Conference on the
Ecological Dimensions of Biofuels

Ronald Reagan Building and International Trade Center
Washington, D.C. · March 10, 2008
ECOLOGICAL SOCIETY OF AMERICA

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ECOLOGICAL DIMENSIONS OF BIOFUELS

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MARCH 10, 2008 – WASHINGTON, DC

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Dear Attendees:

On behalf of the Ecological Society of America (ESA), the ESA Governing Board, and the ESA staff, we welcome you to Ecological Dimensions of Biofuels. Much attention is currently focused on the use of biofuels as an alternative energy source, both to decrease US dependence on foreign oil supplies, and as a means of addressing one facet of global climate change. Supplying the emerging biofuels industry with enough biomass to meet the US biofuel energy target – replacing 30 percent of the current US petroleum consumption with biofuels by 2030 – will have a major impact on the management and sustainability of many US ecosystems. Biofuels have great potential, but the ecological impacts of their development and use must be examined and addressed if they are to become a sustainable energy source.

The sustainability of alternative biofuel production systems must be assessed now, in order to maximize the potential for developing truly sustainable scenarios – that is, profitable systems that can provide adequate biomass with the least amount of environmental impact. Today you will hear presentations by leading scientists addressing the sustainable development of biofuels across a wide range of perspectives, including ecology, industry, agriculture, forestry, and socioeconomics. The final two presentations will provide syntheses of these perspectives from the points of view of ecology and the use of this information in decision making. At the end of the day, you will have the opportunity to talk directly with today's speakers and the authors of additional poster presentations to learn more about this important field.

This conference is one of many activities that ESA conducts in pursuit of our mission of promoting the science of ecology and ensuring the appropriate use of ecological science in environmental decision making. These activities would not be possible without the dedicated support of our sponsors and of volunteers like the members of our conference Steering Committee. We extend to them our deepest gratitude, and urge you to thank them in person when you see them today. Finally, we thank you for caring enough to attend, to listen, to ask, and to learn about one of the critical environmental issues of our day.

Sincerely,

Norman Christensen, President

Katherine S. McCarter, Executive Director

Ecological Society of America

ABOUT THE CONFERENCE

The Issue

Biofuels are receiving much attention as a potential means of reducing dependence on fossil fuels and net emissions of atmospheric carbon dioxide, the major contributor to global climate change. However, the environmental benefits and costs of the various paths to biofuels production have not been fully explored. The sustainability of alternative biofuel production systems must be assessed now, in order to maximize the potential for developing truly sustainable scenarios – that is, profitable systems that can provide adequate biomass with the least amount of environmental impact.

Response

An assessment of the environmental dimensions of biofuels production is needed to assist policymakers, producers, and the public in developing this resource in a sustainable fashion. The Ecological Society of America (ESA) has organized this Conference to address key questions about the state of the science, including:

- What is known about opportunities for sustainable production of biofuels, including crop selection, farming practices, feedstock transportation, and refinery location?
- What management strategies would best sustain important ecological services while increasing biofuel production?
- What are the implications of biofuel production for water quality and landscape dynamics relative to other land uses such as food and fiber production or wildlife conservation?
- What are the key knowledge gaps that need to be addressed so that policymakers, environmental managers, and producers are able to support environmentally sustainable biofuel production?
- What are the potential effects of biofuel production on landscapes that are both managed and relatively unmanaged, including intensively farmed areas, rangelands, natural grasslands, and forests?
- What emerging technologies may reduce or mitigate adverse impacts of biofuels production?

Products

ESA is generating a number of products related to today's conference, including:

- This program which provides a summary of each oral presentation, and abstracts of poster presentations. In addition, speakers have been invited to contribute papers for publication in a supplement to ESA's journal *Ecological Applications*.
- A group of participants who will be developing a contribution to ESA's *Issues in Ecology*. This publication series reports scientific consensus on issues relevant to the environment and in language understandable by nonscientists. See http://www.esa.org/science_resources/issues.php for details and free downloadable copies.
- A position statement on biofuels sustainability that offers ecological principles necessary for biofuels to help decrease dependence on fossil fuels and reduce carbon dioxide emissions that contribute to global climate change. See http://www.esa.org/pao/policyStatements/Statements/biofuel.php.
- A website which lists resources related to the ecological dimensions of biofuels: http://www.esa.org/science_resources/biofuelsResources.php.

ABOUT THE ECOLOGICAL SOCIETY OF AMERICA

ESA, with more than 10,000 members, is the world's largest society of professional ecologists and publishes four premier journals. ESA was founded in 1915 to:

- promote ecological science by improving communication among ecologists;
- raise the public's level of awareness of the importance of ecological science;
- increase the resources available for the conduct of ecological science; and
- ensure the appropriate use of ecological science in environmental decision making by enhancing communication between the ecological community and policy-makers.

Ecology is the scientific discipline that is concerned with the relationships between organisms and their past, present, and future environments. These relationships include physiological responses of individuals, structure and dynamics of populations, interactions among species, organization of biological communities, and processing of energy and matter in ecosystems.

ESA's members conduct research, teach, and use ecological science to address environmental issues that include:

- biotechnology;
- natural resource management;
- ecological restoration;
- ozone depletion and global climate change;
- ecosystem management;
- species extinction and loss of biological diversity;
- habitat alteration and destruction; and
- sustainable ecological systems.

This conference is a contribution to ESA's mission of promoting the science of ecology and ensuring the appropriate use of ecological science in environmental decision making. ESA's Science Office has a 15-year history of bringing together researchers and managers from among the Society's membership and the wider biological sciences community to assess the state of the science in a wide range of environmental topics. Our Public Affairs Office is a key provider of ecological knowledge to Congress and others on emerging environmental issues, and our journals are the leading publishers of that knowledge. The Education and Diversity Programs Office works to increase diversity within ecology-related professions, to engage the public in a dialogue on ecological research and issues, and to improve the quality of ecology education at all levels.

Additional information about ESA programs and publications is available at www.esa.org, and from our headquarters office at 1990 M Street NW, Suite 700, Washington, DC 20036 (tel. 202-833-8773).

USDA Forest Service Biomass Program

Our Biomass Vision

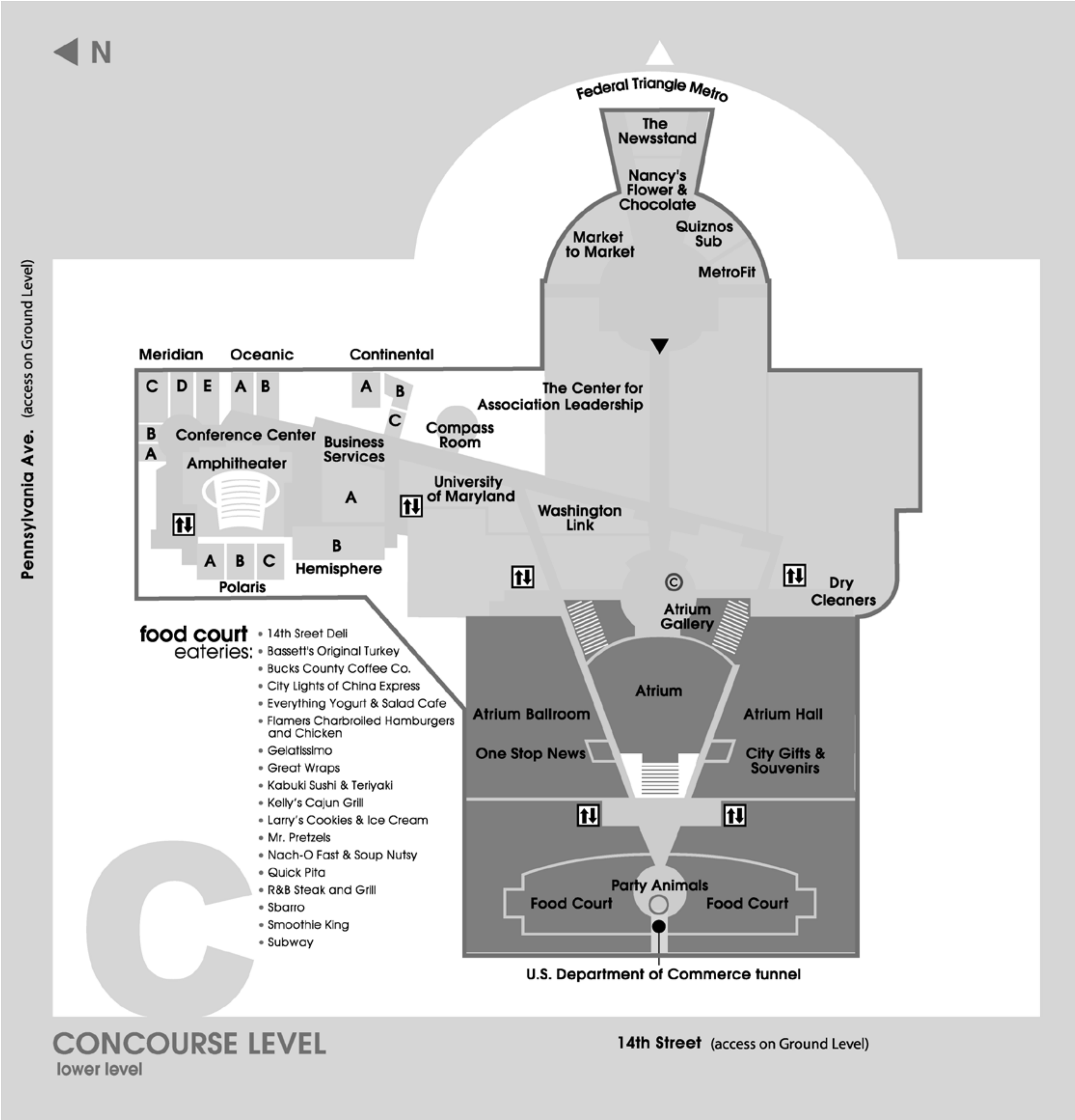
- Better manage and utilize forest biomass to improve our nation's forest health and sustainability
- Add value to industry and the forest community through research and development
- Improve our rural and national economy
- Provide energy security, improved ecological functions and environmental benefits

Our Effort

- Develop integrated management and use systems
- Create innovative biobased products and biofuels
- Assessing ecological, economic and social impacts on communities of woody biomass utilization

Our Success

- Billion Ton Report to asses biomass availability
- Patented yeast to produce bioethanol
- $14.5 million dollars in technology transfer grants
- Coordinated resource offering program
- Advanced forest biorefinery research



RONALD REAGAN BUILDING AND INTERNATIONAL TRADE CENTER

AGENDA

TIME	TOPIC	SPEAKER
8:30 am	*Environmental Impact of Biofuel Cropping Systems: Introduction*	**Bill Parton** Colorado State University
9:00 am	*Defining Sustainable Biofuels - or, "It isn't Easy Being Green"*	**John Sheehan** LiveFuels, Inc.
9:30 am	*Field to Fuel - Developing Sustainable Biorefineries*	**Robin Jenkins** Dupont Central Research and Development Experiment Station
10:00 am	**BREAK**	
10:30 am	*Biofuels and Water Quality in the Midwest:* *Corn vs. Switchgrass as Feedstocks*	**Catherine Kling** Iowa State University
11:00 am	*The Biogeochemistry of Bioenergy Landscapes:* *Clean Water, Clean Air, and Climate Mitigation vs. Business as Usual*	**Philip Robertson** Michigan State University
11:30 am	*Interactions between Biofuel Choices and Landscape Dynamics* *and Land Use*	**Virginia Dale** Oak Ridge National Laboratory
12:00 pm	Keynote Address (with lunch) *Environmental and Ecological Dimensions of Biofuels*	**José Goldemberg** Global Energy Assessment Council & Universidade de Sao Paulo, Brasil
1:30 pm	*Biofuels and Biodiversity*	**John Wiens** The Nature Conservancy
2:00 pm	*Production of Biofuels Feedstock on Agriculture Land and Grasslands*	**Wally Wilhelm** US Department of Agriculture, Agricultural Research Service
2:30 pm	*Are Rangeland Biofuel Feedstocks Ecologically Sustainable?*	**Linda Wallace** University of Oklahoma
3:00 pm	*Sustainable Biofuels and Bioproducts from our Forests*	**Marilyn Buford** US Department of Agriculture Forest Service
3:30 pm	**BREAK**	
4:00 pm	*Municipal Solid Waste as Supplemental Feedstocks*	**Donna Perla** US Environmental Protection Agency
4:30 pm	*A Global-Scale Biofuels Program and its Environmental Consequences*	**Jerry Melillo** The Ecosystems Center, Marine Biological Laboratory
5:00 pm	*The Rush to Biofuels and Ecological Perspectives in the Policy Process*	**Otto Doering** Purdue University
5:30 pm	Poster Social & Reception	

Marilyn A. Buford

Marilyn Buford joined the National Program Staff for US Department of Agriculture (USDA) Forest Service (FS) in August, 1998, serving as National Program Leader for Quantitative Ecology Research, co-lead for FS Global Change Research Program and co-lead for FS Biobased Products and Bioenergy Research Program. In January, 2006, she accepted the position of National Program Leader for Silviculture Research and continues to co-lead the FS Biobased Products and Bioenergy Research Program. She is an active member of the USDA Biobased Products and Bioenergy Coordination Council, the Interagency Woody Biomass Utilization Group (WBUG), and the FS Woody Biomass Utilization Team. Marilyn currently serves as the Chair of the Short Rotation Woody Crops Operations Working Group (SRWC OWG), a public-private partnership to promote collaborative efforts in developing needed operations for SRWC plantations. Marilyn served as Project Leader in Charleston, South Carolina, (Forested Wetlands) and in Research Triangle Park, North Carolina (Southern Forest Productivity). Her personal research and publications have focused on forest stand dynamics, forest carbon management, and forest productivity.

Virginia Dale

Dr. Virginia H. Dale is a Corporate Fellow in the Environmental Sciences Division at Oak Ridge National Laboratory and was selected as the 2006 Distinguished Scientist for the Laboratory. Her primary research interests are environmental decision making, effects of land-use and climate change on forests, landscape ecology, and ecological modeling. Dr. Dale has authored more than 160 published articles, is coauthor of the book Road Ecology, and has edited five books. She has served on national scientific advisory boards for five federal agencies: the Environmental Protection Agency (EPA), US Departments of Agriculture, Defense, Energy, and Interior. She is currently chair of the US National Committee of the Scientific Committee on Problems of the Environment (SCOPE) and of the EPA Science Advisory Board's Hypoxia Advisory Panel. She also is Editor-in-Chief of the journal *Environmental Management.*

Otto Doering

Otto Doering is Professor of Agricultural Economics at Purdue University. His responsibilities include teaching, research, and public service on policy issues relating to agriculture, resources, and the environment. His experience includes service on Department of Energy's Energy Research Advisory Board Biomass Advisory Panel, DOE's Energy Extension Advisory Board, and Indiana's Energy Development Board. He was director of Purdue University's Energy Policy Research and Information Program, was founding director of Indiana's State Utility Forecasting Group, has served on the Research Advisory Committee of the National Regulatory Research Institute, and was a National Science Foundation Evaluator for the Power Systems Engineering Research Center. He was economic team lead for the National Hypoxia Assessment, served on the National Academies' Committee on the Mississippi River and the Clean Water Act, the National Research Council's Committee on Water Implications of Biofuel Production, and serves on the EPA Scientific Advisory Board Committee on Integrated Nitrogen. He has held advisory positions with USDA for the '77, '90, and '96 farm bills and with the Natural Resources Conservation Service for the design and assessment of agricultural conservation programs. He has been chairman of the National Public Policy Education Committee and is currently president of the American Agricultural Economics Association. Dr. Doering has degrees from Cornell University and the London School of Economics.

José Goldemberg

Professor José Goldemberg earned his Ph.D. in Physical Sciences in 1954 from the University de São Paulo in 1954 of which he became Rector in 1986. He has served as the President of the Brazilian Association for the Advancement of Science, Minister of State for Education of Brazil and Secretary for the Environment of the State of São Paulo. He has authored many technical papers and books on nuclear physics, sustainable development and energy.

SPEAKERS

Robin Jenkins

Robin Jenkins has a Bachelor of Science degree in Chemical Engineering from The Pennsylvania State University. During her 9 years of experience at DuPont, Robin has contributed to a variety of DuPont businesses. In her current role in the Engineering Evaluations and Sustainability group within DuPont Engineering Research and Technology, Robin guides research and manufacturing teams by analyzing new or existing processes from an engineering, economic, and life cycle perspective. Robin has 4 years experience as a Life Cycle Assessment (LCA) practitioner and currently leads LCA efforts for biofuels in DuPont. In previous roles, she aided manufacturing operations as a process engineer for the Packaging and Industrial Polymers business and managed key customer relationships as a technical services engineer for the Nonwovens business.

Catherine Kling

Dr. Catherine Kling is a Professor of Economics at Iowa State University and head of the Resource and Environmental Policy Division of the Center for Agricultural and Rural Development. Prior to her Iowa State appointment, she was an Associate and Assistant Professor in the Department of Agricultural Economics at the University of California, Davis. Dr. Kling holds a B.A. in Business and Economics from the University of Iowa and a Ph.D. in Economics from the University of Maryland. She is a Fellow of the American Agricultural Economics Association and has served as a member of their board of directors and awards committee chair. She has also served as vice president and member of the board of the Association of Environmental and Resource Economists, is a member of US EPA's Science Advisory Board, chairs the Science Advisory Board Environmental Economics Advisory Committee, and has held editorial positions at several environmental and agricultural economics journals.

Jerry Melillo

Professor Jerry Melillo is the Co-Director of The Ecosystems Center at the Marine Biological Laboratory in Woods Hole, Massachusetts, and a Professor of Biology at Brown University. His center in Woods Hole focuses on environmental research in three areas: global change; management of coastal zone ecosystems; and globalization and transformation of the tropical landscape. Professor Melillo specializes in understanding the impacts of human activities on the biogeochemistry of ecological systems, using a combination of field studies and simulation modeling. In 1996 and 1997, he served as the Associate Director for Environment in the US President's Office of Science and Technology Policy. Professor Melillo just completed terms as the President of the Ecological Society of America and of the Scientific Committee on Problems of the Environment (SCOPE), the environmental assessment body of the International Council for Science. He is an honorary Professor in the Institute of Geophysical Sciences and Natural Resources Research, Chinese Academy of Sciences, a member of the American Philosophical Society, and a Fellow of the American Academy of Arts and Sciences. His publication record includes more than 200 peer-reviewed articles, two ecology textbooks and three edited volumes on biogeochemistry.

