Energy Biosciences Institute

ENVIRONMENTAL IMPACT AND SUSTAINABILITY OF FEEDSTOCK PRODUCTION

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Summary of Scientific Objectives and Approaches:

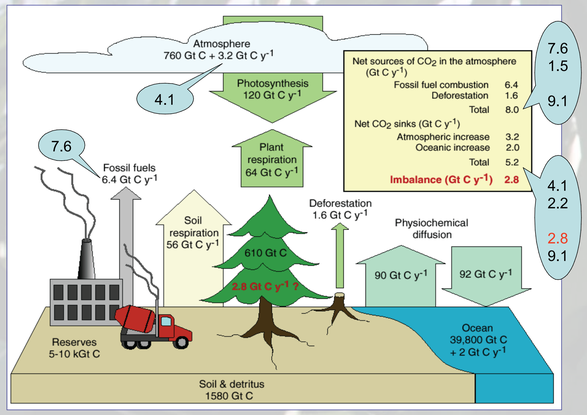
1) ***quantify all major pools and fluxes for biogeochemical cycles of carbon, nitrogen, and water for potential biofuel feedstocks***

2) ***quantify the role of the microorganisms and arthropods in regulating these biogeochemical cycles***

3) ***determine short- and long-term ecological impacts and sustainability issues of potential ligno-cellulosic feedstocks for applicable ecosystems***

Overview:

The widespread deployment of biofuel feedstocks may herald a new era for US agriculture; an era in which feedstock production and ecological impacts are balanced leading to a sustainable system. Because of their high rates of biomass accumulation with minimal nutrient inputs, *Miscanthus x giganteus*, switchgrass (*Panicum virgatum*), and restored prairie hold great promise as potential feedstock crops in the US Midwest. Before the self-scouring steel plow, this region was expansive grassland with enormous stores of soil organic matter. The conversion of this vast grassland to row crop agriculture with artifical drainage dominated by the soybean-corn rotation, depleted soil carbon and nitrogen stores, caused extensive soil erosion and caused pollution of surface and ground water primarily by nitrate derived from fertilizer. Because of their perennial growth habit, extended growing season, and low demand for nutrients, replacement of a portion of this corn-soybean landscape with feedstock crops has the potential to mitigate many of these environmental impacts.



K.L. Griffin, Columbia U. 2002; *Canadell et al. 2007 PNAS*

The injection of CO_2 into the atmosphere from the combustion of fossil fuels and deforestation is rapidly increasing the concentration of this potent greenhouse gas in the atmosphere and fueling global warming. The numbers in bubble represent revised values from Canadell et al. 2007; the annual rate of increase of CO_2 was ~1.5 ppm and it is now over 1.9 ppm. By harvesting solar energy, replacing fossil fuels with cellulosic ethanol will reduce the accumulation of CO_2 in the atmosphere and slow global warming.

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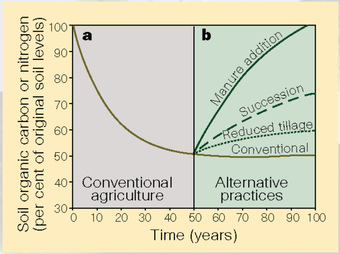
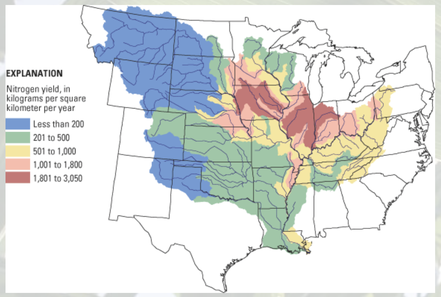
To date, there has been no side-by-comparisons of potential ecosystem impacts of feedstock crops with corn, also used in the production of cellulosic ethanol. The objective of the proposed research is to quantify the major pools and fluxes in the biogeochemical cycles of carbon, nitrogen and water in large plots of *M. x giganteus*, switchgrass, restored prairie and corn, and to determine how and on what timescale interactions with soil microbial and insect populations affect these biogeochemical cycles. By "closing" the biogeochemical cycles of C, N and water, we will develop a mechanistic understanding of how different feedstock crops affect major ecosystem services, such as the capacity to sequester atmospheric carbon, retain soil nitrogen and minimize water contamination and the production of important greenhouse gases including methane and nitrous oxide.



