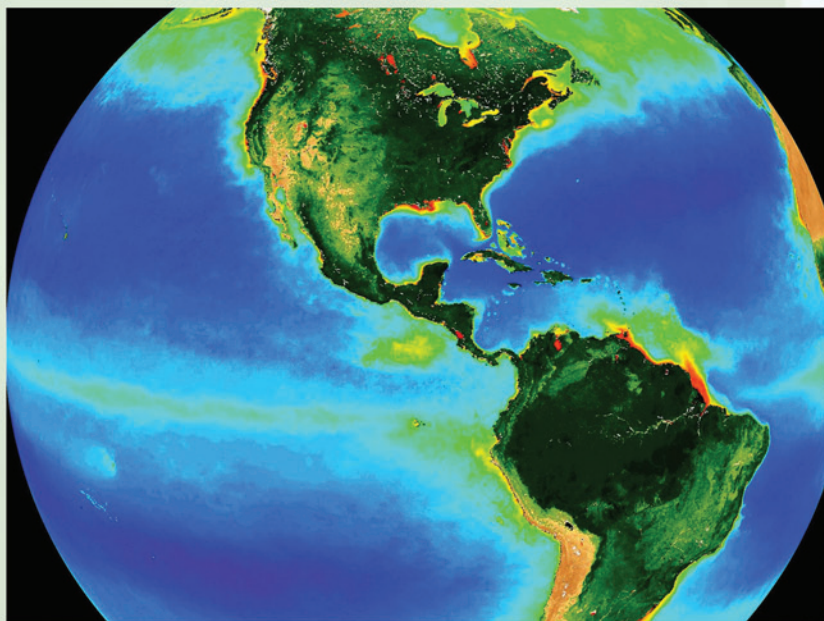


Land-Use Change and Bioenergy

July 2011



This summary was prepared in July 2011 by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Biomass Program. It was informed by “Land-Use Change and Bioenergy: Report from the 2009 Workshop,” available online from Oak Ridge National Laboratory’s Center for Bioenergy and Sustainability.

Cover page: NASA SeaWiFS image showing satellite-based remote sensing of Earth’s primary productivity (left); photo courtesy of ocean-color.gsfc.nasa.gov; a field of switchgrass (right) photo courtesy of BCS, Incorporated.

Examining land-use change and bioenergy

To achieve a domestic, viable, and sustainable bioenergy industry, the U.S. Department of Energy (DOE) Biomass Program directs a diverse portfolio of research, development, and deployment on all aspects of the biofuel supply chain. This portfolio includes life-cycle analyses of biofuels-related greenhouse gas (GHG) emissions, including the effects of land-use change.

Land-use change analysis is focused on the processes that alter landscapes and the implications of those changes. Land-use change can greatly affect carbon stocks—the amount of carbon stored—in plants and soil. There is significant carbon release to the atmosphere when forest stands or wetland areas are converted to pasture or agricultural lands. Conversely, forest aggregation or grassland maturation can increase carbon stocks. These and other types of land-use change are driven by cultural, technical, biophysical, political, economic, and demographic forces.

Accurately assessing the level, types, and impacts of bioenergy-driven land-use change is critical in the national and global regulatory arenas. Because of the implications of bioenergy as a strategy for climate change, energy security, and economic growth goals, the Biomass Program and its research partners are developing strategies to integrate our understanding of land-use change, bioenergy, economics, and GHG emissions.

Legislation requiring land-use change assessments

The Energy Independence and Security Act (EISA, December 2007) set guidelines for a new U.S. Renewable Fuel Standard, including requirements to improve the sustainability of biomass-derived fuels. Consequently, biofuels production must achieve significant GHG emission reductions without adversely impacting the environment or natural resources. EISA also requires analysis of the life-cycle impacts of renewable fuels in order to assess the “aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land-use changes).” The Biomass Program’s investigation of the sustainability of land-use change impacts associated with biofuels is driven by the EISA legislation and the 2008 National Biofuels Action Plan, developed by the interagency Biomass Research and Development Board.



Deforestation in the Amazon rainforest.