Bill Parton

Dr. Parton has worked extensively during the last 30 years on the development of ecosystem models and the use of these models to evaluate the impact of land use change and global environmental changes on natural and managed ecosystems around the world. He is a Professor Emeritus and Senior Research Scientist at Colorado State University. His recent research has focused on evaluating the environmental impact of biofuel cropping systems on net greenhouse budgets and other environmental impacts.

Donna Perla

Donna Perla is a Senior Advisor in the Office of Research and Development at the US Environmental Protection Agency. She leads the Office of Research and Devleopment's biofuels effort and assists EPA's representative to the federal Biomass Research and Development Board and participates in several interagency teams related to the development of a National Biofuels Action Plan. Her work focuses on looking at the sustainability of the biofuels system, including environmental and human health considerations of feedstock, technologies, distribution and use. Donna also leads an EPA Waste-to-Energy network, which explores the environmental aspects of conversion technologies for a wide variety of wastes, including disaster debris. Other positions in her 22 years with EPA include: Director of the Innovative Pilots Division in the Office of Policy, Economic, and Innovation; Chief of the Waste Minimization Branch in the Office of Solid Waste; Chief of the Colorado/Montana Permitting and Enforcement Section, EPA, Region 8; Chief of the Economic Analysis and Risk Assessment Section in the Office of Solid Waste; and Special Assistant to the Director of the Office of Solid Waste. She holds a B.S. in Biology (University of Hartford), and a Masters of Public Health (Yale University).

Philip Robertson

Phil Robertson is a Professor of Ecosystem Science in the Department of Crop and Soil Sciences at Michigan State University (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 national chair of the US LTER Network's Science Council and Executive Board. Dr. Robertson's research interests include the biogeochemistry and ecology of field crop ecosystems, and in particular nitrogen and carbon dynamics, greenhouse gas fluxes, and the functional significance of microbial diversity in these systems. His undergraduate teaching includes agricultural ecology, biogeochemistry, and soil biology courses. Dr. Robertson has been a SCOPE-Mellon postdoctoral fellow at the Royal Swedish Academy of Sciences (1980-1981) and a sabbatical scholar at Cooperative Research Centres in Adelaide (1993-1994) and Brisbane (2001-2002), Australia. His service also includes membership on the US Carbon Cycle Scientific Steering Committee, chairmanships of competitive grants panels at the USDA (the NRI and Fund for Rural America Programs), and membership on several NSF panels in the Biological and Geosciences directorates. Dr. Robertson served on the National Research Council Committee to Evaluate the USDA NRI Program (1998-1999), and he chaired the Environment Subcommittee of the NRC Committee on Opportunities in Agriculture (2000-2002). He has testified before the US Senate Agriculture, Forestry, and Nutrition Committee and participated in briefings for the US House Science and Agriculture Committees. He has also served as an editor for the journals *Ecology*, *Ecological Monographs*, and *Plant and Soil* and is currently an editor for Biogeochemistry. In 2003 he was elected a Fellow in the Soil Science Society of America. In 2005 he received MSU's Distinguished Faculty award. Dr. Robertson received his B.A. from Hampshire College and his Ph.D. in Biology from Indiana University.

John Sheehan

John Sheehan recently joined LiveFuels, Inc. as their Vice President of Strategy and Sustainable Development, where he is helping to forge a path to commercial production of biofuels from algae. From 1991 to 2007, he served as an analyst and project manager at the US DOE's National Renewable Energy Laboratory (NREL). At NREL, Sheehan has led research on the production and use of biodiesel and ethanol. From 1993 to 1998, he was the project manager for DOE's Biodiesel from Algae Program. Sheehan is the lead author of the 1998 close-out report that summarized the 20+ years of R&D accomplishments of the algae program. Sheehan has authored groundbreaking life cycle assessment studies related to biodiesel and ethanol technology. From 2002 to 2007, John also led strategic planning and analysis activities for the DOE's Biomass Program and, more broadly, for the entire program portfolio in DOE's Office of Energy Efficiency and Renewable Energy. Prior to NREL, John worked as a biochemical engineer at W.R. Grace and Company and Merck Pharmaceutical. He holds B.S. and M.S. degrees in Biochemical Engineering from the University of Pennsylvania and Lehigh University.

SPEAKERS

Linda Wallace

Dr. Linda Wallace is professor of botany and Director of the Kessler Farm Field Laboratory at the University of Oklahoma (OU). Since joining the faculty at OU in 1981, she has studied grassland ecology in the Great Plains and examining grazing ecology at Yellowstone National Park. While on sabbatical in the Park, the fires of 1988 erupted and working in concert with scientists from across the US, Dr. Wallace examined system response to this very large perturbation. This resulted in the Yale Press publication, After the Fires: The Ecology of Change in Yellowstone National Park. She has since been working collaboratively on two large global change experiments and is currently collaborating on a project examining both grassland and feedstock production system responses to global climate change. She was named a Samuel Roberts Noble Presidential Professor at OU in 1999, was panel manager of the USDA Ecosystems Panel in 2000, and has served on numerous advisory panels for both USDA and NSF, including the 20 year review of the LTER network.

John Wiens

John Wiens grew up in Oklahoma as an avid birdwatcher. This led to degrees from the University of Oklahoma and the University of Wisconsin-Madison (M.S., Ph.D.). With this training under his belt, he joined the faculty of Oregon State University and, subsequently, the University of New Mexico and Colorado State University, where he was a Professor of Ecology and University Distinguished Professor. He has held Visiting Professor appointments at the University of Oslo, the University of British Columbia, the Tropical Ecosystem Research Centre of CSIRO in Darwin Australia, and the National Center for Ecological Analysis and Synthesis in Santa Barbara, California. His work, which has emphasized landscape ecology and the ecology of birds and insects in arid environments, has led to over 200 scientific papers and 7 books. John left academia in 2002 to join The Nature Conservancy as a Lead Scientist, with the challenge of putting years of classroom teaching and academic research into conservation practice in the real world. His current scientific work at TNC addresses the broad issue of conservation in a rapidly changing world – "conservation futures."

Wally Wilhelm

Wally Wilhelm is a research plant physiologist with the USDA-Agricultural Research Service Agroecosystems Management Research Unit and adjunct professor of agronomy and horticulture at the University of Nebraska, Lincoln, Nebraska. He leads the ARS Renewable Energy Assessment Project (REAP), a multi-location effort to develop tools and cropping practices that maximize sustainable harvest of biomass as bioenergy and bioproduct feedstocks. He has worked to help the cellulosic ethanol industry understand that crop residues are not wastes of grain production and that residues play a vital role in maintaining soil functions and preserving the capacity of agricultural lands to produce food, feed, and fiber when remained to the soil.

SPEAKER ABSTRACTS

ABSTRACT: *Sustainable Biofuels and Bioproducts from Our Forests*

Marilyn A. Buford, Bryce J. Stokes, and Daniel G. Neary (*US Forest Service Research & Development)*

Our forests are a strategic asset in achieving energy security, environmental quality, and economic opportunity. Wood is a renewable source of transportation fuels, heat, and power. Additionally, a wide array of wood-based bioproducts, from solids to chemicals, can often be used to displace fossil fuel-based products. Wood is an abundant, renewable, home-grown lignocellulosic resource that provides tangible benefits to landowners. These managed forests provide a multitude of critical goods and services to the public.

In the broad sense, our desired resource outcome is that forest systems are healthy and productive, and provide a sustainable supply of goods, services, and values that enhance the quality of life for present and future generations. We must consider the range and quantity of goods, services, and values that we will require our forests to provide in the future.

In significant measure, we will expect these lands to produce water, wood and non-wood products, recreational opportunities, varying habitats, climate change mitigation measures, and energy needed by our growing population and its economies. While it is common to focus on disruptions in these goods and services as a result of past, present or future actions and influences, it is far more useful to think in terms of managing through changing conditions to continue to supply needed goods, services, and values, including bioenergy.

Our challenge is not in merely sustaining the systems we have, or in restoring selected systems. The real challenge is to enhance the capacity of all systems to meet future resource needs. This recognizes that our natural resource systems will be stretched to meet domestic needs and that they will additionally be strained to meet demands in the expanding global economy. Meeting the need for clean water, fiber and solid wood, recreational opportunities, suitable habitat, and energy depends on managing our systems to provide for increasing levels of a variety of benefits.

Generally, woody biomass can be any tree or part thereof. In simple terms, woody biomass is derived from any and all parts of the tree – the bole wood, the limbs, the tops, the roots, and the foliage. It can also include trees that have been killed or damaged by drought or disease, and those that have been grown specifically for production of biofuels (i.e. purpose-grown wood). Typically woody biomass refers to trees or the parts of trees or stands that are not useful for production of paper or wood products or is a by-product of a stand prescriptive treatment or processes. However, woody biomass can technically be commercial trees as well. In the broadest sense, it can also include pre- and post-consumer recovered paper and wood products that are not being reused or are unsuitable for reuse or recycling.

Issues associated with development of wood-based fuels include: 1) resource availability, feedstock sources, feedstock production and management, and other components of supplying wood feedstock; 2) harvesting and forest operations technologies, transportation, in forest pre-processing technologies for feedstock added value; 3) types of conversion technologies including their feedstock needs, conversion efficiencies and costs; 4) integrated management systems for energy and other goods and services; 5) information, data, and decision tools; and finally 6) development and deployment of biomass to energy facilities.

The primary issues are whether we can provide the quantities of wood needed in the future while ensuring the conservation and sustainable production and delivery of other benefits. These questions have been, and are being, addressed through research, synthesis, and development of management options, strategies, systems and practices. These issues put forests and forestry directly in the forefront of debate and opportunity.

We will expect our forest lands to continue to provide needed goods, services, and values into the future. We must be able to sustainably manage dynamic forest systems in a changing physical and social environment to continue to deliver needed goods, services, and values. We need to address potential negative impacts and to capitalize on the benefits that working forests provide in the landscape.

Areas of research critical to sustainable production and use of wood feedstocks for biofuels and bioproducts include:

- developing sustainable management and utilization systems for forest biomass and residues, forest health and fuels reduction treatments, and production forests;
- developing and demonstrating the science and technology for sustainable, economical woody cropping systems at multiple operational scales;
- developing sustainable management and land use systems for specific functions;
- developing more efficient, light-on-the-land harvest, collection, and transportation systems;
- developing highly productive feedstocks with improved water- and nutrient-use efficiencies; and
- developing efficient technologies for wood conversion to biofuels and bioproducts.

This paper will review current assessments of forest feedstock supply capabilities, address wood resources useful for bioproducts and bioenergy, and consider production options for a sustainable flow of raw materials. Additionally, it will address management issues, perceived threats, and opportunities associated with wood-based fuels and bioproduct production and what science can be used, synthesized or executed to address the issues and capitalize on the opportunities.

ABSTRACT: *Interactions between Biofuel Choices and Landscape Dynamics and Land Use*

Virginia Dale (*Oak Ridge National Laboratory, Environmental Sciences Division)*

Key decisions that affect the long-term sustainability of biofuels are about land-use practices and landscape dynamics. The way the land is used includes what crops are grown and how are they planted, fertilized, and harvested. These choices determine the effects of biofuels on native plant diversity, competition with food crops, and influences on water and air quality. That decision also affects economic viability since the distance that biofuels must be transported has a large effect on the market cost of biofuels as well as the quality of the lives of those who live in communities through which the bulky fuel is transported.

In this context, landscape dynamics refers to changes that are made in landscape properties to account for biofuels. Such changes can affect the juxtaposition of land-cover types that, in turn, influences pollinator habitats, the distribution of habitats across the landscape, and the potential for migration and dispersal.

The proposed vast increase in bioenergy usage and production will have interdependent environmental and socioeconomic impacts[1]. Several potential technological pathways connect the various biomass sources to diverse forms of bioenergy (fuels, heat, and power). Moreover, local decisions, driven by regional or national policies to adopt alternative biomass production methods, are strongly coupled with land-use practices, which are a key driver for environmental and socioeconomic changes at various spatial scales[2]. Currently, the complexity and scale dependency of such land-use decisions and their impacts are not understood, defined, or described with adequate clarity to enable policy makers to develop strategies to ensure a sustainable bioenergy future with acceptable environmental and socioeconomic consequences, particularly under a changing climate regime.

Expanded use of bioenergy is a key part of the President's Initiative for energy security and requires assuring that the production and consumption of bioenergy are truly sustainable. Yet the current capability to produce ethanol using corn starch in wet and dry mills is insufficient to help this country meet those goals and will likely have detrimental environmental effects[3,4,5,6]. It is understood that new crops and crop residue collection systems will need to be

introduced and combined with commercially efficient, economically viable, and environmentally sustainable conversion of lignocellulosic materials to ethanol[7,8].

To develop and implement such a sustainable bioenergy infrastructure requires determining 1) What are the environmental implications of different feedstock options; 2) What are the opportunities / constraints for feedstock locations (where should they be produced or collected); 3) What forms of bioenergy (fuels, heat, power, other biochemical coproducts) should be produced; and 4) Where should bioenergy conversion facilities be located.

Tradeoffs will have to be made across space and time among the economic, ecological, and social consequences of alternative choices. For example, increased biofuel use of corn at a local scale may mean more pesticide use and negative effects on human health, at a regional scale may mean increased nutrient flux and thus degraded water quality, and at the scale of the Mississippi River watershed (41 percent of the US) may mean a larger hypoxia zone in the Gulf of Mexico and declines in the shrimp harvest. Also, changing climate conditions will influence possible crop choice and energy needs.

Current research activities address feedstock resource analysis, feedstock logistics including harvesting, handling, storage, pretreatment, and transportation from field to biorefinery, and biorefinery thermochemical and biological conversion to ethanol. But there is no activity that seeks either to integrate these activities and data to take into account the scale-dependencies in a quantitative way or to understand multiple environmental factors and subsequent trade-offs. We address this pressing need by exploring the landscape implications of bioenergy choices. Therefore it is critical to develop an approach that will help policy makers understand environmental and socioeconomic consequences of alternative bioenergy regimes and policies.

The components considered in this approach include current environmental and socioeconomic conditions and the bioenergy features [type of fuel, plants species, management practices (e.g., fertilizer and pesticide applications), type and location of production facilities] and ecological and biogeochemical feedbacks. Significantly, while water (availability and quality) emerges as one of the most limiting factors, the linkage between water and bioenergy choices on medium and large scales is poorly quantified[9]. An approach that considers both environmental and socioeconomic changes in land use and landscape dynamics provides a way to quantify the influence of alternative bioenergy choices on water quality and other components of the environment.

References

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ABSTRACT: *The Rush to Biofuels and Ecological Perspectives in the Policy Process*

Otto Doering *(Purdue University)*

Biofuel development and production is being driven by government policies, particularly subsidies, even with high energy prices. What this says is that changes in biofuel development will come through the political process that directs biofuel policy and subsidies. An ecological perspective is only effective insofar as biofuel policies crafted in the political process take account of these. The increased influence of ecological perspectives appears to have occurred in Europe with the recent decision to reassess biofuels policy on the basis of ecological concerns, but this reflects the different character of European public opinion and the different structure of European agriculture as well.

Current corn based biofuel systems, from feedstocks to final product, are the joint creation of high petroleum prices and the government subsidy of $0.51 a gallon for ethanol blended with gasoline. A market response to the subsidy by investors in ethanol capacity and a response by corn feedstock producers to high corn prices have propelled us rapidly to where we are today. Unless there is a reaction in the US to ecological concerns akin to that in Europe, we cannot expect the corn ethanol system to be modified soon on ecological grounds. The most promising arena for ecological concerns to have impact is in the development of the next generations of land based biofuels – be this cellulosic or some other process and feedstock base. It will be in the policy instruments designed to foster such next generation developments that ecological perspectives may be able to influence feedstock choices, production, and biofuel processes.

If it is the community of ecological sciences that are to supply the ecological perspectives to policy makers, then there needs to be an understanding in this community of the kind of information input that has impact, and how best to make such input. A consideration of this leads to the conclusion that external validity can be as important as

internal validity. Another characteristic to be illustrated here is the concept of the teachable moment in the success of scientific information to inform policy. Illustrations also indicate that context can be important as well.

The debate that is occurring in the environmental and ecological sciences about increasing the impact of science on policy also involves attempts to find a better vehicle to demonstrate the relevance of the ecological landscape. One issue is whether to hang one's hat on ecological services and as an extension of that to stress the valuation of such ecological services. The conclusion is that the valuation of environmental services may not obtain the results many hope for. A critical underpinning is that the biophysical relationships need to be well understood in order for the valuation of environmental services to have any currency. In addition, economic valuation aside, the impact of such analysis is going to depend upon public views of what services are important. The ability to provide defensible relative values or priorities for ecological phenomena or services may be as or more important than providing and trying to defend absolute values. The public wants to know definitively what is most important.

The ecological sciences have to answer the 'so what' question with evidence based on measurement and/or relative values that the public perceives as valid. I.e. the public must have confidence in where the science is in its ability to measure change, compute relative differences, and project impacts. In addition ecological science will have to adopt the public perception of what markers or 'canaries in the mine' are critical. The public and its political representatives are most concerned with discrete signals or thresholds that give reliable signals for action to prevent catastrophe or to declare success. As in the Chesapeake Bay, the issue becomes one not just of appropriate markers, but also one of context in measuring success or failure of public efforts to improve the Bay. Unfortunately, the more discrete and straightforward the signals, the less likely they fully include the complexity of spatial and temporal dimensions, but the more likely the public is to find them comprehensible.

Let us assume the ability to meet many of the challenges outlined above. Also assume that large subsidies will be needed to move to the next generation of biofuels. There are policy devices that can encourage improved ecological performance across the system in the development of biofuels. The current per gallon subsidy is not one of them, nor is the direct subsidy proposed to encourage farmers to grow switch grass. What might succeed would be a program of government assistance that effectively, if indirectly, encompassed the whole process from feedstock production to final product. The device described here is a performance subsidy that flows backward from the final product to the production of the feedstock. Such an approach would require all parties involved to be part of a life cycle analytical process that would harness each player's incentive to participate and profit. It is not outside of our institutional experience to have performance contracts to meet national needs within defined criteria. If the subsidies are going to have to be large in any case, the public would have an opportunity to obtain a level of ecological performance at marginal additional cost where the players in the game have every incentive to accomplish this in the most cost effective manner.