The conversion of grasslands to agriculture released enormous stores of CO_2 derived from soil organic matter to the atmosphere. The oxidation of soil organic matter contributes to global warming and its loss from the soil decreases fertility and crop production. Theoretically, perennial feedstocks have significant potential to sequester atmospheric CO_2 and restore soil organic matter (from Tilman, Nature, 396, 211).



The enormous Mississippi River watershed is largely in row-crop agriculture. Fertilization, particularly of corn, leads to large loses of nitrate through drainage tiles to streams and rivers, and ultimately to the Mississippi River. Increased nitrate loading to the northern Gulf of Mexico is the primary dirver of the hypoxic zone that forms each summer. Preliminary results indicate that low input, perennial feedstocks such as *Miscanthus x giganteus* efficiently recycle nitrogen and require little fertilization. Deployment of these feedstocks on the landscape may have the capacity to greatly improve the quality of surface waters. (Image from: http://pubs.usgs.gov/fs/fs-076-02/images/nitrogenyield.gif)

To compare environmental impacts and sustainability, potential feedstocks, including *Miscanthus x giganteus,* switchgrass (*Panicum virgatum*), tallgrass prairie, and corn (*Zea mays*) will be established in replicate plots at the University of Illinois Energy Farm. Planting will be initiated during winter 2008 and initial biogeochemical measurements will begin soon thereafter.

Specific objectives of this program over the next 3 years are:

1) To develop large, replicated plantings of *Miscanthus*, switchgrass, prairie, and corn to compare the relative yields, biogeochemistry, ecological impacts, and sustainability of these ecosystems.
2) To understand and describe the environmental consequences of land conversion from current use to ligno-cellulosic (LC) feedstock production.
3) To quantify an accurate and complete carbon budget for each ligno-cellulosic (LC) feedstock species including all known anthropogenic and environmental inputs and outputs.
4) To obtain statistically robust measurements of soil carbon sequestration for each LC species.
5) To develop accurate measurements and modeling of diurnal, annual, and event based soil respiration.
6) To quantify an accurate and complete nitrogen budget for each LC feedstock species including all known anthropogenic and environmental inputs and outputs. N cycle inputs included are fertilization, wet and dry deposition, as well as atmospheric N_2 fixation by microbes. Harvest, nitrate leaching, as well as N_2O and N_2 production from denitrification are outputs of interest.
7) To closely monitor pools of soil organic nitrogen and fluxes of N mineralization to assess sustainability for each LC feedstock.
8) To quantify significant fluxes such as precipitation, evaporation, transpiration, and leaching as well as implement vertical soil water profiles to accurately describe the hydrologic impact of each LC species.
9) To characterize the bioenergetics of important arthropod herbivores that consume biofuel crop tissue on production and nutrient cycling.
10) To characterize soil microbial diversity, abundance, and activity in each plot. Soil microorganisms play a key role in biogeochemical transformations critical to sustain aboveground production.
11) To quantify major ecosystem drivers such as soil C sequestration, greenhouse gas fluxes, and microbial communities along a latitudinal gradient to examine what changes in climatic variables may differentially affect ecosystem processes and sustainability in target biofuel crops.
12) To provide EBI and the wider biofuels community with essential foundation knowledge of unanticipated environmental impacts and possible mitigation strategies for use by future agronomy and engineering groups.

The sustainability and ecological impact of different "energy crops" will be evaluated with micrometeorological measurements of energy and material exchange between the surface and the atmosphere. Instrumented towers, similar to the one illustrated above (top left of image) will be installed in large plots of *Miscanthus x giganteus*, switchgrass (*Panicum virgatum*), tallgrass prairie, and corn. In addition to measuring CO_2, water and energy fluxes, these towers will be used to make real-time measurements of other important trace gases.