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Providing a Framework for the Analysis of the Cultivation of Genetically Modified Crops: The First Reference Document of the European GMO Socio-Economics Bureau

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An increase in the cultivation of genetically modified (GM) crops in the EU could have a number of socio-economic consequences for farmers, upstream and downstream industries, as well as consumers. The European GMO Socio-Economics Bureau (ESEB)—composed of representatives of EU Member States, Norway, and the European Commission—has compiled topics, indicators, methodological guidelines, and potential data sources to carry out analyses of these socio-economic effects into a Reference Document entitled *Framework for the Socio-economic Analysis of the Cultivation of Genetically Modified Crops*. This article describes the development and the findings of the Reference Document. The Reference Document provides a framework that is applicable to any GM crop that has been or might be grown in EU Member States. Almost 100 indicators, which range from farm adoption rates to consumer surplus, have been identified by the ESEB. The Reference Document found that evidence of impacts in the EU already exists for some crop/trait combinations both *ex post* and *ex ante* but that for most topics it is very limited. Methodologies have been developed by the scientific community for many of the topics and indicators, from simple partial budget analysis to complex aggregated models. It is concluded that while methodologies are available for many of the topics and indicators, the main constraint is a lack of data.

Key words: European Union, farm survey, genetically modified crops, genetic engineering, impact assessment, socio-economic analysis, welfare analysis.

Introduction

Genetically modified (GM) crops were grown by 18 million farmers in 28 countries worldwide in 2014 (James, 2014). Due to several factors—including national bans—European farmers have not adopted GM crops on a large scale, with the notable exception of Spain, where Bt maize[1] now covers about one-third of the total maize area (136,962 hectares). Ninety-three percent of the total EU Bt maize acreage is in fact in Spain, while Portugal, Czech Republic, Romania, and Slovakia also grow it, but on a comparatively small area.

The cultivation of GM crops can have a number of socio-economic effects, some of which have been investigated by scientific research. For example, farmers using GM crops have seen effects on yields, pest management practices, and gross margins. However, the socio-economic impacts are also the subject of political debates, which in turn influence the future development and adoption of GM crops.

Directive 2001/18/EC[2] requires the European Commission to deliver an assessment of the socio-economic implications of GM cultivation. However, in 2011 the Commission concluded that there had been insufficient experience to make such assessments (European Commission, 2011). As a result, the European GMO Socio-Economics Bureau[3] (ESEB) was established in order to

1. *Bt maize is a GM crop that contains a gene derived from a soil bacterium (Bacillus thuringiensis), which produces a protein toxic to the European Corn Borer (ECB) and related maize pests. The ECB damages maize plants, provoking significant yield and economic losses. Bt maize is currently the only GM crop available to EU farmers.*

2. *Article 31(7d) of the Directive 2001/18/EC of the European Parliament and of the Council of March 12, 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC. Official Journal of the European Communities L 106, 17.4.2001, p. 1.*

3. *https://ec.europa.eu/jrc/en/eseb*

organize and facilitate the exchange of technical and scientific information regarding the socio-economic implications of the cultivation and use of GMOs between Member States and the Commission. The mission of ESEB is to develop Reference Documents that will enable a science-based assessment of these impacts in Member States across the European Union. These documents are of a purely technical nature and not intended to serve any regulatory purpose.[4]

The purpose of this article is to summarize the development and main results of the first ESEB Reference Document. The next section describes the background and drafting procedure of the Reference Document, followed by a summary of the methodology for assessments. A listing of the topics and indicators related to different groups in society, such as farmers, upstream and downstream industries, and consumers is included, and then the article concludes with a brief summary of the main results of the Reference Document and a view to the future work of ESEB.