ABSTRACT: *Environmental and Ecological Dimensions of Biofuels*

José Goldemberg *(University of São Paulo, Brazil)*

In order to discuss the environmental and social dimensions of biofuels it is useful to compare two very large areas of activities of our present civilization: agriculture (i.e. food production) and energy. Agricultural production is based on the use of 1.4 billion hectares of surface land and generates approximately an average of 1 tonne of food per year per inhabitant. Energy comes mostly from fossil fuels and relies on underground deposits of coal, oil and gas; present average consumption is 1.6 tonnes of oil equivalent per capita. Oil represents one third of that, mostly used for transportation.

About half the world's oil production is consumed by road vehicles. The fleet's annual increase is about 10 million automobiles (doubling every 20 years or so) and 5 million buses and trucks worldwide. If the trend continues, more than a billion vehicles will be in the world's roads by 2030. Not only is the number of automobiles and trucks growing but there is also a tendency to drive more, so the number of vehicles-miles traveled is increasing rapidly in countries such as the US. Also, vehicles tend to stay more time in traffic jams, consuming more energy per distance traveled.

Transport systems can adversely affect the environment in a variety of ways, such as disfiguring the landscape, but the most pervasive impacts arise from their exhaust gas and particulate emissions. One can attribute to transportation:

- more than 70 percent of all carbon monoxide (CO) emissions;
- more than 40 percent of nitrogen oxides (NO_x) emissions;
- almost 50 per cent of total hydrocarbons (HCs);
- around 80 per cent of all benzene emissions;
- at least 50 per cent of atmospheric lead emissions; and
- 14 percent of all greenhouse gas emissions to the atmosphere and 19 percent of the CO_2 emitted.

Roughly speaking human beings consume on the average approximately the same amount by weight of agricultural products and energy "per capita" although there are enormous inequities in the distribution of food and energy among countries and between the rich and the poor. There is really – in physical terms – no lack of food or energy today in the world but access is another matter and approximately one third of mankind lacks both. The other two thirds, particularly in the OECD countries, have reached a level of access and satisfaction without precedent in industry.

Why can't such a system work forever? For a simple reason: agricultural production is renewable and has been going on for hundred centuries; with suitable correction of soil and water access it can be maintained forever. Oil reserves as a fossil fuel are finite and presumably will not last many more decades.

No wonder, therefore, attempts have been made to use agricultural products as an energy source. Since remote antiquity wood has been used as a source of energy for cooking and heating and still represents today some 10 percent of all energy consumption, particularly in Africa where it is used with low efficiency. The problem today is in transportation, for which liquid fuels are needed.

Biofuels include ethanol produced from sugars and starch by fermentation with yeasts. Ethanol can be used pure or as a gasoline extender in spark-ignition engines. In addition, lignocellulose – from energy forestry, agricultural and forest industry residues, and the carbohydrate fraction of municipal solid waste (MSW) – is a further source of biomass liquids. Such a resource is 20 times more plentiful in the US than maize, and does not compete with food production. Since agricultural products grow in many areas of the world they are a solution to the problem of access, in addition to being renewable. A number of plant-derived oils have also been considered for possible use as fuels in diesel engines, including sunflower, soya, groundnut, cottonseed, rapeseed, palm oil and castor oil. However they might pose environmental and social problems depending on the scale of production involved.

In 2006 the ethanol production of 34 billion liters (from sugarcane in Brazil and from corn in the US) replaced 3 percent of the world's gasoline use of 1,2 trillion litters. The land requirements for the production of such amount was 3 million hectares in Brazil (5 percent of total agricultural area in case in Brazil) and a similar fraction in the US. It is clear therefore that concerns on "fuel versus food" competition are presently blown out proportion, certainly in Brazil. In the US the situation is more complex because there is a direct competition between corn and soy which resulted in price increases of corn.

Concerns on the sustainability of biofuels production are being widely discussed which is somewhat unexpected because such questions were not asked in the past when the oil era started. Today 30 billion barrels of oil are being burned per year. Biofuels production today is 300 million barrels equivalent per year which is the production of a modest oil field. Such production requires 6 million hectares of land and generates 2 million direct jobs. In the petrochemical industry – for the equivalent production of oil – only 10,000 jobs are generated.

To generate one job in ethanol production one requires an investment of 11,000 US dollars. The petrochemical industry requires 220,000 US dollars per job.

This does not mean that a large expansion of biofuels production - which is contemplated in a few countries particularly the US and Brazil - will not exacerbate environmental and ecological problems. To avoid or minimize them a large effort is being conducted to introduce sustainability criteria in the production of biofuels approximately along the lines of sustainable forest development. The present "status" of the efforts to introduce such criteria will be discussed.

ABSTRACT: *Field to Fuel – Developing Sustainable Biorefineries*

Robin Jenkins[1], Carina Alles[1], Susan Hennessey[1], Jamie Ginn[1], David Culver[1], Bruce Vrana[1], Robert Sylvester[1], Julie Friend[1], Mark Emptage[1], Seungdo Kim[2], and Bruce Dale[2] *([1]DuPont, Wilmington, DE; [2]Michigan State University)*

Biofuels are part of a growing number of product and technology opportunities within DuPont Applied BioSciences™. Cellulosic ethanol is one potential biofuel which provides a sustainable solution to the nation's growing concerns around energy supply and climate change. DuPont is leading the way towards demonstrating the feasibility of a cellulosic ethanol concept. DuPont received matching funds from the US Department of Energy (DOE) for the Integrated Corn-Based Bio-Refinery (ICBR) program in collaboration with Diversa Corporation, the National Renewable Energy Laboratory (NREL), Michigan State University (MSU), and Deere & Company. DuPont scientists and engineers are committed to making advanced biofuels and energy-efficient biofuel processes a reality.

A successful ICBR begins with sustainable removal of biomass from the field. As part of the ICBR program, MSU used Life Cycle Assessment (LCA) to estimate the environmental footprint of corn grain, corn stover, and the corn cob portion of the stover, grown under various farming practices for several corn growing locations in the US Corn Belt. The locations included in the study were Hardin County in Iowa, Fulton County in Illinois, Tuscola County in Michigan, Morrison County in Minnesota, Freeborn County in Minnesota, Macon County in Missouri, Hamilton County in Nebraska, and Codington County in South Dakota. The environmental impacts considered in the study were greenhouse gas (GHG) emissions, fossil energy use, eutrophication, and air acidification. By removing only corn cobs, which make up 17 percent of the stover, the removal rate is well within limits to meet erosion tolerances [Kim].

The corn cobs are converted into fermentable sugars for the production of fuel ethanol in the ICBR. The ICBR process uses both glucose and xylose from cellulose and hemicellulose, effectively converting nearly all of the useful sugars into liquid transportation fuel. The ethanol is transported to distribution centers and then to retail centers and eventually combusted in a vehicle. When this entire supply chain is considered, a well-to-wheel (WTW) LCA can be conducted. Figure 1 shows the system boundaries for a WTW LCA.

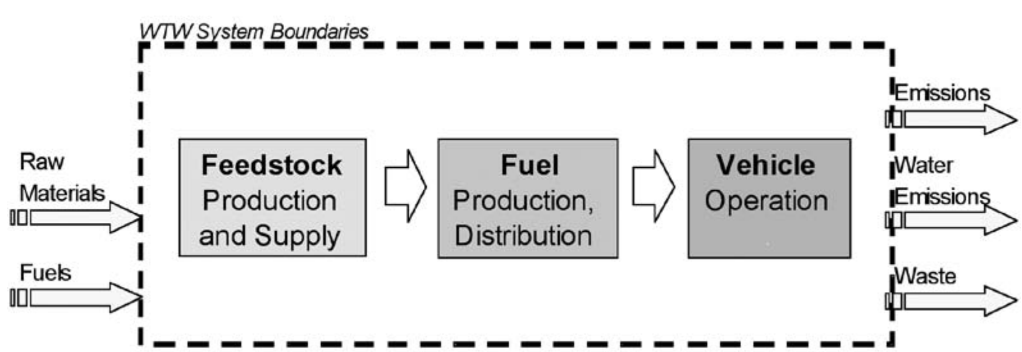

Figure 1: System boundaries for a well-to-wheel system boundaries for biofuels.

There are variations on the current farming practices worth consideration. Transitioning from predominantly conventional tillage in the Current Situation to a no till practice reduces the environmental footprint of the ICBR feedstock in terms of the impacts considered in this study. Incorporating a winter cover crop can further reduce the impact of corn cob harvest, in terms of the impacts considered. LCA results for corn cobs grown under these alternative farming scenarios were generated by MSU. Practicing no till farming and planting winter cover crops increases the rate of carbon sequestration into the soil while also decreasing the N^2O emissions from the field, thereby reducing overall GHG emissions. Figure 2 shows results for Cradle-to-farm GHG emissions using various farming practices. Cradle-to-farm LCA results are established when the system boundaries in Figure 1 stop at feedstock production [Kim].

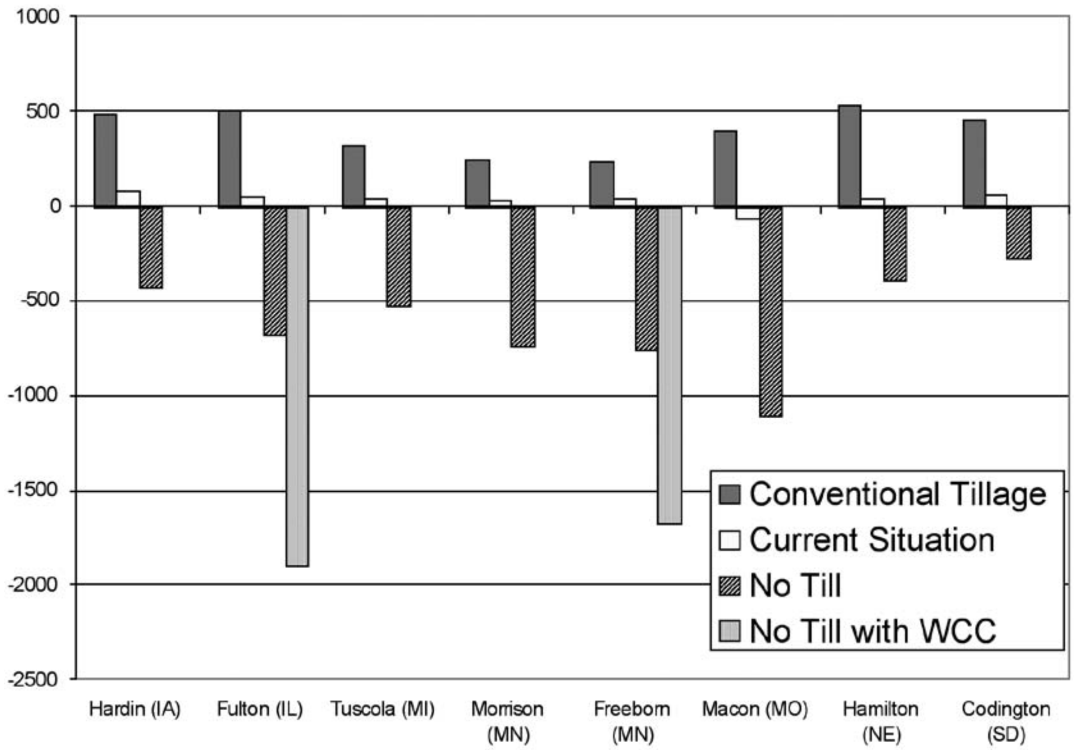

Figure 2: Cradle-to-farm greenhouse gas emission results for the eight farming locations under various farming practice scenarios for the corn cob feedstock.

In order to benchmark ICBR cellulosic ethanol with existing technologies, LCA results are compared to alternative ethanol processes and conventional gasoline. The future technology option for producing ICBR cellulosic ethanol shown in this analysis appears favorable when compared to corn grain ethanol and conventional gasoline in terms of WTW GHG emissions and fossil energy use [Alles, 2008]. Figure 3 shows WTW GHG performance of ICBR ethanol compared to ethanol benchmarks and gasoline. Corn cobs from Fulton County grown under the Current Situation are the feedstock for the DuPont Cellulosic Ethanol in the case shown on the following page.

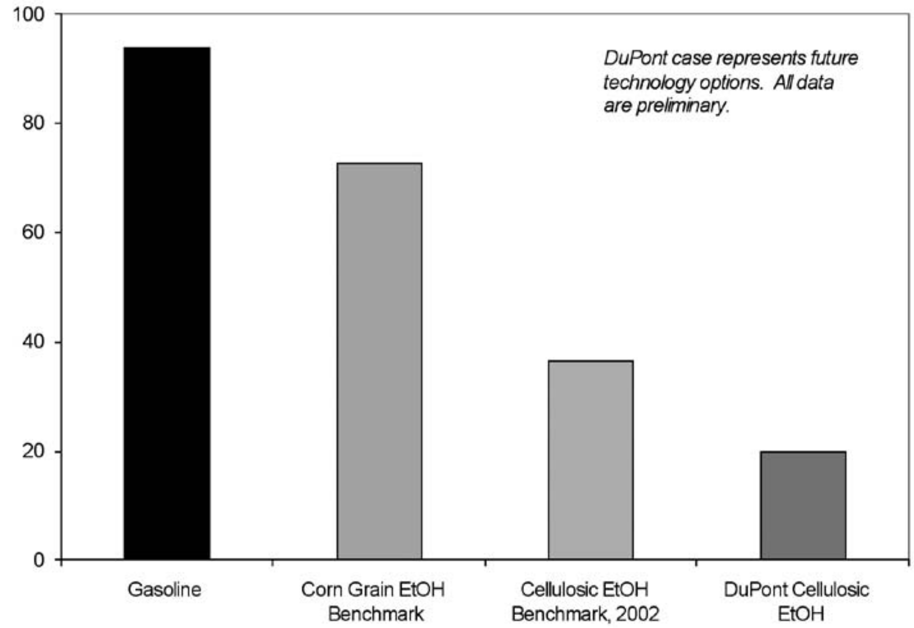

Figure 3: Well-to-Wheel greenhouse gas emissions of DuPont cellulosic ethanol compared to gasoline and ethanol benchmarks.

Alexander Farrell reports WTW GHG emissions for conventional gasoline in his 2006 report on fuel ethanol [Farrell, 2006]. The dry mill corn grain ethanol benchmark shown in Figure 3 is based on Michael Graboski's data set "2000-2004 Incremental Industry" from his report "Fossil energy use in the manufacture of corn ethanol", prepared for the National Corn Growers Association [Graboski, 2002]. The cellulosic ethanol benchmark is based on experimental data from lab or pilot plant studies reported by the National Renewable Energy Laboratory [Sheehan, 2004]. Input data for the benchmarks were appropriately aligned with the DuPont Cellulosic EtOH case.

DuPont highly values input from stakeholder groups and understands that societal acceptance of new technologies is critical to success. In order to engage stakeholders directly, the ICBR LCA Advisory Panel was formed. This panel is made up of representatives of several stakeholder groups including industry, LCA experts, farmers, NGOs and government organizations. The Advisory Panel helps DuPont to identify critical issues, review LCA methodologies and results, discuss communication methods, and improve the credibility of the LCA.

DuPont is developing a sustainable biorefinery solution by encouraging sustainable feedstock production, reducing fossil energy use and GHG emissions compared to current fuel choices, and striving to address key stakeholder concerns.

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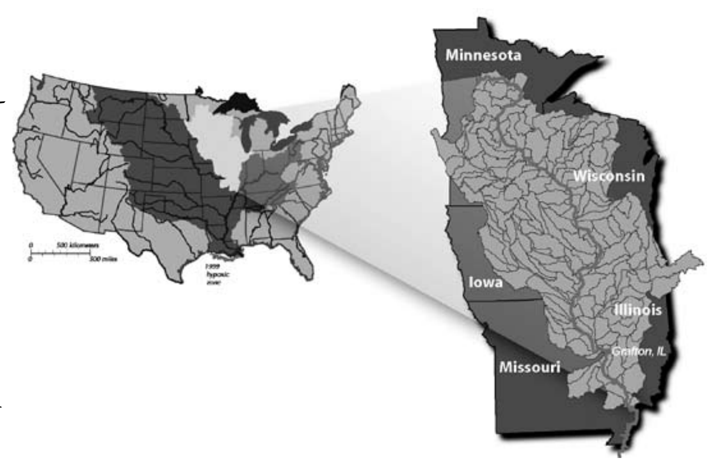
ABSTRACT: *Biofuels and Water Quality in the Midwest: Corn vs. Switchgrass as Feedstocks*

Silvia Secchi, Philip W. Gassman, Manoj Jha, Lyubov Kurkalova, and **Catherine L. Kling** *(Iowa State University)*

Unprecedented increases in biofuel production are occurring: the US now produces seven billion gallons of ethanol compared to less than two billion in 2002. Moreover, the recently passed energy bill mandates 36 billion gallons of ethanol by 2022 with only 15 billion coming from corn. The remaining 21 billion gallons are expected to come from second generation technologies which currently are not profitable, such as cellulosic ethanol.

The increased demand for corn wrought by increased ethanol production has brought equally unprecedented price increases and returns to farmers, particularly in the fertile cornbelt. This has encouraged increased corn production. While the renewable nature of ethanol and other biofuels is environmentally appealing to many, others have raised concerns about the potential environmental degradation associated with biofuel production, especially via corn based ethanol. Concerns related to water quality are particularly troublesome as nitrogen from corn production is often cited as a contributor to Gulf of Mexico hypoxia and local water quality concerns throughout the Midwest.

In this paper, we use an integrated economic and water quality modeling framework of the Upper Mississippi River Basin (UMRB) to conduct scenario analysis to shed light on potential water quality gains associated with using perennial feedstocks in lieu of corn for biofuel production. While cel-



lulosic ethanol has a much higher net energy balance and it produces less greenhouse gases than corn-based ethanol, it is not currently economically competitive with corn. Thus, a change to perennial feedstocks will be costly. Our modeling framework allows us to estimate these costs and to consider the optimal placement of perennial feedstocks based on cost-effectiveness to achieve either an environmental goal (such as improved water quality) or to achieve a given level of perennial feedstock for a given budget. Thus, the modeling system can be used to inform a wide range of future policies related to agricultural land use and conservation.