Land-Use Change and Bioenergy Workshop

- To help DOE set its research agenda and to forge international cooperation on the topic, the Biomass Program and Oak Ridge National Laboratory’s Center for Bioenergy Sustainability sponsored a workshop on land-use change and bioenergy in May 2009. The workshop assembled leaders in global land-use change modeling, as well as experts in the land cover and land-use datasets upon which the models rely.
- The workshop reviewed the state of the art of land-use models, identified opportunities for collaboration, and mapped out a research agenda on the direct and indirect effects of bioenergy production on land resources.

Key data challenges

Modeling efforts are limited by knowledge of the driving factors of land-use change. Additional challenges arise from the availability, quality, and consistency of the data that serve as inputs for modeling and analysis:

- Historical data is limited and often non-existent, especially in developing countries. Such data can be used to identify and predict trends and correlations, and validate models.
- Different sources and inventory techniques are used for land cover and land-use characterization, making dataset aggregation difficult and sometimes impossible.
- Remote sensing techniques have changed over time. Thus, datasets from different time periods can be difficult to aggregate.
- The resolution of carbon stock data is coarse and highly variable, causing uncertainty in calculating the impact of land conversion on carbon stocks.
- Input data have varying spatial and temporal scales and generate different results depending on the extent of the analysis.

Key modeling challenges

Like most models, land-use change models cannot represent the social, economic, and environmental effects of biofuels on global land use without uncertainty (Figure 1):

- Most land-use change models currently focus on specific sectors in land systems, such as agriculture, forestry, urbanization, or economic trade phenomena, while representing other sectors as external drivers or treating them in a simplified manner.
- Due to complex interactions of socio-economic forces, biomass feedstock production in one part of the globe may influence changes in land use in another. Such direct and indirect land use impacts could benefit or adversely affect the sustainability of biofuels production.