Background

Socio-economic Impact Assessment of GM Crops

The cultivation of GM crops can have a wide range of socio-economic impacts on agriculture, asssociated industries, and consumers. Many empirical studies have been undertaken to estimate these impacts. A number of recent reviews and meta-analyses have summarized the results of these studies (Areal, Riesgo, & Rodríguez-Cerezo, 2013; Brookes & Barfoot, 2015; Carpenter, 2010, 2011, 2013; Finger et al., 2011; Fischer, Ekener-Petersen, Rydhmer, & Edvardsson Björnberg, 2015; Franke et al., 2011; Klümper & Qaim, 2014; National Research Council, 2010). Most studies have focused on a small number of impacts, primarily farm-level economic effects of the most common GM crops (soybean, maize, cotton, and canola) and traits (herbicide tolerance [HT] and insect resistance [IR]). These studies have mainly examined aspects such as yield, pesticide use, and profitability (Areal et al., 2013; Carpenter, 2010; Finger et al., 2011; Klümper & Qaim, 2014). Several studies have also looked at the impact on labor use and non-pecuniary factors such as ease of management, as well as the distribution of impacts between farmers, technology providers, and consumers (Carpenter, 2013). Regarding environmental issues, some aspects have been studied extensively and others less (Brookes & Barfoot, 2015; Carpenter, 2011; National Research Council, 2010). Fewer studies are available on gender issues, food security, and the distributional impact on farmers of different sizes and income group (Carpenter, 2013; Kouser & Qaim, 2013). Many socio-economic impacts have rarely or not at all been studied (Fischer et al., 2015; Franke et al., 2011).

Socio-economic issues surrounding GM crops have increasingly become part of political and regulatory discussions in recent years (Ludlow, Smyth, & Falck-Zepeda, 2014). There is a growing public interest in the socio-economic dimensions of GM crops. Socio-economic issues, or socio-economic considerations (SECs), have played implicit and explicit roles in regulatory policy in several countries, and the use of SECs for certain regulatory purposes is also allowed under the Cartagena Protocol for Biosafety (CPB).[5] It is in the context of these political and regulatory discussions that the umbrella term 'socio-economic' and the topics it covers has gained increasing importance. Various publications have made contributions to this debate, providing lists of issues to be considered in socio-economic assessments (e.g., COGEM, 2009, 2014). Depending on the definition, socio-economics may comprise a large number of topics including economic, social, ethical, cultural, legal, health, and environmental aspects (Ludlow et al., 2014).

ESEB and the First ESEB Reference Document

The objective of the first ESEB Reference Document, entitled *Framework for the Socio-economic Analysis of the Cultivation of Genetically Modified Crops* was to provide a list of topics that could be included in assessments, along with indicators and methods that are appropriate for each topic (Kathage, Gómez-Barbero, & Rodríguez-Cerezo, 2015). The essence of any assessment for a given topic is to use a recommended method to answer the question: how does the cultivation of a particular GM crop/trait combination[6] affect the value of the selected indicator? Every assessment therefore requires a comparison between a scenario with cultiva-

4. *Directive (EU) 2015/412 allows Member States to prohibit the cultivation of authorized GMOs on their territory, citing socio-economic reasons, among others (European Commission, 2015). However, the first ESEB Reference Document has no regulatory function in the context of Directive (EU) 2015/412.*

5. *https://bch.cbd.int/protocol*

tion and a scenario with no (or less) cultivation of the selected GM crop/trait.

The first Reference Document was prepared with regards to GM crops that have been or can be expected to be grown in EU Member States. Future Reference Documents to be produced by ESEB will be targeted at specific crop/trait combinations detailed in the work-program of ESEB, and therefore some of the indicators listed in the first Reference Document may not be of relevance to all of them.

The first Reference Document was created based on contributions from the ESEB Technical Working Group (TWG) composed of representatives of EU Member States and Norway, with assistance of the ESEB secretariat at the European Commission's Joint Research Centre (JRC). Group members were invited to consult with experts and stakeholders in their respective countries and send their suggestions. Based on the contributions, the ESEB secretariat drafted the document and organized a meeting in March 2014 to discuss and finalize it. The document was sent and presented to the Regulatory Committee of Directive 2001/18/EC (Competent Authorities) and the Advisory Group on the Food Chain and Animal and Plant Health[7] in late 2014 and amended as necessary.

The scope of the first Reference Document encompasses impacts inside the EU. Potential impacts in third countries were excluded, with the exception of trade flows into or out of the EU.