We begin the paper with a brief history of land use in the UMRB, noting the role of agricultural policy in affecting land use decisions as well as the role of conservation policy in influencing the productivity and profitability of corn as an annual crop. Of particular note is the role policy has played in shaping the landscape.

Next we describe the two key components of the integrated modeling framework which incorporates the notable spatial heterogeneity in the region and integrates micro behavior and natural system responses over small units, rather than relying on typical agent behavior or average physical responses. The units of analysis employed in the system are the National Resources Inventory sample points. There are over 110,000 such points in the UMRB, each representing a combination of weather, soil characteristics, crop choices, rotations, and other agro-ecological conditions, thus allowing us to retain the rich economic and environmental diversity of this managed ecosystem. The economic model is linked to a watershed-level hydrological model, the Soil and Watershed Assessment Tool (SWAT). SWAT is a conceptual, physically based, long-term continuous watershed scale simulation model that operates on a daily time. SWAT is calibrated to existing land use, flow and water quality data for this study.

To help understand the tradeoffs in using perennial feedstocks vs corn for biofuel production, we investigate alternative scenarios with the modeling system, each of which results in increased switchgrass acreage in the UMRB. Specifically, each scenario is designed to result in about 10 percent of the corn acreage being converted to switchgrass. While somewhat arbitrary, this amount of acreage represents the amount needed to achieve about 10 percent of the 2022 goal for cellulosic ethanol. This is in line with large scale crop production models which predict that the UMRB will continue to be a major corn producing area in the future, as the watershed's land has a comparative advantage in corn production

The scenarios considered include one in which the 10 percent of corn acreage converted to switchgrass is chosen based on the lowest cost—i.e., the land taken out of corn production is the land with the lowest cost to achieve the acreage conversion. The SWAT model is used to estimate the changes in nutrients (phosphorous and nitrogen) as well as sediment loadings as a result of this change. The cost of such a conversion is also estimated. In a second scenario, ten percent of the current corn acreage is likewise converted, but this time the land chosen for conversion is targeted to the subwatersheds that have the highest concentrations of nitrate loadings to the Gulf of Mexico. While targeting perennial feedstocks in these locations are likely to be much more costly than the conversion costs in the first scenario, the water quality improvements are likely to be greater as well.

While biofuels may yield renewable fuel benefits, there are likely to be downsides in terms of water quality and other environmental stressors if corn-based ethanol is relied upon exclusively as the feedstock. In this paper, we describe a modeling system that can help identify the costs of encouraging alternative feedstocks, such as switchgrass, to support renewable energy goals. This issue is likely to be a particularly important one in the transition period during which cellulosic ethanol is not economically viable unless its environmental benefits are considered. Our analysis can also help assess ways in which the biofuel mandates of the new energy bill can be implemented, and their associated costs and environmental impacts.

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([1]The Ecosystems Center, Marine Biological Laboratory; [2]Joint Program on Global Change, MIT)

At the beginning of the 21st century, the world's energy consumption was about 400 exa-joules (EJ) per year (12.8 TW), with fossil fuels contributing about 85 percent and all others (nuclear, biofuels, hydro, wind, solar) contributing the remainder. Typical projections of the world economy imply energy demands in 2050 of 550-1000 EJ per year (17.6 – 32 TW), depending on resource availability, and the price, scope and effect on energy demand of policies to limit greenhouse gas (GHG) emissions and air pollutants. If we choose to limit GHG emissions, we will need a variety of non-fossil-fuel energy sources operating at very large scales; that is, supplying 55-100 EJ/year (1.8-3.2 TW) so that each meets about 10 percent of the estimated demand.

Biofuels are being discussed as an important part of the global energy mix in the coming decades. Recently, there has been considerable emphasis on the benefits and costs of current and future biofuels technologies, and on the policies that would encourage their development and implementation. What has been largely missing in these analyses is consideration of the environmental impacts of biofuels operating at multi-terawatt scales.

Here, we use a general equilibrium economic model, EPPA, coupled with a terrestrial biogeochemistry model, TEM, to explore some of the environmental consequences of an aggressive global cellulosic biofuels policy over the first half of the 21st century. The land-use scenario is developed from an extended version of the EPPA model designed to capture economics of "second generation" biofuels and land-use change. We focus on a climate policy scenario that simulates a global effort to control greenhouse gas emissions that starts with the Kyoto Protocol, and intensifies emissions reductions in succeeding years. The climate policy makes the use of fossil fuels more expensive and speeds up the introduction of biofuels, and ultimately increases the size of the biofuel industry, with additional effects on land use, land prices, and food and forestry production and prices. The GHG policy scenario follows Paltsev et al. (http://mit.edu/globachange/www/MITJPSPGC_Rpt125.pdf7) and reflects a path whereby developed countries would gradually phase in a 50 percent reduction in emissions by 2050, like that suggested in recent G8 meetings and consistent with proposed goals in Europe and in pending Bills before the US Congress. Developing countries delay their mitigation action until 2025, and intensify reductions in 2035. The cumulative level of GHG emissions from fossil energy and other industrial activities is approximately consistent with a frequently discussed 550 ppm CO_2 stabilization goal. Reflecting provisions of existing climate policies, fossil emissions of CO_2, including that used in production of biomass, are controlled but land-use emissions are not. As a result, climate policy does not provide incentives to avoid land-use emissions as they may be aggravated by land requirements needed to produce biofuels.

The extended EPPA model explicitly treats crops, livestock, forestry, and food production sectors and five land classes—cropland, pastureland, managed forests, unmanaged grasslands, and unmanaged forest—and conversion among these land types driven by economics. Greenhouse gas emissions as projected by EPPA drive the MIT Integrated Global Systems Model's atmosphere-ocean components, which then drive TEM, leading to changes in crop, pasture, and forest productivity due to changing climate and levels of CO_2 and tropospheric ozone. The productivity changes predicted by TEM are then used to force the EPPA model—changing yields in the agricultural sectors. These changes in yields, together with changing demand for these products over the horizon of the model, as driven by population and income growth, lead to a reallocation of land among uses, and conversion of land among land types. The regionally aggregated land-use types are downscaled to the 0.5o latitude x 0.5o longitude grid level based on a statistical approach for use in TEM. This process generates scenarios that capture first order interactions among land use, climate, and the economy where the pattern of land use is affected by population and economic growth, changing climate, and atmospheric concentrations of CO_2 and tropospheric ozone as they affect both overall productivity and

the regional pattern of production, and by climate policy and energy demand as it drives demand for biofuels.

In addition to evaluating the potential of land to produce biofuels feedstocks, we use TEM to simulate the consequences of biofuels production on various aspects of the global carbon cycle. These include the fraction of global terrestrial NPP co-opted by humans and the degree to which terrestrial carbon storage is reduced during the establishment of biofuels crops or increased due to the fertilization of biofuels crops grown on marginal lands.

We estimate that the land share associated with the production of biofuels feedstocks by 2050 will be 14.4 million km2; about 11 percent of the earth's land surface, and almost the same amount of land currently used to grow food crops. To make way for the new biofuels production areas, we project a release of 39 Pg C to the atmosphere by 2050 from the clearing of native vegetation, especially tropical forests, and the acceleration of soil organic matter decay accompanying the clearing. Release of this large amount of carbon to the atmosphere means that we will not realize a net greenhouse gas benefit from a large global biofuels program until the middle of the 21st century. As more land is brought under intensive management to grow feedstocks for the production of cellulosic biofuels, and with a projected 50 percent increase in the area of croplands, we estimate that the relative proportion of all terrestrial net primary production co-opted by humans will increase from 32 percent today to 53 percent in 2050. The increase in the amount of terrestrial NPP co-opted will likely diminish the ability of land ecosystems to supply essential services to society and reduce biodiversity in biofuels hotspots. Our analysis suggests that biodiversity in critical sub-tropical and tropical ecosystems would be at high risk from an aggressive, large-scale biofuels program.

Approaches to ways of representing the economics of land-conversion decisions is an ongoing area of research, and new work points to the possibility of less conversion of natural areas and greater intensification of production on pastures and grazing lands. Thus, appropriate management of land with proper incentives to avoid deforestation may make it possible to have a substantial biofuels industry while at the same time protecting natural systems. At present, however, climate policy architecture and biofuels mandates provide little or no protection against land conversion, and we need to be concerned that the potential environmental risks we illustrate in this analysis will be realized.

ABSTRACT: *Environmental Impact of Biofuel Cropping Systems: Introduction*

William Parton *(Natural Resource Ecology Laboratory, Colorado State University)*

This talk will focus on the objectives of the Ecological Society of America's (ESA) Biofuel Environmental Impact Conference and present a brief description of the talks presented at this meeting. ESA's concern about the potential environmental impact of large scale implementation of biofuel cropping systems leads them to sponsor this symposium. Converting a substantial fraction of current agriculture cropping systems into biofuels and the potential to expand intensive cropping systems into undisturbed natural grassland and forest systems has the potential to enhance the negative impact of agriculture crop production on the environment. This could result in an increase on greenhouse gas fluxes and nitrate leaching from agricultural systems and lead to further degradation of wildlife habitat. It is important to note that conversion of annual cropping systems (i.e., corn/soybean) into perennial biofuel systems (i.e., switch grass and poplar) has the potential to reduce the negative environmental impact of current agricultural cropping systems. The net impact of major expansion of biofuel cropping systems in the US and the world is uncertain and needs to be evaluated.

ESA members are heavily involved in research to determine the environmental impact of mankind's activities at local, regional, and global scales. ESA is committed to provide accurate scientific information about the impact of man on the environment to the public, and to government agencies at local, regional, and national levels. ESA

does not take positions on specific policies, but is trying to provide the best scientific ecological information for use in both public and private environmental decision making processes. The potential expansion of agricultural cropping systems to produce ethanol, biodiesel, and other biofuel crops will have both positive and negative impacts on the environment. Recent attempts to quantify the impact of biofuel crops on net greenhouse gas production and on the environment have shown that the use of biofuel cropping systems on existing agricultural land results in a reduction in net greenhouse gas production when compared to the use of gasoline. However, expansion of biofuel cropping systems into undisturbed forests and grasslands can actually result in a net increase in net greenhouse gas production when compared to the use of gasoline.

The papers presented at this meeting will focus on evaluating the environmental impact of expansion of biofuel cropping systems on natural and managed ecosystems in the US and will touch on how it could also impact global ecosystems. This symposium will feature the following talks about the diverse impact of biofuels on ecosystems:

- Sustainable Development of Biofuel Cropping systems;
- Private Sector Perspective on Bioenergy Production;
- Socioeconomic Perspective on biofuel feedstock selection;
- Impact of Biofuels on Ecosystem Biogeochemistry (i.e., carbon, nitrogen, erosion and trace gas fluxes);
- Influence of Biofuel Production on Landscape Dynamics;
- Effect of Biofuels on Conservation and Biodiversity;
- Influence of Biofuels on Agriculture and Grasslands;
- Effect of Biofuels on Rangelands;
- Potential use of Forest and Short Rotation Woody crops;
- Use of Secondary Feedstock's for Biofuel Production;
- Synthesis of the Impact of Biofuels on Ecosystems; and
- Use of Ecological Data in the Biofuel Decision Making.

These talks will attempt to: 1) synthesize existing information about known impacts of biofuel systems on the environment, 2) consider all of the major impacts of biofuels on ecosystems, and 3) suggest new research needed to evaluate the environmental effects of biofuel cropping systems. An important output from this conference will be a set of published papers that synthesize the current knowledge about the impact of biofuel crops on the environment.

ABSTRACT: *Municipal Solid Waste as Supplemental Feedstocks*

Donna Perla and William Brandes *(US Environmental Protection Agency)*

In recent years there have been a number of policies, initiatives, and Statutes that have served as critical drivers in the development of alternative transportation fuels, including President Bush's National Energy Plan, the Department of Energy's 30 x 30 Program, President Bush's Twenty-in-Twenty Initiative, the Energy Policy Act of 2005, and the newly enacted Energy Independence and Security Act of 2007 (EISA). All of these include the common goals to create a sustainable domestic biomass industry producing renewable biofuels, that:

- enhance US energy security;
- reduce our dependence on fossil fuels, particularly oil;
- create economic opportunities across the nation, particularly in rural America; and
- reduce greenhouse gas emissions and provide other environmental benefits.

This presentation will consider how one alternative feedstock, municipal solid waste (MSW), could help achieve several of our national biofuels goals and highlight other environmental benefits as well. We note that while this paper focuses on MSW, there are many other energy bearing waste materials that could also be used to support the attainment of these goals.

Keeping Our Eye on the Goals

The recently enacted Energy Independence and Security Act increases the required volumes of renewable fuels in US liquid fuels from 7.5 Bgal/yr by 2012 (required in the Renewable Fuel Standard promulgated in May of 2007), to 36 Bgal/yr by 2022. Corn ethanol production will eventually be capped at 15 Bgal/yr and advanced biofuels and cellulosic fuels will increasingly play a larger role. EISA also mandates three different greenhouse gas reduction performance standards, ranging from 20 percent to 60 percent, to be assessed over the full life cycle of production of the fuel. Greater reliance on a diversity of feedstocks and conversion technologies will be needed.

The goal therefore, is not just to produce biofuels, but to also meet the four national goals, stated above.

- To meet a volumetric goal while also creating economic opportunities, production of biofuel needs to be cost-competitive with fossil fuel. The US Department of Energy (DOE) wants to make cellulosic ethanol cost-competitive at \$1.33/gallon by 2012 and \$1.20 by 2017.
- The drive to significantly increase production will also present additional stressors to air, soil, water quality, water quantity, land use and productivity, ecosystems, and human health; therefore there's a need to understand what environmental improvements and impairments may occur throughout the biofuels supply chain.
- Ensuring greenhouse gas reductions requires measuring the greenhouse gas emissions over the full life cycle of production and use of biofuels, (i.e., from feedstock production, to conversion into fuels, to distribution of fuels, to consumer use).

- Although the amount of energy required (i.e., energy input) and the type of energy used for both feedstock production and conversion is not the only factor contributing to greenhouse gas emissions, these do significantly affect the amount of greenhouse gas emitted over the life cycle of biofuel production and use.

The Feedstock/Conversion Technology Connection

Not all feedstock/conversion technologies result in the same fuels and co-products, as seen in Figure 1 (below). Likewise, they also result in different costs, energy demand, GHG emissions, and environmental impacts, and present unique barriers and advantages.

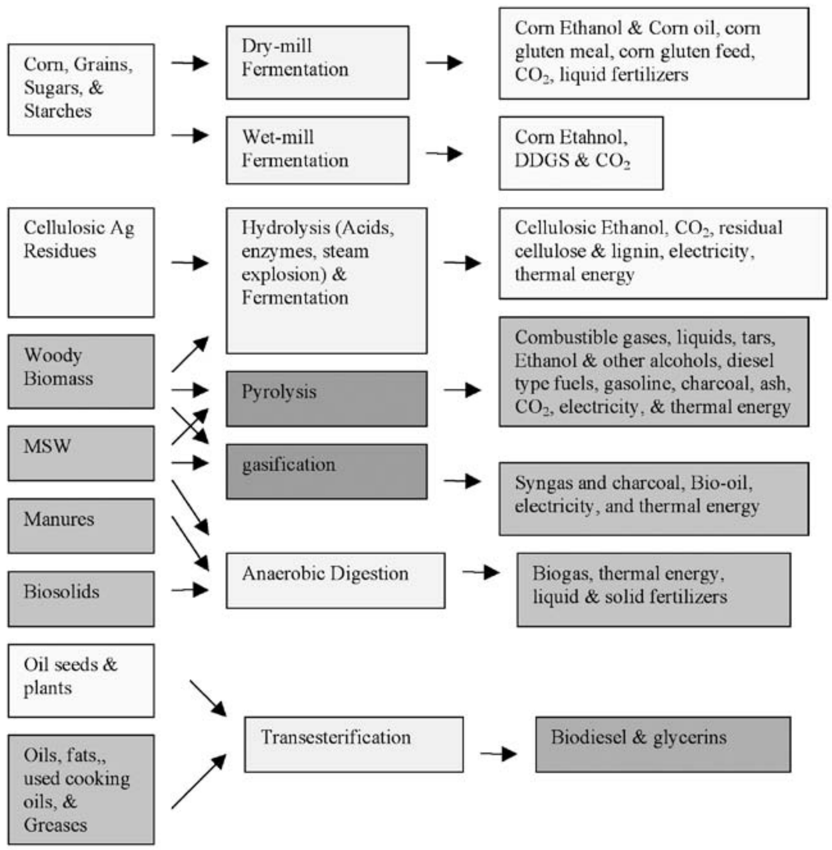

Figure 1: Feedstocks, Conversion Technologies, and Products

The inextricable relationship between feedstock and conversion technology can impact the overall benefits of biofuels production. The costs, energy demands, and GHG emissions of both feedstock production and conversion are significant in proportion to other activities within the biofuels supply chain. Distance between feedstock and conversion technology is a significant contributing factor to the cost, energy input, and GHG output. In addition, different feedstock and conversion technologies will require different land and natural resources, such as water. Clearly, the methods by which we produce these biofuels will affect whether we meet all our stated national goals, rather than a select few. This presentation proposes that further exploration is needed to understand how municipal solid waste as a feedstock can contribute to cost-effectiveness, environmental benefits, GHG reductions, and production capacity for large volumes of biofuel in comparison to other feedstocks.

Why Waste As a Feedstock?

Besides agricultural biomass many solid wastes contain carbon and could serve as a feedstock to produce alternative fuels, including tires, construction and demolition debris, animal wastes, and sewage sludge.

In 2006, the United States generated about 251 million tons of municipal solid waste (MSW), or about 687,000 tons per day. Of this total, approximately 65 percent was biogenic in origin (from plant materials), mostly paper, yard trimmings, food scraps, and wood, while twelve percent was plastics, and the remainder was metal, glass, and other low carbon materials. Thus, up to 77 percent of MSW is theoretically capable of serving as a carbon source for use in the production of alternative fuels either for conversion to fuels or for use as a fuel for power and heat which could serve to significantly reduce both the energy demand and GHG emissions for production of fuels.

In 2006, MSW was managed in the following ways: 82 million tons (32.5 percent) was recycled, 20.8 million tons (8.3 percent) was composted, 31.4 million tons was combusted with energy recovery (12.5 percent), and the remaining 138.2 million tons was discarded (55 percent). EPA's near term goal is to increase the national recycling rate to 35 percent or higher, which by itself serves to significantly reduce GHG emissions by conserving energy and use of fossil fuels.