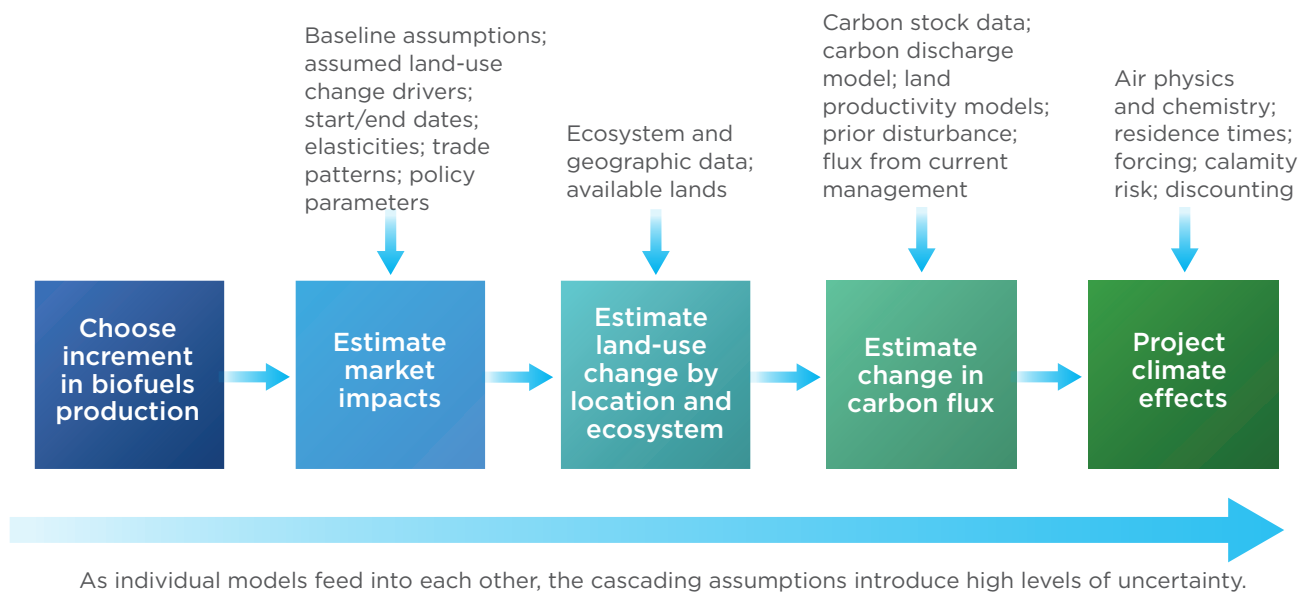


Figure 1: An example process of modeling the effects of biofuels production on land-use change. Each stage contributes uncertainties to the estimates of carbon emissions and economic effects. Adapted from “Land-Use Change and Bioenergy: Report from the 2009 Workshop.”

Addressing research needs

Constructive dialogue among researchers from a variety of disciplines is necessary in order to determine how to handle uncertainties related to the development of new, targeted land-use change models, as well as for data improvement and integration. The Biomass Program is addressing these challenges through data collection and model development, in order to research and evaluate the overall sustainability of biofuels production. Figure 2 provides a framework for these research areas.

Data collection and use:

- Improve the quantification of land cover conditions, and the measurement of the environmental impacts of land-use change
- Validate models with empirical data
- Develop improved scenarios with better documentation and analysis
- Include integrated and more sustainable production systems and reference cases to ensure fair comparison among energy alternatives.

Model development:

- Acknowledge, document, quantify, and reduce uncertainty in land-use change models
- Improve integration with global economic models
- Define a conceptual framework for modeling land-use change that includes major drivers of land-use change, such as drivers linked to bioenergy, evidence-based causal linkages related to land-use change, and standard reference data and scenarios-of-change
- Create more refined modeling approaches to extrapolate future land-use changes that can include improved linkages between models as well as data, and between different models.

