the surface, soil sampling depths at each point are planned to be 0-2, 2-4, and 4-6 inches in each field. On selected fields, deeper soil sampling at depths up to 3 or 4 feet may also be done at selected soil increments, using the same surface 6 inch sampling, with additional samples from 6-12, 12-18, 18-24, 24-36, and 36-48 inches. Adequate soil from each point at each depth will be taken for subsequent soil analysis. Analyses will include soil organic carbon, and nitrogen. Other analyses will be soil pH, phosphorus, potassium. A number of other microbiological soil measurements may also be made on these samples. An adequate number of soil bulk density measurements will need to be made on each field to adequately asses this variable for conversion of concentration to a soil volumetric basis.

The bulk density measurements will be done with a volumetric core sampler. Total carbon and nitrogen analysis will be done by combustion. Other analyses will be done by internal and/or private laboratories. Other chemical and microbiological measurements, as possible, based on funds, etc., will be done by appropriate procedures by UT researchers.

These measurements will be done on all initial samples from each field. The same sampling procedure will be used for an early spring sampling each year. This repeated sampling would allow a determination of selected soil property changes in switchgrass production across a wide array of initial soil conditions, and soil and landscape situations. This combined with yield data should result in an excellent data set for modeling switchgrass yield potential at a field and watershed scale.

PROJECT MILESTONE CHART:

Year 1	• Using GPS information place soil map over fields to be converted and identify sampling points in each field. • Take initial Carbon Samples from 725 acres using the predetermined sampling points of each mapping unit. • Evaluate soil samples for carbon and other characteristics • Write a paper analyzing first year findings.
Year 2	• Take Carbon Samples from same 725 acres using the same points as in the original sampling protocol. • Evaluate soil samples for carbon and other characteristics • Write up findings

<u>Objective 2-Technology Resources Development and Support</u>: The BioWeb, http://bioweb.sungrant.org, is an important tool for providing science-based, peer reviewed biomass and bioenergy information to all interested parties. The website offers content written for a variety of expertise levels, offer technical, general, and at-a-glance versions of each subject area. Content is continually being developed and added.

Funding in this project area will be utilized for salary and fringes for the IT Analyst responsible for development and maintenance of technology upon which BioWeb operates. This funding amount will cover approximately four months (1/3 appointment) of this position. The IT

Analyst will assist in addition of content and operational features for BioWeb. They will also aid in the development of a web-based biomass utilization facility siting model based upon data collected by other Sun Grant research.

Activities of North Central Regional Sun Grant Center
Sub-Award to Cornell University

To meet the challenge of creating sustainable agricultural-based biofuels and bioproducts systems we need to develop system models and analytical tools that not only consider process optimization, but also allow the designers of integrated energy and product systems to consider the impact of introducing alternative means of production, alternative energy, and alternative management practices on the global system(Walker, 1984). Many of these concepts need to be explored from a quantitative system perspective in order for us to measure the effectiveness of our system design effort. As noted by Koeing and Cantlon (2000), "industrial ecosystems are defined, not as natural ecology for industrial application, but as bounded networks of engineered ecological processes that are interdependent in a measurable mass, energy, and information sense." Thus, we propose to develop an interactive input/output modeling method for structuring and analyzing agricultural-based biofuels and bioproducts systems.

Our specific goal is to use the Cornell University Master of Engineering Program to build a team of engineers that would develop a modeling and simulation framework for designing and evaluating agricultural-based bioindustries like those currently being used to produce bioenergy and biodegradable polymers. To accomplish this goal, the three to four master of engineering students would assume responsibility for generating the technology coefficients, energy and monetary cost functions needed to build the library of material processing, transport and storage processes that could be networked together to form an input/output model of cellulosic ethanol. This would involve literature research, visits with New York companies working in the biofuels space like N. E. Biofuels, and dialogue with the other Sun Grant Centers. Students will use linear algebra and state space tools in the MATLAB toolbox to simulate static and dynamic behavior of these complex webs of connected processes and to conduct lifecycle analysis of these complex webs.

Another major goal is to have a graduate student develop more specific technology coefficients and comprehensive energy and monetary cost functions for the energy intensive process of pretreatment. Pretreatment is an essential process for liberating five and six carbon sugars from lignocellulosic materials and it can represent upwards of 25% of the energy used in the production of ethanol from cellulosic feedstocks. Our goal is to generate technology coefficients and energy and monetary cost functions from both experimental and literature studies on water pretreatment. All of the equipment needed to carry-out experiments will be provided as part of Cornell's new Biofuels Research Laboratory project that is funded by the New York Empire State Development Corporation.

The expected outcomes from the first year of this project are (1) the development of the database; and (2) complete a series of energy and carbon analyses of three systems that are representative of biofuels and bioproducts systems under consideration by the Sun Grant Institutes of Excellence. Ultimately the goal is to develop a system modeling and simulation tool that can be used to carry out life-cycle analyses of agricultural-based biofuels and bioproducts systems.

Facilities and Equipment
The five Regional Sun Grant Centers have the necessary facilities and equipment to complete this project as described.

Project Timetable
The first year will be utilized to collect the first round of data for calculating the technology coefficients and energy/monetary cost functions. The simulation framework will also be developed during the first year. During the second year the initial data set will be processed through the model and preliminary results reviewed and critiqued. Additional data will be added to the dataset during the second year. A final set of analysis for three potential biorefinery systems will be completed by the end of the project. A final database of input-output model "technology coefficients" and capital, operating and energy cost functions in three core subsystems (feedstock production, feedstock logistics and feedstock conversion) will be completed by the end of the project.

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