However, even with these recycling rates, 55 percent of our waste is still landfilled, leading to significant releases of methane. EPA estimates the amount of energy available from the 138.2 million tons of MSW currently being landfilled, at 4,800 BTUs/lb, to be potentially 1,327 trillion BTUs. That is the energy equivalent of 10.7 billion gallons of gasoline. Of course, not all the energy contained in the waste can be captured, but the potential energy available for direct liquid fuel production or for electrical power generation is significant. Given today's carbon, energy, and resource constraints, it is important that an integrated waste management approach be taken to determine the highest and best use of these remaining materials. The benefits of recycling, composting and waste to energy must be compared to establish the optimal combination of management practices. Once the portion that is best recycled or composted is removed, the rest of the materials will be available for the production of alternative fuels to meet our energy needs.

A Comparison of Waste to Other Prevalent Feedstocks

The US Department of Energy's (DOE) Biomass Program plays a primary role in furthering the development, demonstration, and deployment of feedstock and conversion technologies for biofuels production. In implementing the strategy of developing cost competitive biomass technologies for national biofuels production the current focus is primarily on cellulosic ethanol produced via biochemical conversion technologies involving fermentation and hydrolysis. However, some RD&D projects in the past have focused on presorted MSW conversion to liquid biofuels (at Amoco and Masada) and DOE is now beginning to reconsider feedstocks including municipal solid waste, urban wood waste, and construction and demolition wastes.

This presentation broadly compares municipal solid waste and required thermochemical conversion technologies to other agriculturally based cellulosic feedstocks and the biochemical platform. Beyond the carbon and energy value of MSW there are other benefits to MSW as a feedstock.

1. MSW is a domestic source of carbon that is distributed along population lines. It is therefore readily available in all parts of the country, can be converted and used in close proximity to its origin, and therefore would demand less energy resulting in reduced GHG emissions.
2. MSW already is collected in centralized locations. The energy to do this is already being expended and the infrastructure is well established.
3. MSW used to produce electrical energy or alternative fuels could potentially generate revenue for local governments.

The table below highlights some of the key factors that would ensure biomass feedstocks and conversion technologies remain successful in producing biofuels and compares agriculturally based feedstock and the biochemical platform to MSW and the thermochemical conversion platform. Gaps in information are indicators of where further analysis is needed to understand how waste can contribute to domestic production of biofuels.

Characteristics	Agricultural Feedstock & Biochemical Conversion	MSW Feedstock & Thermochemical Conversion
FEEDSTOCKS		
Estimated available quantities	Without cost considerations With cost considerations	Significant, well-distributed, over 138 million tons/year
Reliability & proven technical & economic feasibility of feestock management	Per acre yield uncertain; dependent on climatic conditions, pests, and season by nature	Reliable source that is continuously generated, already collected and managed
Sustainable, cost-effective feedstock supply	Cost to produce feedstocks influenced by irrigation needs and type of energy used for pumping	Collection costs already a part of municipality's budgets, diversion to WTE would reduce disposal costs
BTU value of available feedstock		4500 – 5500 BTU/lb
Feedstock infrastructure: collection, separation, transport, and storage mechanisms	Infrastructures need to be enhanced to handle the volumes of agricultural feedstock; storage sites need to be developed	Infrastructures for collection, separation, and storage of MSW already exist for every county in the US and manage the volumes of wastes that are generated
Natural resource demands in producing feedstock	Expanded land use and shifts in land use; extensive water demands	No increased land demands; MSW is already generated
Emmission/Environmental releases from feedstock production	Significant non-point source run-off of nutrients, pesticides, and soil erosion	Zero if you assume that feedstock will always be generated and managed anyway
CONVERSION TECHNOLOGY		
Provent technical & economic feasibility of conversion technologies	Biochemical platform: Being developed on pilot commercial scale. Cost effectiveness uncertain	Thermochemical platform: Very limited commercial scale deployed in Europe and Japan using wastes and used in US industrial chemical applications
Produce mulitple products (i.e., fuels, chemicals and materials, and heat and power), that maximize the value derived from the biomass feedstock	Biochemical platform: Use lignin co-product as fuel for on-site power and heat	Thermochemical platform: Use syngas co-product as fuels for on-site power and heat

ABSTRACT: *The Biogeochemistry of Bioenergy Landscapes: Clean Water, Clean Air, and Climate Mitigation vs. Business as Usual*

G. Philip Robertson[1], Stephen K. Hamilton[1] and William J. Parton[2] *([1]W.K. Kellogg Biological Station, Michigan State University, [2]Natural Resource Ecology Laboratory, Colorado State University)*

The biogeochemical liabilities of grain-based biofuel systems are in most respects identical to those of grain-based food systems: excessive nitrate leakage, carbon and phosphorus loss, nitrous oxide production, and attenuated methane uptake. Contingent problems are well-known, increasingly well-documented, and recalcitrant: freshwater and coastal marine eutrophication, groundwater pollution, soil organic matter loss, and a warming atmosphere. The conversion of marginal lands not now farmed to annual grain systems, including the repatriation of CRP and other conservation set-aside lands, will further exacerbate the biogeochemical imbalance of these landscapes, as will pressure to further simplify crop rotations.

The expected emergence of biorefineries that accept cellulosic materials offers an alternative outcome: agricultural landscapes that accumulate carbon, that conserve nitrogen and phosphorus, and that lose only small amounts of nitrous oxide to the atmosphere. Fields in these landscapes are planted to perennial crops that require less fertilizer, that have the ability to trap nitrate and phosphorus that would otherwise be transported to groundwater and streams, and that accumulate carbon in both soil organic matter and roots. If mixed-species assemblages, they additionally provide biodiversity services.

A realistic scenario? Perhaps. Maximizing production of crop and forest biomass to support a cellulosic bioenergy program will require the expansion and intensification of agricultural and silvicultural practices. Intensification will almost certainly alter biogeochemical processes that will be a major aspect of these systems' long-term sustainability. But whether intensification of one part of the landscape will help to mitigate biogeochemical excess elsewhere will depend on a detailed understanding of the components of the biogeochemical response and the factors that affect their complex interactions.

Biogeochemical responses of these systems fall chiefly into two areas: carbon neutrality and water and nutrient conservation. Fluxes must be measured and understood in proposed cropping systems sufficient to inform models that will predict biogeochemical behavior at field, landscape, and regional scales. Because tradeoffs are inherent to these systems, a systems approach is imperative. The environmental advantages of maximizing biofuel yields using N fertilizers, for example, may be offset by greater N_2O fluxes and downstream export of nitrate. Only by measuring all major sources of global warming potential (GWP) and nitrogen/phosphorus impact in replicated biofuel systems can we sufficiently evaluate these tradeoffs, which can then be incorporated into models and extended to other landscapes.

Carbon Neutrality (Full Cost Accounting)

A main rationale for biofuel production is its carbon neutrality, i.e. that that there will be no net emission to the atmosphere of CO_2 (or its equivalent in the case of other greenhouse gases). That there is the possibility for a negative carbon balance – by, for example, enhanced soil carbon storage – is an intriguing possibility that could make biofuel production even more advantageous as a net greenhouse gas mitigation strategy. Included in this accounting must be the systems' carbon-equivalent energy yield (the fossil-fuel carbon that is being offset), the ecosystem change in carbon status (whether the production system is storing or releasing carbon over its rotation cycles), the carbon used to plant, maintain, and harvest the system (fuel use, whether biomass or fossil based), the carbon cost of inputs such as nitrogen fertilizer, agricultural lime, and pesticides, and the carbon-equivalent fluxes of other greenhouse gases such as nitrous oxide (N_2O) and methane (CH_4). Additionally there are external terms such as energy consumed by trans-

portation and processing and the opportunity costs associated with putting more land into production that would otherwise have supported unmanaged ecosystems with a different greenhouse-gas balance.

It seems possible that creatively designed biofuel production systems can provide net greenhouse gas (GHG) mitigation at both field and landscape scales. Net mitigation can be achieved through greater soil carbon retention; lower fuel, lime, and nitrogen fertilizer use; lower N_2O emissions; and a positive energy yield. Mitigation potentials will vary among production systems and with time. Soil carbon sequestration, for example, will be greatest in fertilized woody perennial crops and in native grasslands but will diminish with ecosystem age as soil carbon pools level out. N_2O mitigation, on the other hand, will be greatest in perennial systems with low N inputs but will not diminish with age and, with no risk of future release, will have more long-term impact. We expect sustainability (maximum net mitigation relative to energy yield) to be best achieved by some combination of perennial vegetation, low synthetic-N use, and high aboveground net primary production (ANPP) on marginal lands with depleted soil carbon stores.

Water and Nutrient Balances

Well-designed biofuel cropping systems have substantial potential for minimizing environmental impacts apart from those related to greenhouse gas mitigation. Perennial crops, for example, offer the opportunity to minimize nutrient loss and soil erosion while maximizing aboveground net primary productivity, as do annual crops grown with winter legumes or grasses – opportunities that are costly in systems cultivated for grain alone. In a conversion to bioenergy production systems, certain key factors controlling biogeochemical responses are subject to change in ways that are poorly predicted using present knowledge; water and nutrient fluxes will respond to these changes differentially, with implications for soil fertility, crop productivity, and water quality. In addition, alternative production systems will differ in their need for fertilizers, the stability of their soil carbon stocks, seasonal soil water limitation of plant growth, and losses of nutrients to infiltrating waters. Further research on these topics is critically needed as we debate the sustainability of a biofuels economy.

ABSTRACT: *Defining Sustainable Biofuels—or, "It isn't Easy Being Green"*

John Sheehan *(LiveFuels, Inc.)*

The idea of sustainability is one of those concepts that may be easier to define than to apply. Or is it? Consider a few definitions offered by "experts." The seminal definition of sustainability, at least in the past few decades of increased environmental awareness, is the one developed by the United Nations' World Commission on Environment and Development. Their definition is simple, but eloquent. "Sustainable development," the commission concluded after a number of years of careful deliberation, "meets the needs of the present without compromising the needs of the future generations." Sustainability, in other words, is a commitment to future generations in everything we do. This is what I call the "Kumbaya" definition of sustainable development. It is hard to argue with. Beyond this broad and highly idealized view of sustainable development lies a more problematic definition—one that recognizes sustainable development as a careful balancing act among issues of environmental protection, stewardship of natural resources, public health and well being, and sound economic development.

The world-renowned naturalist and conservationist E. O. Wilson puts the concept of sustainability in more stark terms. "The common aim," he writes, "must be to expand resources and improve quality of life for as many people as heedless population growth forces upon Earth, and do it with minimal prosthetic dependence. That, in essence, is the ethic of sustainable development."

In this view of the world, we are required to take a more systemic view of the trade-offs we face in sustaining our lives. The ethical, and ultimately political, aspect of sustainability also comes through loud and clear in this definition. E. O. Wilson's gloomy view of sustainability and his emphasis on the pressures of population growth is reminiscent of one of the earliest voices warning about the limits of economic (and population) growth—the 18th century Anglican parson Thomas Malthus.

Sustainable Development: Buzzword or Buzz Saw?

In the United States, most policy makers have been hesitant to take on the question of sustainability—for very good reasons. It seems a daunting task to take on the question of what is sustainable and what is not in a setting in which individual notions of "good" are as varied as individuals. Recognition of the common good is increasingly rare. In a market-driven society founded on the notion that what is good for the individual is good for the society as a whole, "sustainability" is in the eyes of the beholder. In this menagerie of values and priorities, policy debates about sustainability are apt to fall into a fruitless fight over "special interests."

The "scary" aspect of claims or calls for sustainable development in our actions is that they drag us into moral controversy—something most of us are not comfortable dealing with. If sustainability is a "buzzword", it is because we never seem to come to a common understanding of the ethical judgments that must go into its definition and application. If sustainability is a "buzz saw", it is because it will force us to engage in a difficult dialogue steeped in questions of individual ethics and social justice in which the participants run the risk of being cast as uncaring "Scrooges" , greedy profiteers or reckless plunderers of the planet.

Tackling the Sustainability of Biofuels

Sustainability is better seen as a directional measure. This view moves us from the impossible task of defining an absolute understanding of sustainability into the more manageable (but still problematic) task of deciding if one set of actions or options is more or less sustainable than our current practices. Biofuels are often touted as a means of achieving greater sustainability in our society. But, this is far from an accepted view—nor should it be. Are biofuels sustainable? The answer depends on a lot of things, such as the particular products being proposed; the strategies for production, collection and conversion of the biomass; the economics of the products; the social impacts of the technology, etc. The list could go on. Any new industry has the potential to be badly implemented. For this reason, talking about sustainability in the earliest stages of developing and promoting new technology is critical.

In assessing the sustainability of biofuels, I take my cue from E. O. Wilson's view of sustainable development:

A focus on the Earth as a whole. Wilson is an ecologist. As such, he recognizes the importance of a holistic and systemic view. Such a view inevitably leads to a life cycle-based approach to understanding sustainability. By choosing a life cycle framework, we are forced to explicitly identify how broad and comprehensive we want to be in setting the boundaries of the system within which we quantify the impacts of biofuels. Life cycle analysis requires us to consider the system's use of natural resources extracted from the Earth, as well as the system's environmental burdens on the Earth. This is a global perspective, one that has become increasingly important today as we witness the unintended consequences of biofuels deployment in the developed world on the rest of the developing and third world nations.

Expanding resources. By definition, we cannot "expand" the nonrenewable resources of the Earth. This leaves only two options: 1) we can use existing nonrenewable resources more efficiently and effectively, and 2) we can shift, where possible, from a reliance on nonrenewable resources to the use of renewable resources. In assessing any technology, it is never a simple choice of one approach or the other. There is no such thing as a technology that is purely renewable. All depend on some nonrenewable resources. Anyone who suggests otherwise is either disingenuous or naïve. Ultimately, even renewable resources are not infinitely expandable. The one resource upon which renewable resources depend is land—and it is most definitely limited.

Quality of life. Improving the quality of life for the society as a whole is a fundamentally political and economic question. At a minimum, we can begin to address this issue by looking at the economic aspects of the technology. In the case of biofuels, we can at least understand the direct costs to society of replacing non renewable petroleum with renewable biomass resources. We can try to understand the possible benefits that biofuels offer to our rural community. But these questions barely scratch the surface. When fuel competes with food, feed and fiber for use of our arable lands, we are faced with a deeply ethical and political set of choices.

The ethic of sustainable development. An ethical life is a life of deliberate choices. These choices usually involve trade-offs. These trade-offs come in the sacrifices that we bear today, and in the form of sacrifices that will be borne by future generations. This is what makes sustainability so difficult. Some of the trade-offs can be quantified in purely technical terms, while others cannot. The mistake so often made in assessing sustainability is to focus on technical issues that are the purview of the "experts" for which "expert opinions" can be handed down to the public at large. Purely technical answers are trivial, compared to the kinds of answers we need to make as a society when it comes to something as basic as meeting our energy needs. Furthermore, because it is difficult to separate the technical issues from the ethical and political issues, expert studies often have little credibility in the political debate. At best, they ignore the social issues that lie at the root of the question they are attempting to address. At worst, they conceal the social and political choices on which they are based.

In this talk, I will sprinkle each of these aspects of sustainable development with examples relevant to the current debate on the role of biofuels as part of a sustainable energy future.

Open Dialogue

The only credible and useful way to broach the question of the sustainability of biofuels is through a combination of technical analysis and open dialogue. Unfortunately, this has rarely, if ever, been done. That is our challenge. If we are successful, this workshop will have begun a conversation in which many more questions have been raised than have been answered. If we are wise, we will avoid the trap of adversarial political warfare in which the lobbying foot soldiers—armed with opposing expert opinions—blast each other with contradictory studies and findings. This will only leave the public at large even further confused than they already are. I leave you with the words of one of my heroes, the 20th century philosopher and educator Mortimer Adler: "Let us engage in the serious business of conducting our discussion rationally and logically to discover the truth about points on which we disagree."

ABSTRACT: *Are Rangeland Biofuel Feedstocks Ecologically Sustainable?*

Linda L. Wallace[1] and Robert B. Mitchell[2] *([1]University of Oklahoma; [2]USDA Agricultural Research Service, Grain, Forage & Bioenergy Research Unit)*

We have examined several aspects of biofuel feedstock production from rangelands, primarily focusing on switchgrass (*Panicum virgatum*). Defining sustainability as the long-term maintenance of energy flow, nutrient cycling, and ecosystem services (including biodiversity, habitat maintenance and usage, genetic diversity, etc.), we have examined how each of these components has fared in switchgrass cultivation, compared with the production of biofuels from grain crops, mixtures of grassland species and our current fossil fuel usage. Studies on these issues have been reported from plot studies, farm-scale trials, and modeling studies at a regional or larger scale.

Like most warm-season grass species, switchgrass can be tremendously productive in moist, fertile sites. Biomass yield for established switchgrass stands managed for Bioenergy production has ranged from less than 3 to more than 20 Mg ha-1, depending on location and cultivar. Although switchgrass production can not compete with the amount of corn grain and stover that can be produced on prime cropland, switchgrass is competitive on marginal cropland. Additionally, the nutrient and fossil fuel inputs required to optimize production are far less for switchgrass than for corn or soybean systems. Mixed grassland systems dominated by warm-season grasses can be highly productive with native warm-season grass standing crop ranging from less than 2 to more than 10 Mg ha-1 being reported for native tallgrass prairie.

A critical element in biofuel production is the energy ratio of the crop, i.e. how much energy can be produced vs. that energy used in the establishment, management, and harvesting of the crop. Again, switchgrass has performed favorably with a mean petroleum energy ratio of 13.1 being reported from sites in the north central US Few studies have been conducted on grass mixtures. Energy ratios (output/input) of 5.51 to 8.09 have been reported for experimental biodiversity plots in Minnesota. More data on energy ratios directly comparing switchgrass, native prairie and other diverse grasslands are needed.

Most studies show switchgrass fields to be carbon-negative, but this is highly dependent upon the amount of fertilizer applied. High fertilization rates can result in a crop being carbon-positive. Switchgrass response to N fertilization is very site-dependent. A study in South Dakota Conservation Reserve Program (CRP) land dominated by switchgrass reported the application of 56 kg N ha-1 increased total biomass, but there was no benefit to applying more N. However, in Nebraska and Iowa, biomass yields of 'Cave-In-Rock' switchgrass increased as N rate increased from 0 to 300 kg N ha-1, but residual soil N increased when more than 120 kg N ha-1 was applied This is crucial to examining the impact of biofuel feedstock production on other nutrient cycles. Superfluous fertilization can result in nutrients entering surface or groundwater. More research on the effects of growing feedstocks in diverse mixtures, native prairies and the inclusion of legumes in the field is needed, particularly to reduce exogenous N inputs and obviate nutrient leaching from the system. Little work has been done examining the hydrology of these energy crops.

