Row crop agriculture and climate mitigation: A science perspective View Abstract
(organized by Dr. Neville Millar and Dr. G. Phillip Robertson, MSU)

- **Carbon dioxide (CO2) fluxes from agricultural crops of the US Midwest: the effect of land use change for new biofuel**
  Dr. Terenzio Zenone, Landscape, Ecology & Ecosystem Science Laboratory, University of Toledo
- **Growing biofuels for climate change mitigation: Can we customize the water footprints?**
  Dr. Ajay Bhardwaj, Great Lakes Bioenergy Research Center, MSU
- **The energy efficiency of conventional, organic, and alternative cropping systems for food and fuel production in the US Midwest**
  Dr. Ilya Gelfand, Kellogg Biological Station, MSU
- **Farmers and climate change: Some socio-economic challenges to implementing mitigation practices**
  Dr. Julie E. Doll, Kellogg Biological Station, MSU
- **Offset opportunities for row-crop agriculture in the U.S. Midwest: The role of nitrogen fertilizer management for nitrous oxide (N20) mitigation**
  Dr. Neville Millar, Kellogg Biological Station, MSU

SESSION ABSTRACT

Overview

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This session presents preliminary results from new research on agricultural row–crop and biofuel cropping systems conducted at the recently established Great Lakes Bioenergy Research Center (GLBRC) and Long–term Ecological Research (LTER) field sites at the MSU W.K. Kellogg Biological Station (KBS) in S.W. Michigan.
The session will present results and recommendations from work that has investigated the environmental impacts of maintaining current and introducing proposed new biofuel cropping systems into the Michigan agricultural landscape, as well as the effects of various management practices on farm productivity and energy efficiency as it relates to the ongoing food versus fuel debate.
We will also discuss some of the socio–economic factors and farmer outreach strategies that must be considered for the effective implementation of proposals from this research, and a fertilizer–based greenhouse gas mitigation protocol recently submitted to the international carbon registries that can provide an economic and environmental benefit for local farming communities in the US carbon market.

PRESENTATION ABSTRACTS

Carbon dioxide (CO2) fluxes from agricultural crops of the US Midwest: the effect of land use change for new biofuel cultivation

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Land use change, primarily the expansion of annual cropping systems into forests and grasslands, is deemed responsible for 20–25% of the increase in atmospheric carbon dioxide (CO2) that has occurred over the past 150 years. In this study we used the eddy covariance (EC) technique to examine annual CO2 fluxes at seven agricultural sites in the US Midwest. The experimental sites are located in southern

Michigan in the northeast portion of the US Corn Belt at the MSU W.K. Kellogg Biological station (KBS). Of the seven field sites, three had been under continuous corn and the other four were managed as conservation prairies during the past 20 years. In order to study the effects of land use change, during May 2009 six of the fields (three conservation prairie and three corn) were converted to soybean cultivation, with the remaining site left as a managed prairie for reference. In early May, herbicide (Glyphosate- Roundup) was applied to kill the vegetation before planting all six sites to soybean. Soybean was planted to 'homogenize' the fields prior to their conversion to biofuel cropping systems in 2010 (data not presented).
Preliminary results obtained from the EC tower show the temporal trend of CO2 flux across the sites: the corn fields were substantially carbon (C) neutral during winter while the prairies were C sources, with average emissions of 15 g C m-2 month-1 between December 2008 and March 2009. In April 2009, when the corn fields continued to be a source of CO2, the prairie sites switched from a source of C to a sink for C. Two days after herbicide application, in early May, the prairie sites switched back from a sink for C to a source of C. After sowing to soybean (middle of June) all sites continued to show emissions of C until the end of June. In July, due to photosynthetic activity associated with soybean cultivation, the sites previously cultivated with corn became C sinks, with C accumulation values ranging from 15 to 50 g C m-2 month-1. Conversely, due to strong C emissions, the conversion from prairie to soybean resulted in those sites remaining a C source. The temporal variation of CO2 absorption/emission at the prairie reference site showed the typical trend for an unmanaged ecosystem, with low emissions of C during winter and C sequestration in spring and summer due to photosynthetic activity. Data from the remainder of the growing season in 2009, along with the effects of land–use conversion on annual ecosystem C balance will also be presented.

Growing biofuels for climate change mitigation: Can we customize the water footprints?

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The motivation for renewable fuels is not only energy independence but also climate change mitigation, which has been hailed as 'the defining challenge' by the United Nations. One of the most uncertain consequences of climate change includes effects on the hydrological cycle and therefore, the global availability of water. The water footprint of a crop almost always determines where it can and cannot be grown; and biofuel crops are no exception. Water use may prove to be a central issue in the global and local development of the biofuel industry. While most studies on biofuel water use only take into account the processing phase, feedstock cultivation may account for more than 90% of the life-cycle embedded water for fuels. We are studying water use and production efficiency of biofuel crops at different stages and over a prolonged period of cultivation, revealing patterns of water replenishment and use, and potential water limitations to biomass accumulation. A comprehensive understanding of water productivity and water quality implications in biomass production is necessary to develop a sustainable biomass economy. Here, we present preliminary results from recently established bioenergy cropping systems at the Great Lakes Bioenergy Research Center (GLBRC) intensive field site at the MSU W.K. Kellogg Biological Station (KBS).

