

# Environmental Sustainability and Biotechnology: Introduction to *AgBioForum* Special Issue of the 19<sup>th</sup> ICABR Conference

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The application of biotechnology and novel bioprocesses has proven itself to be an effective solution to the many challenges facing the agriculture, environment, and energy sectors. From genetically modified (GM) crops that increase yields and lower pesticide use to bio-fuels that meet energy needs with renewable resources, the new bioeconomy has resulted in considerable welfare improvement. In spite of this, modern bio-based techniques and production systems has its critics—many of whom view them as being unsustainable and incompatible with traditional production methods, among other sins. At issue is whether sustainable ecosystems security is possible through the development of bio-based resources and processes, and, if so, how might it be achieved? What are the implications of, and relationship between, environmental sustainability and agricultural production that is increasingly reliant on biotechnology? What are the policy, governance, and regulatory challenges and opportunities that would harness the potential of biotechnology for greater production but in an increasingly sustainable manner?

These and related issues were discussed at the 19<sup>th</sup> International Consortium of Applied Bioeconomy Research (ICABR) Conference on “Impacts of the Bioeconomy on Agricultural Sustainability, the Environment, and Human Health.” This special issue presents eight articles from the conference that span four themes: herbicide resistance management, climate change, technology impacts, and governance. These articles provide a broad assessment of the current state of biotechnology research and application, offering insights into how farmers, firms, consumers, and governments are managing the technology to meet high food demands under challenging conditions.

## Managing Herbicide Resistance

Insect-resistant and herbicide-tolerant crops have significantly increased yield, but there are real concerns that they may have also accelerated buildup of pest resistance that would dramatically reduce the benefits of GM crops. Miranowski and Lacy examine the farm and

social aspects of this important issue within the context of western-corn-rootworm (WCR) resistant varieties of GM corn. First introduced in 2003, WCR-resistant varieties contained a Bt trait by 2014 and accounted for about 80% of corn planted; this significantly reduced corn insecticide use. The authors find that this rapid and widespread adoption has led to some resistance development. Short-term solutions to resistance development include voluntary adoption of resistance management practices (RMPs). Miranowski and Lacy consider possible spillovers of resistance on neighboring farmers from mobile WCR, concluding that this should not be a serious issue, especially if neighbors use RMPs.

Resistance management of GM crops is further taken up by Pannell, Tillie, Rodríguez-Cerezo, Ervin, and Frisvold, who present comparative perspectives from Australia, the European Union, and the United States. Herbicide-resistant (HR) weeds threaten GM crop sustainability; establish environmental risks from alternative, less effective weed-control methods; and alter public and private research and development programs. Institutional responses to HR weeds across the three regions take different forms but confront similar problems. The authors discuss public policies and private-sector strategies that have been developed and implemented to address weed-resistance problems. The comparative assessment reveals that while solutions to HR weeds will have certain common attributes, it does not imply there are ‘one size fits all’ solutions. Given the differences in institutions, farm structures, the extent of GM crop deployment, and environmental regulations in the three regions, it will be important to craft policy responses to specific agronomic, environmental, and institutional settings.

## Climate Change

The impact that climate change will have on agricultural production and strategies to lessen these impacts has been an area of active research. While previous research has identified the effects of climate change on crop yields, there has been little consideration of outliers,

structural change, information decay, and model complexity. McFadden and Miranowski incorporate these features in their estimate of corn and soybean yields for Iowa, Illinois, and Nebraska. Their analysis of climate change impacts identifies corn yield growth of 7-26% and soybean yield growth of up to 32% over 2011 averages by 2031. McFadden and Miranowski also observe further effects of climate change such as a shift in temperature importance from July to August, as well as a shift from average precipitation to intense precipitation. The changing time paths of weather impacts and associated yield forecasts have key adaptation implications, which could affect the long-run sustainability of the Midwestern bioeconomy.