A great deal more research is needed on the effects of biofuel feedstock production on ecosystem services. Greenhouse gas mitigation has been shown for a number of systems, with the caveat that increased production of N_2O can occur in highly fertilized systems. Highly diverse grasslands are excellent habitat for a large number of wildlife, bird and insect species. Most studies of the habitat quality of biofuel plots have shown that small mammals, for example, primarily key in on the availability of canopy cover, rather than being focused on which species constitute that cover. However, bird species richness and insect occurrence in switchgrass fields are different from those found in native grasslands. It is critical to note that comparisons of insect occurrence, abundance, and species richness in switchgrass fields and native grasslands are areas needing further research.

Switchgrass has a tremendous amount of genetic diversity. In some cases, switchgrass monocultures function

well in variable environments due primarily to high genetic diversity within the plot. The effects of these plots on gene flow and the effects of genetic diversity on plot stability are also areas ripe for further research.

To fully answer the question of whether or not rangeland cellulosic biofuel feedstock production is sustainable, we need more empirical work on monocultures throughout the Great Plains. In addition, we need studies directly comparing monocultures, mixed grass species, and native grasslands. This work needs to include not only careful ecological analyses, but also needs to look at economic feedbacks and how both ecological and economic sustainabilities may be related.

ABSTRACT: *Biofuels and Biodiversity*

John Wiens and Joe Fargione *(The Nature Conservancy)*

Conservation of species, communities, functional ecosystems, ecosystem services, or natural values all depend on protecting places where biodiversity can persist and prosper. Much of the recent emphasis of conservation has therefore been on public or private protected areas – places that are owned, managed, or have a legal obligation to foster biodiversity. But protected areas by themselves are insufficient to stem the erosion and loss of global biodiversity. Conservation must be extended to include the landscapes where people live, work, and produce food and fiber – and now biofuels. These land uses may often be compatible with conservation objectives, at least to some degree.

Landscapes are not static, however. Changes in global economics, particularly those that affect agriculture, can lead to rapid shifts in land uses. For example, expanding demand for soybeans has altered cropping practices in the Midwestern United States and led to the conversion of large areas of natural vegetation and pasturelands in the Cerrado of Brazil. More recently, demand for ethanol has increased corn acreage in the United States and reduced soybean acres, exacerbating landscape changes in Brazil and elsewhere. Lands that were once considered marginal for agriculture are being pressed into crop production, usually with heavy subsidies of fertilizers, water, and pesticides. Prime agricultural lands are being eroded by expanding urban and suburban developments, even as the demands of agriculture to feed a growing population escalate.

Biofuels production and processing capacity have grown at a nearly exponential rate over the past several years. This growth has resulted from the convergence of several factors – rural economic development, increasing energy costs, energy security, growing global energy demands, and awareness of the need to reduce global carbon emissions to mitigate climate change. There has been considerable discussion of the economic, energetic, and carbon-balance costs and benefits of various biofuels. Our emphasis here is on the intersection of biofuels and conservation: How will the production of biofuels affect land use, and are there ways to enhance the compatibility of biofuel production with biodiversity protection?

The most immediate consequences of expanding biofuels production are on habitat quantity and quality, through the conversion to biofuel crops of existing agricultural and abandoned lands and other lands considered marginal for agriculture. For example, replacing even a tenth of the current fossil fuel demands in the United States by biofuels such as corn ethanol could require over 40 percent of the land currently under crop cultivation. The production targets of 15 billion gallons of corn ethanol by 2015 and an additional 21 billion gallons of advanced (cellulosic) biofuels by 2022 proposed by the US Congress may require an increase of 20 million acres of corn cultivation and as much as an additional 50 million acres of a cellulosic biofuel such as switchgrass. Such demands would entail massive changes in land use, extending well beyond lands currently used for agriculture.

Some indications of the potential impacts of such changes on biodiversity are already apparent. In many parts of the country, particularly the Midwest, economically marginal land or areas vulnerable to soil erosion have been enrolled in the Conservation Reserve Program (CRP). The benefits of this land for wildlife have been well-documented, particularly for birds. Elevated corn prices will cause significant conversion of many, if not most, CRP lands, both through direct conversion to corn and indirectly, as corn replaces other crops, which move onto more marginal land. At current corn prices, for example, as much as 50 percent of the CRP land in Iowa is likely to be converted to corn in the next few years. Higher corn prices also increase the costs of livestock production where corn is used in feedlots. One consequence may be an increase in the economic returns for free-range beef, potentially reducing the loss of rangelands to development and thereby fostering land uses with greater conservation compatibility. The development of cellulosic ethanol sources may also yield significant conservation advantages over corn ethanol by allowing marginal lands to be retained in perennial biomass.

Biofuels must be processed to produce liquid fuels or energy, which requires that they be transported to the processing sites. The landscape footprint required to support a processing facility depends on the production yield of the biofuel stock and the transport distance and costs. The acreage of corn required to supply a processing plant, for example, may be more than 7 times that of a cellulosic stock such as Miscanthus. In either case, however, transport economics favor monoculture cropping, which reduces landscape diversity, increases disease susceptibility, and may foster the spread of invasives.

Given the current trajectories of biofuel demand and development, the outlook for conservation is not encouraging. Enhancing the compatibility of biofuels with biodiversity will require that the conversion of marginal lands and native habitats to biofuels be minimized, perhaps by rewarding the use of abandoned agricultural lands. The development of high-yield biofuel stocks that have a small footprint on the landscape should be emphasized. Above all, decisions and incentive programs should be based on comprehensive accounting of the costs, benefits, and long-term sustainability of different biofuels options, an accounting that includes indirect economic and environmental effects, an accurate assessment of the potential effectiveness in contributing to reductions in atmospheric carbon levels, economic and non-economic ecosystem services, and the conservation of biodiversity over entire landscapes.

ABSTRACT: *Production of Biofuels Feedstock on Agriculture Land and Grasslands*

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Managed agricultural systems are being proposed as major contributors to future biomass feedstock systems according to the Billion Ton Vision and the 30 by 30 Plan. It has been estimated that between 550 and 1200 million Mg of biomass will be required annually to meet these bio-based transportation fuel targets. Grain, crop residues, and dedicated energy crops are projected to contribute about 800 million Mg of feedstock annually by 2030. Additional feedstocks will include: forests; agriculture, industrial, and household waste streams; and unmanaged systems. Sustainable feedstock production at these levels will be a monumental challenge. We discuss three biomass sources coming from managed agricultural systems (grain, crop residues, and dedicated energy crops) and identify environmental issues with each.

Currently the major feedstock for biofuel production, grains have risen to historic prices as demand for feedstock for ethanol production has consumed grain market supplies. Higher prices for other grains reflect the linkage of these

outputs in the marketplace. Responding to prospect of greater return, grain producers shifted wheat and soybean production areas to corn in 2007. Effects of this land use change include fewer rotations, more monoculture, reduced crop diversity, and the use of less desirable land for row crop production. Alternatively, greater demand for grains for biofuel production may be met by increasing yields through improved crop genetics and innovative production practices. However, these approaches, applied inappropriately, may have negative effects on soil, water, and air resources.

Existing and emerging technologies are available that can improve the efficacy of production inputs while improving productivity and protecting the environment. In addition, other underutilized production practices like using cover crops or green manure crops planted at the end of the main crop season have potential for environmental protection. These crops can scavenge residual nutrients from the soil before they enter surface and ground water systems and their biomass production can serve as livestock feed, biofuel feedstock, or soil amendment.

Cellulosic ethanol offers alternatives to intensified and expanded grain production. Residues remaining in the field after crop harvest are viewed as readily available cellulosic feedstock and the knowledge and system to produce this feedstock exists. Because of the tight linkage between crop biomass production and grain yield, more crop residue will be produced as crop grain yields increase. Sustainably available crop residue biofuel feedstock has been estimated based on the amount of residue needed to control erosion in the highly publicized Billion Ton Vision and other analyses. Recent reports argued that these estimates may greatly exaggerate the potential supply as the amount of crop residue needed to replenish soil organic carbon, critically important in a number of soil functions, was substantially greater than the amount needed to control erosion.

Both annual and perennial dedicated feedstock crops are being investigated for biofuel production. Annual crops, such as energy cane, sudan grass, and sorghum, have environmental limitations similar to those identified for grain and crop residues. Annual crops are attractive for producers as they fit into existing cropping practices and produce large amounts of biomass in one season. Use of these relative unusual crops in cropping sequences will increase crop diversity.

Perennial biomass crops (i.e., switchgrass, alfalfa, Miscanthus), because of their multi-year production cycle, have advantages over other feedstock species. Far less tillage is needed for production of perennials than annuals making them better suited for production on more fragile lands. The assumption exists that dedicated feedstock species require fewer production inputs but this assumption is based on systems having relatively inefficient harvest systems (grazing) or low production expectations (CRP). With annual harvests and expectations for yields of 10 Mg ha-1 input of plant nutrients will be comparable to that of row crops with similar biomass remove rates. Wide-scale production of perennial species in monoculture may also experience pest problems similar in magnitude to row crops. For example, commercial forage alfalfa production can require substantial use of pesticides.

Agricultural land and grasslands have the potential to contribute greatly to the feedstock needs of the emerging biofuel industry. An array of feedstocks, production technologies, and solutions must be explored and amalgamated in a collage that provides the sustainable feedstock supply demanded by the biofuel industry. Creating this mix of technologies will require a coherent, coordinated energy policy based on cooperation among agencies, industry and industry groups, and groups in society.

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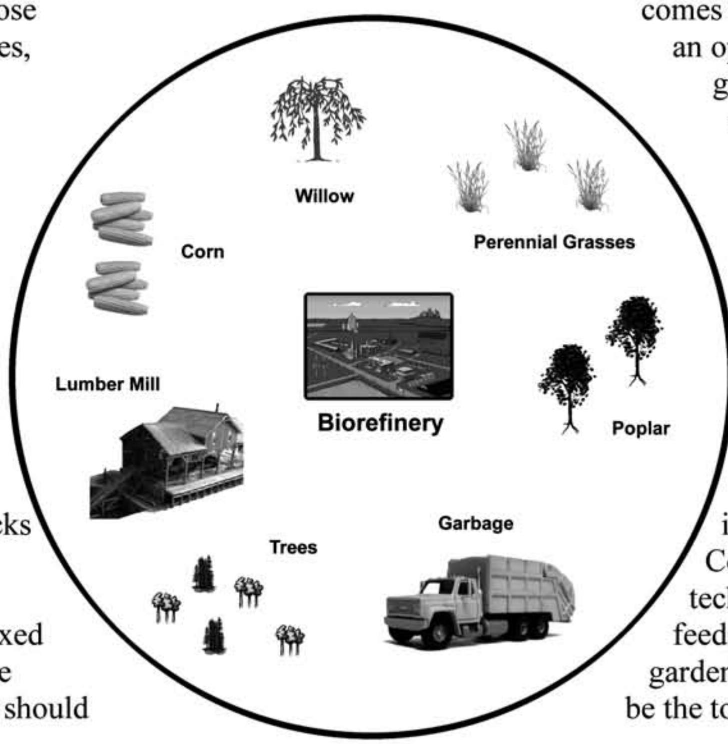
The MACHINE in the GARDEN

Global climate change and oil security pose enormous challenges for twenty-first century industrial society. Science tells us that to avoid dangerous levels of climate change we must reduce greenhouse gas emissions 80 percent by mid-century, while demand for oil increases, and reserves are increasingly concentrated in a few volatile countries.

There is considerable interest in using biofuels to meet these challenges, and production is exploding while governments and investors pour billions of dollars into advanced biofuels, such as those derived from cellulose. Because cellulose comes from many different sources, an opportunity is created to generate a feedstock supply greatly more diverse than our current monoculture approach to agriculture.



Success of this attractive alternative, using native polycultures as a feedstock base, hinges on having a conversion technology that can turn mixed feedstocks into commercially viable fuels. Commercializing a conversion technology capable of handling mixed feedstocks—the "machine in the garden"—is the key to this vision and should be the top priority for research.

The Energy Foundation and the McKnight Foundation work in partnership to promote sustainable biofuels production. For more information visit us at www.ef.org/biofuels.

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POSTER ABSTRACTS

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Greenhouse gas mitigation potential with cellulosic and grain bioenergy crops

The land use impacts, such as nitrous oxide (N_2O) emissions and soil carbon sequestration, are associated with the largest changes in life cycle greenhouse gases from growing bioenergy crops. The biogeochemical model DAYCENT simulates fluxes of carbon (C) and nitrogen (N) between the atmosphere, vegetation, and soil. From weather, soil-texture class, and land-use inputs, DAYCENT simulates crop production, soil organic-matter changes, and trace-gas fluxes. The objectives of this study were to evaluate the ability of DAYCENT to simulate measured N_2O emissions, the largest greenhouse gas source, and quantify life cycle greenhouse gas emissions from bioenergy cropping systems. Switchgrass, reed canarygrass, and a corn rotation with soybeans and alfalfa were grown in central Pennsylvania and N_2O emissions were measured. Given the high variability of N_2O fluxes in natural systems, DAYCENT captured the observed daily variability in N_2O emissions and simulated the observed seasonal patterns within bioenergy crops and differences in annual mean emissions among systems reasonably well. Compared with the life cycle of gasoline and diesel, in the long-term, where soil C sequestration was assumed to no longer occur, ethanol and biodiesel from the corn-soybean-alfalfa rotation reduced net greenhouse gas emissions by 43 percent, reed canarygrass by 97 percent, and 110 percent for switchgrass. Higher yielding switchgrass cultivars further reduced the life cycle greenhouse gases associated with ethanol use.

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Land and net primary production requirements of biofuels

As the global demand for energy continues to increase, biofuels, or fuels made from plant material, are frequently identified as an important component of our future energy supply. Based on calculations of the most optimistic reported net energy values of eight potential sources of biofuel (corn, low-input high-density biomass, palm, rapeseed, soybean, sugar cane, sunflower, and switchgrass), we estimated the amount of land and net primary production (NPP) required to produce enough biofuels to meet current and projected oil demands. Currently, the biofuel sources with the highest net energy per land area (J/ha) are switchgrass, sugarcane and rapeseed. The biofuel sources with the highest net energy per unit biomass (J/kg C) are switchgrass, low-input high-density biomass, and rapeseed. We compared the land and NPP requirements to global available cropland and global land NPP. Our conservative estimates suggest that, using the biofuel sources with the highest net energy values, a minimum of 70 to 232 percent of global available cropland or a minimum of 15 to 44 percent of global land NPP would be required to produce enough biofuels to meet global oil demands in 2005. This could dramatically alter the environment by increasing habitat change and fragmentation, altering species diversity and composition, and impacting soil and water quality and availability. Although the efficiency of biofuel production will continue to increase as technology improves, it is important to consider the potential consequences of conversion to biofuels and develop strategies to minimize the impacts of adding this additional demand on the planet's resources.

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Climate change policy, biofuels, and implications for land use change

Greenhouse gas (GHG) mitigation policy currently being debated will price GHG emissions through a tax or cap-and-trade system. This pricing scheme will increase the demand for biofuels as fossil fuel alternatives and through GHG offset markets. Increasing biofuel demand will impact land use, as landowners alter cropping patterns and increase production onto marginal or idle lands, potentially at the detriment of the environment. Furthermore, the amount, type, and location of biofuels produced will be a function of the per-unit "price" of GHG emissions (or $/tonne CO_2 equivalent). In this study, we use the Forest and Agricultural Sector Optimization Model with Greenhouse Gases (FASOMGHG) to describe the optimal spatial and inter-temporal biofuel strategies for the US at varying CO_2 prices over the next century. FASOMGHG is an economic model of US agriculture and forestry that has been used extensively to analyze GHG mitigation options in the two sectors (McCarl and Schneider, 2001). This poster will present figures detailing the effect of GHG pricing on the biofuels industry and the national land-use implications of such policies, discussing key ecological dimensions at risk (grassland and forest). Results suggest that the optimal portfolio of domestic biofuel production and land use will vary as some activities provide significant GHG offsets, but are only economically feasible at higher CO_2 prices (i.e. switchgrass and hybrid poplar for electricity and cellulosic ethanol). Such energy crops are the dominant biofuel strategy at higher offset rates (>$50/tonne CO Eq.), and can improve environmental quality relative to other agricultural biofuels.

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EPA's new research focus on ecosystem services, with a study of biofuels expansion in the Midwestern US

EPA's Ecological Research Program is initiating new research to characterize ecosystem services and to enable their routine consideration in environmental management and policy. Research will be organized around two foci: ecosystem type (wetlands and coral reefs will be studied) or geographic place (four place-based studies are being initiated). Research themes cutting across these systems and places will include mapping, monitoring, future-scenario analysis and valuation of services; impacts of reactive nitrogen; relationships to human health; development of appropriate decision support systems; and education. This 5-year thrust will require that EPA's ecological researchers develop new partnerships across disciplines (e.g., with economists and other social scientists) and agencies. The research will enable decisions that better account for the full value of ecosystem services and expected changes in service flows.

The "Future Midwestern Landscapes (FML) Study" is one of the four place-based studies currently being planned. Over a 13-state area of the Midwest, for a baseline year and at least two alternative future scenarios, FML will construct detailed land use/land cover maps and characterize a variety of services. Future scenarios will contrast the current path (i.e., the incentivized ramp-up of biofuel production, initially emphasizing corn starch ethanol) with an alternative path in which land uses producing a wider range of services are hypothetically incentivized. A web-based decision-support tool is planned that will construct maps showing interscenario comparisons of produced services, according to user-weighted service indices. The tool will highlight opportunities for conservation and will lower service trading-related transaction costs. Challenges to be overcome in project design involve the linkage of multiple ecological models over a large geographic area and the determination of appropriate valuation methods for each ecosystem service.