The energy efficiency of conventional, organic, and alternative cropping systems for food and fuel production in the US Midwest

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The continuing use of fossil fuels has had an increasingly detrimental impact on atmospheric composition, and global climate and ecosystem functioning. Current US legislation for largescale production of renewable energy from agriculture, or biofuels, has focused attention on the energy efficiencies associated with different agricultural systems and their production goals. In this study, we examined 17 years of detailed data on agricultural practices and crop yields to calculate an energy balance for different cropping systems under both food and fuel production scenarios. We compared four grain systems and one forage system in the US Midwest: corn (*Zea mays*) – soybean (*Glycine max*) – wheat (*Triticum aestivum*) rotations managed with (1) conventional tillage, (2) no till, (3) low chemical input, (4) biologically-based (organic) practices, and (5) continuous alfalfa (*Medicago sativa*). We compared the energy balances under two scenarios: all harvestable biomass used for food versus all harvestable biomass used for biofuel production.

Among the annual grain crops, the average energy costs of farming for the different systems ranged from 4.8 GJ ha-1, for the organic system to 7.1 GJ ha-1 for the conventional tillage system. The energy cost of the no-till system was also low (4.9 GJ ha-1) and the low chemical input system intermediate (5.2 GJ ha-1). For each system, the average energy output for food was always greater than that for fuel. Overall energy efficiencies for output: input ratios ranged from 10 to 16 for conventional and no-till food production, respectively, and from 7 to 11 for conventional and no-till fuel production. Alfalfa for fuel production had an efficiency similar to that of no-till grain production for fuel.

Our analysis points to a more energetically efficient use of cropland for food than for fuel production, and large differences in efficiencies attributable to management.

Farmers and climate change: some socio-economic challenges to implementing mitigation practices

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Prior presenters in this symposium session have discussed research efforts that may inform mitigation management. Here, we broaden the discussion to recognize some socio-economic factors that should be considered for research results to be effectively implemented. Farmers stand to be greatly affected by the changing environmental and policy climates. Changes in temperature and precipitation patterns will affect plant growth, yields, and insect and disease outbreaks. Shifts in policies will provide market incentives, but may also implement a mandatory cap and trade market for greenhouse gas emissions. Field crop agriculture plays a key role in climate change. While growing and harvesting field crops contributes to greenhouse gas emissions through practices such as fertilizer application and soil tillage, farmers can help to mitigate climate change by using techniques that increase soil carbon sequestration and reduce greenhouse gas emissions. For agriculture to contribute towards climate change mitigation, farmers need to be engaged in the process. They need knowledge and skills to adapt to the changing climate and to implement techniques that mitigate climate change. Impediments to doing so include their perception of climate change and the real and perceived difficulties they face adopting climate mitigation farming strategies. In order to overcome these impediments, innovative outreach efforts in combination with economic incentives may be needed. Here we discuss these issues and current education and outreach activities we are pursuing to address them.

Offset opportunities for row–crop agriculture in the US Midwest: the role of nitrogen fertilizer management for nitrous oxide (N_2O) mitigation

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Proposed Federal legislation (Kerry–Boxer: S 1733) provides significant opportunities (1.5 billion metric tons) for regulated (capped) industries that cannot meet greenhouse gas (GHG) reductions to purchase domestic offset credits from projects in sectors outside the cap that mitigate GHG emissions and store carbon (C). Agriculture has been proposed as a major potential contributor to this offset market. However, despite the significant potential for GHG mitigation within agriculture, very few high-quality and widely approved methodologies for quantifying agricultural GHG benefits have been developed for mitigation programs and markets.

Nitrous oxide (N_2O), the major GHG emitted by US agriculture, with its global warming potential (GWP) of 298 (compared to 1 for CO_2), is a major target for offset project development, due to the high payback associated with its emission prevention. Soil management activities, such as nitrogen (N) fertilizer

application account for ~70% of total US N2O emissions. Higher N inputs typically increase productivity, but may also lead to elevated N2O emissions. Knowledge of the trade–offs between N2O emissions, N fertilizer input, and crop yield is essential for informing management strategies that aim to reduce the agricultural N2O burden without compromising productivity and economic return.