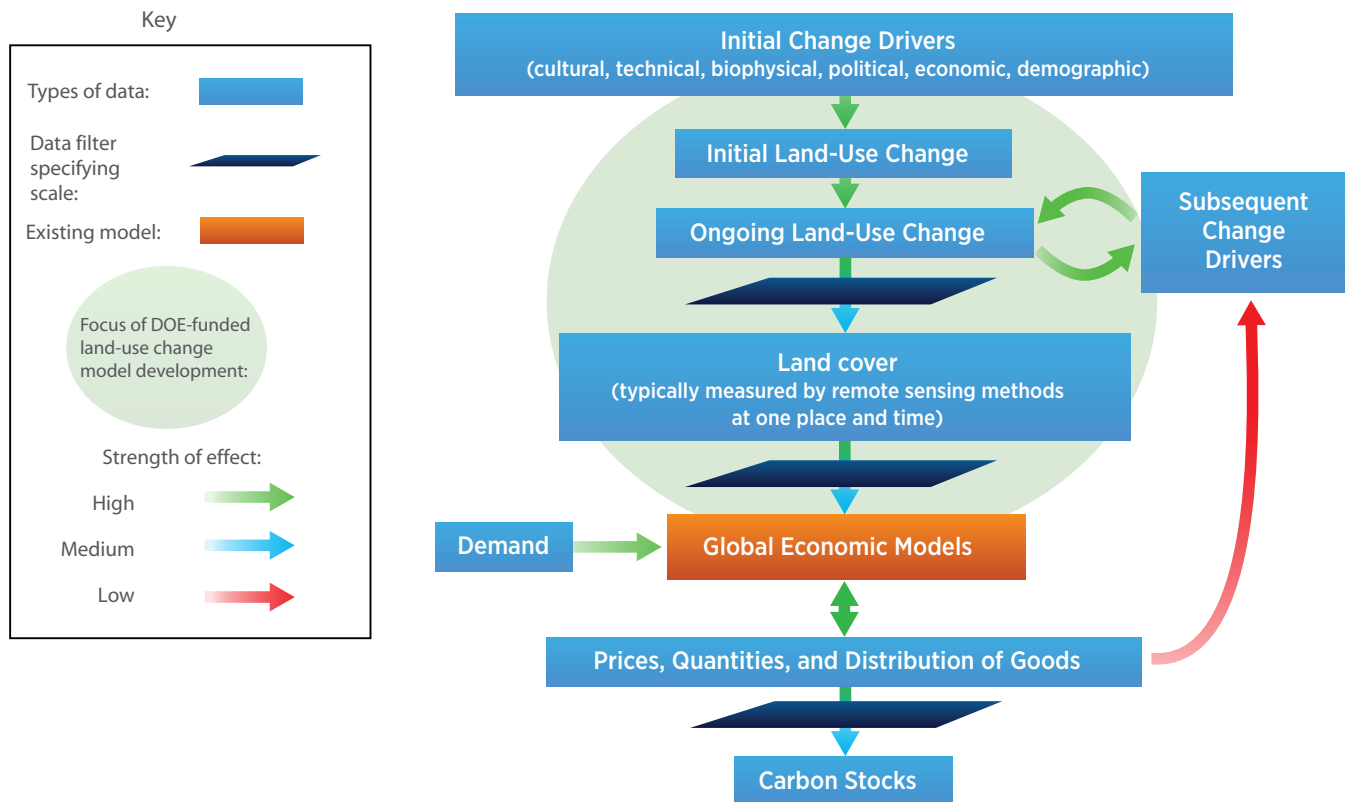


Figure 2: A research framework for land-use change to integrate land-use/land cover and global economic models. The framework includes multiple factors that impact the level of GHG emissions related to land-use change. Data can be filtered to different scales, allowing models to address varying spatial and temporal concerns. DOE-funded research aims to improve data collection and can be used to develop new models, connecting global economic models with geographic information. Adapted from “Land-Use Change and Bioenergy: Report from the 2009 Workshop.”

Path forward

The Biomass Program recognizes the importance of biofuels in a sustainable energy future. Therefore, the Program is developing a comprehensive framework to understand the impact of bioenergy policy on land-use decisions. Current research aims to improve the understanding and modeling of initial land-use change, to discern the environmental effects of additional transitions in land-use change processes, and to link the land-use change framework to existing global economic models. Such efforts are important now because as policy, public opinion, industry development, and research move forward, they will benefit from better-informed science, debates, and models.

The Biomass Program currently funds and works with a number of national labs and universities on the analysis of direct and indirect land-use change. Oak Ridge National Lab leads the Program's international sustainability effort to identify metrics, baselines, and targets for land management related to international bioenergy production pathways, as well as the Program's effort to develop an independent, integrated modeling architecture to assess the direct and indirect impacts of land-use change from U.S. biofuel development at a global scale. Purdue University, in conjunction with Argonne National Lab, recently published a paper that quantified the impact of biofuels production on land-use change as part of a Program-funded project to assess the economics of biofuels production and distribution.¹ In terms of resource assessment, the Program conducts analysis of future bioenergy production scenarios for herbaceous, woody, and waste feedstocks, as well as algae. The update to the *Billion-Ton Study* (publication forthcoming in 2011) evaluates the potential of biomass resources in the contiguous United States to supply sufficient feedstock to displace 30% or more of the country's present petroleum consumption. The revised analysis features a new treatment of land-use changes for feedstock production and biofuels processing, while maintaining baseline food and commodity crop production levels. The Program is also heavily invested in policy evaluation and helps develop standards to build consensus around indirect effects of bioenergy production, specifically as they relate to land management.

Land-use change often has consequences that go beyond the borders of a single nation. Energy and agricultural policies made in the United States and other countries can have repercussions all over the world. Efforts to estimate these repercussions have fueled an ardent debate on biofuels and land-use change. Consequently, the Biomass Program is engaged in research areas that will improve our understanding of land-use change and support better development and use of bioenergy resources in the future.



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For additional information, visit biomass.energy.gov

¹ Wang et al., "Energy and Greenhouse Gas Emissions Effects of Corn and Cellulosic Ethanol With Technology Improvements and Land Use Changes", *Biomass and Bioenergy*, 2011

The complete “Land-Use Change and Bioenergy:
Report from the 2009 Workshop” document is available at

ornl.gov/sci/ees/cbes/workshops/LandUse_Report.pdf



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