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The global potential for biomass energy on abandoned agriculture lands

Increased production of biomass for energy has the potential to offset substantial use of fossil fuels, but it also has the potential to threaten conservation areas, pollute water resources, and decrease food security. The net effect of biomass-energy agriculture on climate can be either cooling or warming, depending on the crop, the technology for converting biomass into useable energy, and the contrast in carbon stocks and reflectance of solar radiation between the biomass crop and the preexisting vegetation. The area with the greatest potential to yield biomass energy that reduces net warming and avoids competition with food is land previously used for agriculture or pasture but now abandoned and not converted to forest or urban areas. At the global scale, potential aboveground plant growth on these abandoned lands has an energy content representing 6 percent to 8 percent of world primary energy consumption in 2006. Increasing biomass energy production beyond this level would likely degrade food security and exacerbate forcing of climate change.

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Carbon footprint from thirty ton switchgrass yields in the irrigated west

Bioenergy crops have the potential to reduce the rate of atmospheric CO_2 enrichment as well as supply a portion of US energy needs. Perennial herbaceous plants (e.g. switchgrass) have been shown to improve soil quality, enhance nutrient cycling, improve wildlife habitat and sequester C. However, none of this work has been conducted in the irrigated west. Our research shows that switchgrass (*Panicum virgatum*) production in the warmer irrigated regions of the PNW is a viable bioenergy feedstock, can improve soil quality and sequester C in soil, and may attain biomass yields of 30 Mg ha-1 in the fifth year of production. These production levels correspond to more than 10,000 l ethanol ha-1, a C export of 12.0 Mg C ha-1, and root production of 13 Mg C ha-1, resulting in 4.0 Mg of soil C ha-1 derived from switchgrass. Switchgrass is an efficient N user, requiring 1 kg of N to produce 83 kg of biomass. This research provides fundamental knowledge of the potential for switchgrass to be a viable energy crop and play a role in C sequestration in the PNW for growers considering changing from annual cropping to a permanent perennial crop.

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Environmental impact and sustainability of feedstock production

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 dominated by the soybean-corn rotation, depleted soil carbon and nitrogen stores, caused extensive soil erosion and contributed to 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. To date, there have 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.

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Ecological and economic suitability of *Liquidambar styraciflua* for biomass production

Interest in cellulosic biofuel production has resulted in considerations of planting fast-growing non-native tree species as monocultures. Liquidambar styraciflua (sweetgum), a valuable and fast-growing native pioneer species has valuable attributes that make it a better choice, from ecological perspective, than all exotic and most native tree species, as well as other fast growing plants. Sweetgum is capable of fast growth at high densities, vigorous stump sprouting, and unlike nearly all other native hardwoods, it can also produce root sprouts and maintain an excurrent crown growth habit (narrow non-spreading crown) at early stages of development. The last attribute makes it capable of growing in very dense pure stands, but it also allows it, at larger spacings, not to occupy all between-crown spaces and therefore grow well in mixtures with other shade intolerant species that do not have fast initial growth. Measurements of approximately 6,500 trees planted at high density (1.5 x 3.0 m) in five blocks showed high survival by age 13, continued excurrent crowns, and live crown ratio (an indicator of tree vigor and crowding) of over 30 percent (excluding edge trees). Comparisons of sweetgum silvics with those of other tree species demonstrate that it is one of the best choices for plant biomass plantings for its abilities, among others, to grow with wide variety of other tree species, thus maximizing ecosystem value and minimizing the negative impact of biofuel production from cellulosic biomass.

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Powering America and the US economy

The Agricultural Research Service is the principle in-house research agency of the United States Department of Agriculture and has been conducting research to find new uses for agricultural commodities and byproducts for over 60 years. USDA-ARS has 2,100 scientists located at 100 locations across the country who carry out research in Animal Production and Protection, Crop Production and Protection, Human Nutrition and Food Safety, and Natural Resources and Sustainable Agricultural Systems. Research in the Bioenergy National Program is conducted nation-wide at 30 locations and is coordinated through three components: Feedstock Development, Feedstock Production, and Conversion &

Co-Products. Feedstock Development research focuses on using basic genetic and molecular science to produce crop feedstocks that have superior traits for conversion to bioenergy and value-added co-products. The Feedstock Production component provides analytical tools to identify the best combinations of sustainable practices for advanced production systems that meet the logistical requirements of biofuel production facilities, while maintaining the quality of the natural resources base. Conversion & Co-Products research develops new technologies to maximize the profitability of biorefining, particularly for small-scale systems that can be fully integrated into farming operations or rural communities. The overall integration of USDA-ARS bioenergy research is accomplished by four cross-component teams that develop optimal systems for the conversion of lipids to fuels, starches and sugars to EtOH/BuO, cellulosics to EtOH/BuOH, and thermochemical processing. This research will lead to new and improved non-food products, including fuels, expand markets for farm products, replace imports and petroleum-based products, and offer new opportunities to overcome environmental challenges.

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Carbon "payback time" for biofuel crop expansion in the tropics

The recent biofuels "boom" has been driven in part by the promise of reduced greenhouse gas emissions. However, the climate benefits of liquid biofuels, such as ethanol and biodiesel, are highly dependent on how and where the feedstocks are produced. Many studies have already pointed to the fossil energy required to produce, transport, and refine agricultural biofuels, and how this reduces their overall carbon mitigation benefits. But nearly all studies neglect carbon dioxide emissions from the likely agricultural land conversion associated with expanded biofuel feedstock production. Here we quantify the carbon flux from biofuel crop expansion pathways in the tropics. We frame our analysis in terms of the "ecosystem carbon payback time" for liquid biofuels – the number of years would it take for the avoided fossil emissions from biofuels to offset losses in ecosystem carbon stocks during land conversion. The different pathways for biofuel crop expansion will have large implications for carbon savings and should be considered when evaluating biofuel strategies. For example, biofuel crop expansion into carbon-rich forests may lead to carbon deficits lasting several decades to millennia because the loss of carbon from deforestation far exceeds carbon savings from biofuel substitution of fossil fuels. On the other hand, carbon savings will begin immediately if biofuels are produced on carbon-poor lands, such as already-degraded grasslands or pastures. Future assessments of bioenergy strategies must take into the account the carbon content of landscapes being used, and cleared, for biofuel feedstock production.

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Policy implications of the Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007 mandates an increase of biofuel production reaching 36 billion gallons by 2022, as well as numerous energy efficiency measures and renewable energy research and development directives. While there are environmental safeguards in place to help ensure that these biofuels are developed in an environmentally responsible manner, the pathways to achieving it are complex. Scientific research will shape how advanced biofuel feedstocks develop, taking into account lifecycle greenhouse gas emissions, ecological and economic impacts in the US and abroad. These studies, along with policy rulemakings, will shape the environmental footprint of biofuels and can pave the way for even higher standards to be met.

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Global and regional potential for biofuels from residue and waste

As co-products, agricultural and forestry residues as well as municipal solid waste (MSW) represent potential low cost lignocellulosic biomass feedstocks for the production of second generation biofuels. For agriculture, the maximum supply is a function of crop-specific attributes (harvest index and energy content of residue) and total crop production (yield and total harvested area). For forestry, two potential residue streams are considered: residue left from timber harvesting (tree tops and branches), and residue from mills (wood scraps and sawdust). The harvest index, milling efficiencies, and energy content of wood are used to estimate the total potential supply of forestry residues. MSW is predicted as a function of GDP and the proportional waste composition indicative of various regions. Limiting factors for supply of biomass feedstock from these sources include agricultural and forest productivity, residue required to prevent soil erosion and maintain soil nutrients, and cost of aggregation and transport. Using the ObjECTS

MiniCAM Integrated Assessment Model, the global role of residue biomass as a feedstock for biofuels is modeled for the next century under different climate policy scenarios.

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Land change scenarios in the Northern Great Plains arising from extensive cultivation of biofuel feedstocks

DOE's "Billion Ton Study" explored the feasibility of redirecting plant biomass into production streams to alleviate national dependence on petroleum for transportation fuels. It has generated both support and skepticism, but the likelihood for land cover change in the Northern Great Plains is very high. This region presently lays at the confluence of the western edge of the Corn Belt, the northern limit of soybean production, and the heart of spring wheat production, and historically encompassed the transition from tallgrass to mixed-grass prairies. It is already the locus of corn ethanol production with many more plants under construction and in planning. Our NASA-funded project explores how changes in regional land cover may affect regional weather patterns during the growing season (including extreme events) and the risk of wildfire to feedstock crops. Understanding these potential effects of changes in agricultural land cover is critical for ensuring the sustainable production of biomass feedstocks and for developing strategies to mitigate potentially adverse environmental consequences. A key challenge in this research is the spatial allocation of land cover change. Although there are various econometric approaches to forecasting land change, their utility is limited by uncertain markets and governmental policies. We will turn instead to a standard approach in the modeling toolbox: Monte Carlo simulations. In this approach we allocate land change in space stochastically by identifying key spatial constraints and linking them to a simple set of equations and rules. By running the change procedure many times, a distribution of potential future land cover patterns can be generated. For the initial spatial distribution of crop area, we use the corn and soybean maps recently generated from MODIS data using a "vegetation continuous fields" approach to crop mapping. We compare contemporary land cover with higher-corn-cover and high-switchgrass-cover scenarios.

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Land clearing and the biofuel carbon debt

Increasing energy use, climate change, and carbon dioxide (CO_2) emissions from fossil fuels make switching to low-carbon fuels a high priority. Biofuels that absorb CO_2 during plant growth are a potential low-carbon energy source, but whether biofuels offer carbon savings depends on how they are produced. Converting rainforests, peatlands, savannas, or grasslands to produce food-based biofuels in Brazil, Southeast Asia, and the United States creates a 'carbon debt' by releasing 17 to 800 times more carbon dioxide than the annual greenhouse gas (GHG) reductions these biofuels provide by displacing fossil fuels. In contrast, biofuels made from waste biomass or from biomass grown on abandoned agricultural lands planted with perennials incur little or no carbon debt and offer immediate and sustained GHG advantages.

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Conversion from HILD to LIHD grasslands by seed addition: impacts on plant diversity and production under hay management

Low-input high-diversity (LIHD) grasslands are a promising system for biofuel production as they provide additional environmental benefits compared to high-input low-diversity systems (HILD). In theory, these systems are analogous to perennial native hay systems which can maintain high diversity and sustainable biomass production. We report the results of a seven-year hay management experiment in which fertilization and native prairie seed addition were manipulated in a Kansas grassland. In this experiment, we used a seed addition to test the rate and extent that HILD plots, which were dominated by introduced C^3 grasses initially sow for haying, would convert to LIHD. We manipulated haying, fertilization, and seed addition in sixteen 20x20m plots in a split-plot design. Seed addition in non-fertilized (LIHD) plots strongly increased plant diversity and altered plant composition leading to high abundance of native C4 tall grasses. Removal of biomass by annual haying in the LIHD plots decreased diversity slightly compared to plots without haying but remained substantially higher than non-seed addition plots. Biomass production in the non-seed addition plots without fertilizer decreased 42 percent relative to fertilized plots, indicating that high inputs are required to maintain high production. Remarkably, four years after seed addition peak biomass in the LIHD plots was equivalent to HILD plots suggesting that this low input system may achieve comparable production to some HILD systems.

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Market-mediated land use change consequences of crop-based biofuel production

Growing biofuel feedstocks on prime cropland creates pressure to both intensify and expand agriculture elsewhere via changes in the prices of commodities and land. This tends to increase greenhouse gas (GHG) emissions and damage biodiversity, but this market-mediated land use change effect is neglected in life-cycle assessments of biofuels. The 2007 Energy Bill may change this situation because it sets ambitious GHG emission reduction goals for advanced biofuels and explicitly requires including these indirect effects. Preliminary estimates indicate that the loss of carbon stocks from off-site land conversion is a large contributor to greenhouse emissions associated with crop-based biofuels, potentially outweighing all other emissions sources combined. Thus, a better understanding of land use change associated with biofuels will greatly inform the development of biofuel technologies and policies that will be compatible with climate change mitigation. The economic and bio-physical models needed to estimate market-mediated land use change effects are fraught with methodological challenges and data uncertainties. We review existing models of land use change and current estimates of indirect GHG emissions in order to quantify the challenge for crop-based biofuels, and to identify the methodological differences and data uncertainties they contain. We also present a research strategy for reducing the uncertainties in these estimates and developing more usable modeling tools.

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Potential impacts of increased corn production for ethanol in the Great Lakes-St. Lawrence River region

Within the United States and Canada, a rising demand for alternative fuels has been spurred by high fossil fuel energy prices, political support and policy decisions, high corn prices and profit margins, and technology improvements. As a result, farmers across the nation are making rapid changes to meet this demand.

Current trends have shown that the rapid expansion of biofuel production and the associated increased production of corn in the Midwest has had – and will continue to have – numerous and profound agricultural, environmental, and economic impacts. These impacts may be positive in some cases, neutral in others, and possibly negative in some instances if decisions and approaches lack foresight. Some impacts that are already occurring may have negative consequences depending on geographic, hydrologic, climatic, and temporal factors. These include the continued conversion of soybean acreage to corn, the loss or reduction of conservation lands, the possible pollution of ground and surface water supplies from increased agricultural chemical applications, and increased soil erosion from corn production using conventional tillage practices. Some of the socio-economic impacts are already evident to the consumer, such as higher grain and food costs resulting from corn price increases.

As we move forward, understanding the landscape-level environmental and economic impacts of biomass for biofuels production will help in the development of appropriate policy tools, as well as technology and management regimes to promote its positive impacts and mitigate its potential negative impacts.

This poster is based on a recent research paper, entitled "The Potential Impacts of Increased Corn Production for Ethanol in the Great Lakes-St. Lawrence River Region" (available online at www.glc.org/tributary/).

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Economic and environmental impacts of biofuels: Implications for land use and policy

We have initiated an integrated, interdisciplinary research program that will investigate the effects of large scale production of biofuels on land use, crop production, farm income and for the environment, over a 20 year horizon. The research program will examine the profitability and spatial variability in profits of growing bioenergy crops in the entire corn producing region of the US and will incorporate the interactions between market prices, supply and demand of major crops that bioenergy crops will have to compete with, utilizing the Agricultural Policy Analysis Model (APAM). We will extend the spatially resolved Integrated Science Assessment Model (ISAM) to assess the biophysical potential to grow various biofuel crops and to determine their potential to sequester soil carbon and to mitigate life cycle carbon emissions from fossil fuels used in crop production and transportation. The program will also address issues related to the economics of transportation of biomass and location of biorefineries as well as trade in biofuels.

A key outcome of this effort will be a comprehensive framework to analyze the socio-economic, biophysical and environmental impacts of biofuel production at an economy-wide level while incorporating detailed spatial heterogeneity at a local and regional scale. This framework will have the flexibility to be modified as new knowledge and insights emerge from the field and laboratory studies. Moreover, results from the assessment will provide guidance for identifying the most critical parameters that could realistically be manipulated or that influence adoption of alternate biofuel technologies. The analysis will provide policy makers and analysts with a scientific basis and a methodology to analyze the impacts of a range of public policies, including gasoline taxes, biofuel subsidies, carbon payments, agro-environmental subsidies, conservation programs and reduction in tariffs on imported biofuels.

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Potential impacts of increased corn-based ethanol production on coastal ecosystems

Nutrient pollution, especially from nitrogen and phosphorus, is the greatest pollution threat to our Nation's coastal and marine resources. Predominantly derived from agriculture in most coastal systems with large watersheds, nutrient pollution has led to severe impacts such as hypoxia (dead zones), loss of seagrass beds, and increases in harmful algal blooms. One of the greatest impacts of nutrient pollution is found in the northern Gulf of Mexico, where a dead zone forms annually off the Louisiana coast. The primary source of nutrients to the Gulf is the Mississippi River, whose watershed encompasses more than 40 percent of the continental United States, and includes some of the most intensively farmed and productive agricultural lands in the nation. The rapid expansion in domestic ethanol production is causing great concern among coastal water quality and resource managers. Since the majority of ethanol is currently derived from corn, which requires heavy fertilization and has the highest nutrient loss rate among major crops, increased corn-acreage in response to rising demand will likely result in increased nutrient loading to coastal waters. With corn-based ethanol production projected to increase over the coming decades, there is a strong need to increase management actions to mitigate the resultant nutrient losses to coastal waters. A transition to cellulosic ethanol production, especially those derived from perennial grasses, may serve to significantly reduce nutrient losses and thus protect water quality and habitat. As a case study, this poster will explore the potential impacts of increased biofuel production on Gulf of Mexico ecosystems and the challenges facing coastal resource managers.

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Agroforest systems: Opportunities for environmentally sustainable biofuel feedstock production in the Lower Mississippi Alluvial Valley

The Lower Mississippi Alluvial Valley (LMAV) is well suited for large-scale biofuel feedstock production because of its high rainfall, relatively long growing season, central location within the US, and well-developed agricultural infrastructure. Production of common biofuel feedstocks such as corn and soybean require significant inputs of fertilizer, pesticides, and water for irrigation. In addition these crops provide a minimal level of ecosystems services such as carbon sequestration, wildlife habitat, and water quality protection. The LMAV was once dominated by forests, but more than 66 percent of the forest land base has been converted to agriculture production. Conservation efforts have targeted the reforestation of marginal agricultural lands to restore many of the ecosystem services lost through forest conversion. Increased demand for biofuel feedstocks have the potential to limit or reduce the reforestation of these marginal lands. Agroforests could be a flexible and innovative cropping system that could be employed on marginal agricultural land to provide both cellulosic biomass feedstocks and ecosystem services. Agroforest systems composed of varying mixtures of feedstock species, such as cottonwood trees and switchgrass, have the potential to provide a suite of ecological services along with high cellulosic biomass production to meet a variety of management objectives, social constraints, and soil/site conditions. We summarize the potential of agroforest systems to increase biofuel production capacity for the US, improve economies of economically faltering rural communities of the LMAV, and enhance environmental conditions, such as soil, water, and wildlife habitat quality.