Fertilizer N rate has been found to be the best single predictor of N2O emissions in row–crop agriculture in the US Midwest. We use this relationship to propose a transparent, scientifically robust protocol that can be utilized by developers of agricultural offset projects for generating fungible GHG emission reduction credits. By coupling predicted N2O flux with the recently developed maximum return to N (MRTN) approach for determining economically profitable N input rates for optimized crop yield, we provide the basis for incentivizing N2O reductions without affecting yields.

Although other management and environmental factors can influence N2O emissions, fertilizer N rate can be viewed as a single unambiguous proxy—a transparent, tangible, and readily manageable commodity. Our protocol addresses baseline establishment, additionality permanence, variability, and leakage, and provides for producers and other stakeholders the economic and environmental incentives necessary for adoption of agricultural N2O reduction offset projects. The protocol, if widely adopted, could reduce N2O from fertilized row-crop agriculture in the Midwest by more than 50%.

PRESENTER BIOSKETCHES

Phil Robertson

Phil Robertson is University Distinguished Professor of Ecosystem Science in the Department of Crop and Soil Sciences at MSU, with which he has been associated since 1981. Since 1988 he has directed the NSF Long-Term Ecological Research (LTER) Program in Agricultural Ecology at the W.K. Kellogg Biological Station, where he is a resident faculty. He currently serves as chair of the U.S. LTER Network's Science Council and Executive Board. He is also program leader for sustainability research in the Department of Energy's Great Lakes Bioenergy Research Center. Dr. Robertson's research interests include the biogeochemistry and ecology of field crop ecosystems, including biofuel systems, and in particular nitrogen and carbon dynamics, greenhouse gas fluxes, and the functional significance of microbial diversity in these systems..

Terenzio Zenone

My research interests focus on the measure of water and carbon dioxide fluxes in terrestrial ecosystems, quantify the contribution of autotrophic and heterotrophic soil respiration, determination of Net Ecosystem Production, calculation and modeling the full budget of Greenhouses gas in forestry and agricultural ecosystems.

Ajay Bhardwaj

My research interests broadly include discovering the critical role of soil as the source and sink of nutrients and contaminants, and interaction of hydrological, physical and chemical processes under diverse management conditions in agricultural, urban and suburban environments. The complexity of the hydro-physicochemical processes that occur in soil have captured the interest and imagination of many researchers in the physical, chemical, biological, and earth science communities. It is becoming widely recognized by scientists, resource economists, and social scientists that soil quality is inextricably linked to water quality/quantity and ecosystem function. Specifically, my future research goals are to develop techniques to analyze the effects of soil, water and crop management on soil-water interaction, understand the existing roles, and evolving new techniques, from the micro- (molecular) to macro-scale (ecological). M.S., 1999 and Ph.D., 2003; Himachal Pradesh Agricultural University, India (www.hillagric.ernet.in)

Ilia Gelfand

My current research focuses on the environmental sustainability of agricultural production of biofuels. Specifically, I am looking on the carbon costs of agricultural production of biofuel feedstocks. The question I am asking, is how “green” the “green” fuels are?

To answer this question I use experimentation, observation, and long-term datasets analyses. My approach is construction of budgets of the elements of interest. I am using variety of tools for measuring and calculating fluxes and pools of nutrients, in order to evaluate environmental influence of different biofuel feedstock production systems. M.S. 2002, The Hebrew University of Jerusalem; Ph.D. 2008, Weizmann Institute of Science

Julie Doll

Dr. Julie E. Doll is the Education and Outreach Coordinator for the Long-term Ecological Research Project at the Kellogg Biological Station, Michigan State University. She works with various stakeholders—including farmers, Extension Educators, policy makers, teachers, students, and the general public—to understand and meet their educational needs regarding ecosystem services from agricultural lands. Previously, she worked as a Postdoctoral Research Associate and Graduate Research Assistant in the Agronomy Department at the University of Wisconsin-Madison. Her dissertation research investigated agronomic, ecological, and social aspects to using native warm-season prairie grasses in grazed pastures. As a Peace Corps Volunteer in Paraguay, Julie fell in love with working with famers, grasslands, and meeting the needs of people through improved agricultural production and enhanced delivery of ecosystem services. She is passionate about strengthening the linkages between people, agriculture, and the environment and relies on the eloquent words of Aldo Leopold to express that passion: “Conservation means harmony between men and land. When land does well for its owner, and the owner does well by his land, when both end up better by the partnership, we have conservation.”

Neville Millar

My research focuses on greenhouse gas emissions and carbon and nitrogen biogeochemistry, with the aim of utilizing various land management strategies to mitigate these emissions, reduce nutrient loss and promote ecosystem sustainability. My past work has looked at agroforestry practices on smallholder farms in East Africa, and the effects of elevated carbon dioxide (FACE) on crop yield and microbial communities in European grasslands. B.Sc. 1994. University of St. Andrews, Scotland, UK; M.Sc. 1996. University of London, UK; Ph.D. 2002. Imperial College London, UK.