The role that GM crops have played in raising agricultural productivity is widely recognized, but less appreciated are the environmental benefits that also occur. Taheripour, Mahaffey, and Tyner take a novel approach to estimating these benefits and consider a counterfactual—what are the economic and environmental consequences of *losing* GM traits in the United States for the major crops of corn, soybeans, and cotton? Using a two-step approach, the authors first use a range of literature estimates on yield losses from moving away from GM traits, followed by econometric modeling to quantify the economic and land-use impacts. Their analyses confirm that without access to GM crops, significant amounts of land would need to be converted from other crops, such as pasture and forest to meet the global food demands. Generally, global savings in land-use emissions from GM crops range from 7-17% of global agricultural emissions. The price changes for corn were as high as 28% and 22% for soybeans. Food price changes in the United States amount to \$14-24 billion per year. As a result, welfare falls both in the United States and globally.

### Technology Impacts

Numerous developing countries show great promise from the commercialization of GM crops, yet the lack of commercialization prevents any benefits from accruing. Nagarajan, Naseem, and Pray present the political economy situation of Kenya. While debates, dialogues, and discussions on the suitability of GM crops for Kenya have occurred for more than a decade, there has been very limited progress in the approval process due to competing interests. The authors examine this issue using GM maize to provide insights into the varying positions held and whether the potential for policy changes leading to the cultivation of GM crops exists.

Through an evaluation of the economic and political motives to lobby for or against GM crop cultivation, they estimate the benefits accruing to participants in the maize value chain, identifying groups that are likely to gain/lose the most.

Critics of GM crops often argue that GM crops only benefit large landowners at the expense of smallholders. Vitale and Vognan examine the evidence for this by carefully documenting the input use and productivity impacts of GM cotton in Burkina Faso. Using six years of farm survey data, they find that GM cotton, as in many other developing countries where it has been adopted, used two-thirds less insecticide and produced higher yields than conventional cotton while reducing farm labor allocated to spraying. Farm size was not found to be a deterrent to GM cotton adoption—farms of all sizes benefitted equivalently, though larger farms were found to be more productive and generated larger absolute benefits.

### Governance

Disputes related to regulatory and governance issues have also been a limiting factor to greater adoption of biotechnologies. Lawsuits regarding the commercial adoption and use of GM crops have precipitated numerous lawsuits and injunction applications in a variety of GM-crop-adopting nations. Blakeney examines the case of organic versus GM agriculture in the Australian and American courtroom. He examines two 2014 cases concerning the potential threat to organic farming from GM crops. The first, concerns a dispute between two neighboring farmers, where the organic farmer claimed that the loss of organic certification was due to the harvesting practices of his GM producing neighbor. The second discusses an unsuccessful application by a number of US organic farmer organizations seeking reassurances against adventitious presence of patented genetic material in their organic products.

Lubieniechi and Smyth provide a Delphi assessment of the leading economic and regulatory barriers that presently exist for the Canadian biofuel industry. Biofuels and their use have been routinely polarized by the mass media and in the academic literature. Although literature on the biofuel effects is increasing, there is limited discussion of the Canadian biofuel industry. Qualitative information was gathered from Canadian public-sector biofuel researchers and private-sector industry managers, identifying three barriers to biofuel development in Canada: 1) lack of a coordinated and integrated federal-provincial policy framework, 2) tech-

nical capacity for scale-up is lagging, and 3) there is a lack of integration between the increased use of biofuels and sustainability.

Finally, Europe remains a notable hold-out in the adoption of GM crops. An increase in GM crop cultivation in the European Union could have a number of socio-economic consequences for farmers, upstream and downstream industries, as well as consumers. Kathage, Rodríguez-Cerezo, and Gómez-Barbero report on

the European GMO Socio-Economics Bureau's (ESEB) efforts to analyze socio-economic effects of GM crop cultivation. The compilation of topics, indicators, methodological guidelines, and potential data sources led to a Reference Document entitled *Framework for the Socio-economic Analysis of the Cultivation of Genetically Modified Crops*. The authors describe the development process and the findings of the Reference Document.