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IEA Bioenergy: Task 31 "Biomass production for energy from sustainable forestry"

The purpose of International Energy Agency Bioenergy Task 31 is to develop an integrative framework for information relating to biomass production for energy from sustainable forestry, based on leading-edge science and technology; and to share and promote the use of such an information framework with advanced information technology and a high level of collaboration. Task 31 membership currently consists of nine countries in Europe and North America. It organizes annual workshops and field study tours, for sharing of scientific and technical information and furthering the Task program, with published proceedings. The Task 31 scope is world wide, including boreal, temperate, subtropical and tropical forest regions, and inviting participants from developing as well as developed countries. The work includes sharing and synthesizing of research information, stimulating new research directions to help meet the sustainable development goals of national programs in participating countries, as well as technology transfer based on integrative models of biomass production systems. The integrated approach incorporates biological, economic, environmental and social components of forestry systems. Multi-disciplinary partnerships of key research, government and industry stakeholders in forest biomass production research, planning and operations are fostered. The task focuses on three distinct aspects of the production of biomass for energy from conventional forestry systems: the growing and cultural treatment of forest stands and plantations; the recovery of biomass for energy through forest operations; and consideration of questions of environmental sustainability of biofuel production. An integrated approach is taken to investigation and sharing of knowledge on these separate aspects. The Task maintains a web site at: http://www.ieabioenergy.com/Task.aspx?id=31.

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A synthesis of biomass utilization for bioenergy production in the western United States

In this synthesis of bioenergy use and potential in the western US, we examine the use of woody residues as a feedstock for direct-combustion bioenergy systems for electrical and/or thermal power applications. We examine opportunities for utilizing biomass for energy at several different scales, with an emphasis on larger-scale electrical power generation at stand-alone facilities, and on smaller-scale facilities such as governmental, educational, or other institutional facilities. We then identify west-wide barriers that could inhibit bioenergy applications, including accessibility, terrain, harvesting costs, and capital costs. Case studies of successful bioenergy applications are reviewed, and new wood energy technologies are identified. Finally, we evaluate the role of government as a catalyst in stimulating new technologies and new uses of biomass material in the western US.

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International biomass synthesis: lessons learned and opportunities for the western United States

Although a plentiful supply of biomass is available in western US forests, challenges remain to find economic uses given the high removal costs and relatively limited markets for this material. Since the cost of harvesting and transporting biomass is often several times the value of biomass products, a key challenge is to find opportunities that will recover at least a portion of these costs while providing other benefits (such as reduced fire risk, community economic development, and wood products industry sustainability).

Many nations have already made significant progress in meeting primary energy needs from bioenergy, including several examples from the European Union. In this synthesis we examine opportunities for utilizing biomass for energy at several different scales. We identify barriers that can inhibit bioenergy applications, and we consider international cases of successful bioenergy projects, with a focus on Europe (including Scandinavia, Austria, and Germany). We review these successes, identifying common themes that could be applied to bioenergy development in the western US.

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Tropical deforestation and biofuel incentives

Biofuel incentive programs in Europe and in the United States lead to higher oil crop prices. China, therefore, is no longer importing rapeseed oil and is expected to nearly double imports of the cheaper, Indonesian palm oil to meet its growing needs for food and for industrial uses of vegetable oil. Europe is also increasing imports of palm oil by nearly a forth as they burn rapeseed oil in their cars. To meet the growing demands, Indonesia's production of palm oil is expected to increase by more than half over the next ten years.

Unfortunately, most of Indonesia's new palm oil production occurs in peat bogs. Each year, when the bogs are drained, the top ten centimeters of peat disappears. This releases CO_2 and Methane, and when combined with the burning of the rainforest, this deforestation has made Indonesia the third largest source of greenhouse gases in the world--even before the acceleration in palm oil production caused by the biofuel boom.

As world leaders meet to devise new incentive schemes to save the forests and savannas, biofuel subsidies, and the resulting higher crop prices and land rents, will pose a major challenge. High farm prices may result from either 1) protection of the tropical forests which provide a sink for CO_2 emissions, or 2) biofuel subsidies which increase CO_2 emissions.

Attempting to accomplish protection of the forests and expanded use of biofuels, both at the same time, could result in very high food prices. Farmers and their policy makers need to consider the above trade-offs, and come up with a rational way to achieve their price and income objectives.

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Bioenergy: Considerations of sustainable bioenergy development

The Heinz Center is currently working on understanding the ecological dimensions of Bioenergy globally. This effort is part of a larger assessment, The Global Energy Assessment (GEA) seeks to examine: the major global challenges and their linkages to energy; the technologies and resources available for providing energy services; future energy systems that address the major challenges; and the policies and other measures to realize sustainable energy futures by assessing the social, economic, development, technological, environmental, security and other issues linked to energy.

The Heinz Center in collaboration with other groups is developing analysis to quantify the energy yields, greenhouse gas emission benefits, and other aspects of socio-environmental aspects of BioEnergy development. We have initiated discussions various groups to support the Global Energy Assessment. These contacts have led to discussions with Global BioEnergy Programme and involvement of the Global Land Project to evaluate land use implications of bioenergy development. The current overall plan is define the ecological dimensions of bioenergy, efforts to determine best practice criteria, and to assess the various technologies which can define the role bioenergy can play in mitigating GHG emissions in the short- and long-term.

Energy Conversions: In a report we are developing to evaluate bioenergy development in different parts of the world we assessing energy conversion ratios. Two repots from Brazil have been useful to evaluate sugarcane ethanol conversion, a study by Macedo et al (2004) and a report by Dias De Oliveira et al (2005). Dias De Oliveira et al (2005) then calculated the amount of energy required for production, conversion, and distribution of ethanol from sugarcane in Brazil. Their findings estimate that the energy-output ratio for production and distribution of ethanol is approximately 3.7.

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The corn ethanol boom: Consequences for insect pest dynamics

Between 2006 and 2007, corn acreage increased nearly 20 percent in the United States. This increase in production has been partly fueled by increasing demands for corn ethanol biofuel. However, the increase in corn acreage may have unintended consequences for insect pest dynamics. Increasing the amount of suitable crop habitat in a landscape may increase the densities of agricultural pests. In regions where favorable habitat patches are abundant, insects may be able to colonize nearby habitat and maintain larger populations than in regions where favorable habitat is less abundant. This idea is explored through simple spatially explicit modeling of herbivore population dynamics in regions with high and low numbers of simulated corn fields. Simulation results are compared to surveys of European corn borer (Ostrinia nubilalis), northern corn rootworm (Diabrotica barberi), and western corn rootworm (Diabrotica virgifera) populations from different counties in upstate New York where corn is more and less abundant. Modeling and field results confirm that land-use patterns may significantly affect populations of some agricultural pests, with their densities being higher where corn acreage is high. However, highly dispersive pest species may not be strongly affected by land-use patterns.

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Strategic development of bioenergy in the western states

The Western US is well positioned to contribute to the nation's bioenergy future. This research examines the West's energy supply potential, the barriers to achieving the full potential, and the policy measures and incentives to enable the transformation to use the supply. The research examines the likely technology progression, costs and performance of technologies, the benefits and costs of bioenergy production including environmental impacts, and the price and supply curves that can make it happen. The goal of this research is to help the Western governors identify their options for promoting biofuels in their states: feedstock and biofuel development and production.

The analysis investigates the biofuel conversion technologies that are currently available as well as technologies that are currently under development. The latter technologies are those that are far enough along the development path to potentially be available on a commercial basis in the relatively near term.

Geographic Information System modeling was used in conjunction with an infrastructure system cost optimization model to develop biomass and biofuel supply curves using biomass feedstocks throughout the Western US Feedstocks considered include agricultural crop residues, beef tallow and yellow grease, forest biomass resources, herbaceous energy crops, orchard and vineyard trimmings, municipal solid waste biomass, biosolids, and grain and oilseeds. The model estimates gallons of gasoline equivalent of biofuels per year that could be produced at varying costs using technology and feedstocks that are anticipated to be available by 2015.

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Woody biomass for energy: Matching the forest resource to the community needs

The US Forest Service is leading the effort to develop, deploy, and demonstrate the production, recovery, and use of wood as an energy source through an integrated program. USFS Research & Development has a focused, accelerated effort to develop the science and technology; State & Private Forestry helps deploy the science and provide assistance to communities and non-industrial private forest landowners; and, the National Forest implements and demonstrates biomass utilization to increase the cost-efficiency of ecosystem restoration and hazardous fuel reduction treatments. Working together with partners, the Forest Service is striving to overcome the barriers of having reliable, sustainable woody feedstocks from public and private lands that are cost-effective, and supporting their conversion to biofuels, biopower, and bioproducts to reduce the use of fossil fuels and help the environment.

The Wood-to-Energy – Biofuels Initiative encourages the use of wood for biofuels from Federal, tribal, State, and private lands in support of the Nation's "20 in 10" initiative to reduce the dependency on foreign oil. Wood is available in many forms – as fuel treatment thinnings, restoration thinnings, and wood residues from production forestry. Wood, as an abundant natural resource, can contribute significantly to energy independence, domestic livelihoods, and an improved environment. Utilizing woody biomass can offset part of the cost of hazardous fuel reduction and ecosystem restoration activities throughout the Nation, provide jobs in rural areas, and contribute to increased economic viability of private forest lands, thereby reducing the likelihood that they are developed for more intensive use.

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The machine in the garden

Global climate change and oil security pose enormous challenges for twenty-first century industrial society. Science tells us that to avoid dangerous levels of climate change we must reduce greenhouse gas emissions 80 percent by mid-century, while demand for oil increases, and reserves are increasingly concentrated in a few volatile countries.

There is considerable interest in using biofuels to meet these two challenges. Production of conventional biofuels is exploding while investors and governments pour billions of dollars into advanced biofuels, such as those derived from cellulose. Because cellulose comes from many different sources, an opportunity is created to create a feedstock supply that is greatly more diverse than our current monoculture approach to agriculture.

However, a number of next-generation companies and government agencies are applying the tools of genetic modification to develop high-yield grasses and trees matched to tailored enzymes. While this approach has some logic, it fails to take into account the effects on the rural landscape, wildlife habitat, and soil and water quality of a continued reliance on a monocultures.

An attractive alternative, using native polycultures as a feedstock base, has caught the imagination of many who seek to restore an ecological balance to agriculture. But for such a feedstock to work, it must meet the demands of industry. This hinges on having a conversion technology that can turn mixed feedstocks into commercially viable fuels.

Development of this flexible conversion technology, which we call "the machine in the garden," would further enable the conversion of a wider range of feedstocks, such as garbage, woodchips, and crop residues. This would offer substantial logistical and risk mitigation benefits to refiners.

The key to sustainable landscape impacts from biofuels, then, is a conversion technology capable of handling mixed feedstocks. This should be the top priority for research.

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The environmental challenges of sustainable biofuels: EPA's biofuels strategy

The Energy Independence and Security Act mandates certain volumetric targets for biofuels, with consideration of greenhouse gases over the biofuels lifecycle and consideration of water quality issues. There are daunting challenges in meeting the national goals of energy independence and security, through development of major volumes of biofuels, while assuring that biofuel production results in reductions of greenhouse gas emissiosn and is environmentally sound and sustainable.

EPA has launched an Agency-wide biofuels initiative that, among other things, will identify priority environmental cross-media impacts for each of the five biofuels supply chains, (i.e., feedstock production, logistics, conversion, distribution, and end use) and will identify research and science needs to manage and address these concerns. Depending on the type of fuel, the feedstock and conversion technology, and the location of facilities, impacts will vary. It is essential to understand the short and long-term demand on natural resources, the potential for release of pollutants into air, water, soil and effects to the food chain, and ecological and public health over the full life cycle of biofuels production and use. Given our reliance on biomass far into the future, it will also be critical to understand how climate change may impact future land use practices and availability of water and biomass.

EPA's biofuel strategy will reflect different regional and programmatic issues and aims to leverage existing programs and identify gaps for future activities both within EPA and in with other federal agencies, states, and local governments. This work will also support the National Biofuels Action Plan being developed by the Interagency Biomass R&D Board.

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Set-asides can be better climate investment than corn-ethanol

Net carbon emissions from biofuel production depend on land-use history and whether carbon is lost from soil organic matter. We compared the effectiveness and economic value of corn- and cellulosic-ethanol production with conservation approaches, such as the Conservation Reserve Program (CRP), for reducing net greenhouse gas emissions. We assembled 142 unique comparisons of soil organic carbon (SOC) accretion in set-aside programs to determine rates of soil carbon storage. Based on our comprehensive dataset, the average SOC accretion in set-aside programs was 570± 185 kg C ha-1 yr-1 (2.088 ± 0.679 tons of CO_2 eq.ha-1.yr-1) after crop production ended. We used these data to refine estimates of net GHG emissions through time for different starting points of corn- and cellulosic-ethanol production, including existing croplands, CRP lands, and grasslands. We then determined the net present value (NPV) for each mitigation strategy, a summary measure of current economic value ($.ha-1) in terms of GHG emissions. After including estimates of SOC change, our analysis shows that maintaining lands in set-aside programs reduces net GHG emissions more than corn-ethanol production for at least four decades. Perhaps most surprisingly, converting land under long-term cultivation to CRP has a more positive GHG balance than corn-ethanol production for 42 (±20) years. Additionally, corn-ethanol production typically had a lower net present value (NPV) for GHG savings than set-aside programs, as well as a higher cost to the US government. Cellulosic-ethanol production, once commercially available, should provide the most efficient tool for GHG reduction of any scenario we examined.

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How green are biofuels?

Global warming and escalating petroleum costs are creating an urgent need to find ecologically friendly fuels. Biofuels—such as ethanol from corn (maize) and sugarcane—have been increasingly heralded as a possible savior. Others have argued that biofuels will consume vast swaths of farmland and native habitats, drive up food prices, and result in little reduction in greenhouse-gas emissions. Each biofuel has certain benefits and potential costs, and there is no common currency for comparing them. We present a study by Zah et al. evaluating different transport biofuels using just two criteria: greenhouse-gas emissions and overall environmental impact. Total environmental impact of each fuel was assessed by aggregating natural resource depletion and damage to human health and ecosystems into a single indicator, using two different methods. Greenhouse-gas emissions were assessed relative to gasoline. Most (21 of 26) biofuels reduce greenhouse-gas emissions by more than 30 percent relative to gasoline. But nearly half (12 of 26) of the biofuels—including the economically most important ones, corn ethanol, Brazilian sugarcane ethanol and soy diesel, and Malaysian palm-oil diesel—have greater aggregate environmental costs than do fossil fuels. Not all biofuels are beneficial when their full environmental impacts are assessed; some of the most important perform poorly in many contexts. There is a clear need to consider more than just energy and greenhouse-gas emissions when evaluating different biofuels and to pursue new biofuel crops and technologies. Governments should be far more selective about which biofuel crops they support through subsidies and tax benefits.

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Environmental dimensions of whole-tree chipping and slash removal for cellulosic biomass supply in the US south

Currently, corn and soybean are the primary feedstocks producing ethanol and biodiesel, respectively. However, it is unlikely that these crops will be sufficient to meet biofuel demands, particularly since they are also important food sources. Cellulosic ethanol has the potential to replace 30 percent of US petroleum use. The collection of post-logging forest residues, or logging slash, is a vital component of a cellulosic biomass supply for biofuel production. Pine plantations produce the majority of harvested forest volume in the US South and are projected to increase 53 percent in area by 2050. Projections estimate that two-thirds of the national softwood harvest will occur on plantations that cover 20 percent of the US forest base. Clearly, pine plantations have an important role in producing biofuel feedstocks. However, whole-tree chipping (i.e., removal of all above-stump biomass) may have deleterious impacts on site productivity and ecosystem services with the removal of high amounts of logging slash. Forest harvesting can reduce the base saturation of soils, and this reduction intensifies with the amount of biomass removed. Whole-tree harvesting also can reduce cycling of soil carbon, thus modifying soil properties and reducing future productivity. The quantity, size, distribution and decay status of woody debris in forests influences plant and animal community composition and diversity. However, removal of logging slash has the potential to negatively impact several species groups. We summarize current knowledge regarding environmental dimensions of whole-tree chipping and logging slash removal in the US South, and identify critical information gaps related to sustainable cellulosic biomass supply.

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Projecting potential impacts of China's ethanol development on carbon and water cycling in agricultural land by integrating ecosystem and economic models

From the perspectives of both reducing China's fast growing dependence on oil imports and lowering air pollution and greenhouse gas emissions, it is clearly a top policy priority to search for alternative sources of energy in China. While China's current bioethanol production based on grain is only about 1 million tons, the nation has begun to implement an ambitious plan to expand its bioethanol production to more than 3 million tons by the end of its Eleventh Five-Year Plan (2006-2010). Anticipated annual production by 2020 is targeted at 10 million tons. To assess ecological and economic consequences of China's bioethanol development programs, in this study, we link CHINAGRO model, a multi-regional, multi-commodity general equilibrium welfare model of Chinese agriculture with DLEM model, a process-based dynamic land ecosystem model to test the feasibility of producing 10 million tons of ethanol in four scenarios, a maize scenario, a sugarcane scenario, a cassava scenario, and a scenario using a mix of the three crops. The potential impacts of these alternative bioethanol development programs on China's agroeconomic (agricultural prices, production and farm income) and ecological (carbon, nitrogen and water cycling) dimensions are assessed for each region of China. Preliminary results indicate that the increases in the prices of these feedstock crops trigger a significant rise in production of these crops and a shift in the crop production structure in each region. These changes induced by biofuel production could significantly alter biogeochemical and hydrological cycling, and further affect food production, carbon sequestration and water resource in China.

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Feedstock production/agronomy program

The primary objectives of the Energy Feedstock Production/Agronomy Program are to provide statistically sound information on yields, geographic variation and agronomic requirements of lignocellulosic feedstocks and tropical lignocellulosic /sugar feedstocks and to identify agronomic procedures and feedstocks that will facilitate sustainable systems for the production of biofuels worldwide. Three secondary goals of the program will be to provide: 1) large scale trials at the EBI Feedstock Research, Development and Demonstration Facility (EBI RDDF) needed to support the farm machinery engineering and environmental research programs; 2) dispersed trials to support the EBI stress and environmental research programs; and 3) statistical data on yields and agronomic inputs at geographically diverse sites to inform the EBI socio-economic programs.

We will initially focus on perennial crops for the provision of lignocellulosic feedstocks in the temperate Americas and Europe, but this will expand to tropical feedstocks and annuals that may provide a stopgap supply of lignocellulose for biomass processing plants while perennials are being established. We will also evaluate the yield potentials of a broad range of currently used and promising energy crops primarily at the EBI RDDF and beyond; identify the best production practices of these crops, focusing initially on mixed prairie, Miscanthus, switchgrass, and continuous corn for comparison; and identify appropriate current germplasm of the perennials for different environments. Because perennial systems require at least three years for establishment, we will conduct limited trials of sorghums that could provide stopgap lignocellulosic production.

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ECOLOGICAL DIMENSIONS OF BIOFUELS

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