The topics contained in the Reference Document were selected from a more comprehensive list compiled from TWG members' contributions covering what they considered as 'socio-economic' topics. However, when assessing whether to include a certain topic in the document, the selection criteria applied were the presence of (a) at least one related indicator that can be measured quantitatively or qualitatively, (b) a plausible causal mechanism by which GM cultivation might affect the indicator, and (c) a sound method to assess the impact (all backed by reputable scientific publications). These criteria were considered necessary to maintain the mission of ESEB to enable science-based assessments.

As the main goal of the Reference Document was to provide a list of topics (and associated indicators and methods) that could be included in assessments, the Reference Document did not attempt to weigh different topics by their relative importance. Nor does it provide a prescription on which basis to select certain topics and indicators from the list or summarize impacts across different topics.

Methodology for Assessments

The first Reference Document states that assessments of the impacts of GM cultivation require the use of "a scientific approach, reliable methods, and appropriate data sources." The approach defines the steps for performing an assessment, which involves the definition "impact and baseline scenarios," as well as an estimation and comparison of the values of the indicator under the scenarios. The estimation of the values depends on how farmers and other stakeholders behave under the different scenarios. While several approaches are available for this estimation, the methodology should as much as possible avoid selection bias. Impact assessments of the cultivation of GM crops can be conducted before (*ex ante*) or after (*ex post*) cultivation takes place. Multiple impact scenarios are recommended for *ex ante* studies.

A number of methods were considered applicable to a range of topics and indicators. Estimating the effects of GM cultivation on farmers often requires surveys of adopters and non-adopters. Data from these surveys should be analyzed using appropriate statistical techniques. Assessing the effects of GM cultivation on upstream and downstream industries requires complex socio-economic models and a combination of primary and secondary data. Welfare economics provides tools for conducting such assessments. The analysis of the segregation between GM and non-GM products in the supply chain from seed suppliers to retailers requires integrated models with endogenous price mechanisms. Regarding consumer behavior, the Reference Document stresses that revealed preferences, which are measured in real purchase situations, are more appropriate than stated preferences.

Impact assessments are often constrained by the availability and quality of data. *Ex ante* and *ex post* assessments of most topics require primary data. The first Reference Document finds that the data needed to estimate the values of most of the indicators described in the first Reference Document are not available. Surveys to be carried out by entities wishing to conduct an impact assessment should be representative of the target population. Furthermore, the establishment of panel datasets can facilitate unbiased impact assessments and

6. *A crop species genetically modified to express a trait (special characteristic), e.g., Bt maize. Note that in this document, 'a GM crop' is used interchangeably with 'a GM crop/trait (combination).'*
7. *http://ec.europa.eu/dgs/health_food-safety/advisory_groups_action_platforms/advisory_group_en.htm*

the analysis of dynamics over time. As long as representative samples are drawn from well-defined farmer/industry/consumer populations, assessments may cover countries or groups of countries, although a more disaggregated analysis can in many cases be more appropriate given regional differences in agronomic, economic, and legal characteristics.

Topics and Indicators

The topics identified by the first Reference Document are divided into effects on crop farming (adopters and non-adopters), effects outside of crop farming (upstream and downstream industries as well as consumers and the government budget), and aggregate welfare effects. Note that a more detailed discussion of individual topics, indicators, specific assessment methods, and data sources is found in the Reference Document (Kathage et al., 2015).

Effects on Crop Farming

To measure the effects of GM adoption in the EU, the Reference Document recommends assessing the overall adoption rate and the typology of adopting and non-adopting farmers. The impacts on adopters were divided into changes in gross margin (and its constituent costs and revenues), management practices (tillage, rotation, and resistance management), input use, and production efficiency. Further topics include coexistence management, including costs of coexistence regulations, and expenses to cover the risk of adventitious presence (AP), and time management. Non-adopters may be affected by the cultivation of GM crops in terms of the availability of non-GM crop varieties, output prices, crop protection spillovers, segregation costs, and opportunity costs resulting from not being able to choose to adopt GM crops.

Adopters. The following topics and indicators were identified for adopters. Topics are written in italics and indicators are listed as bullet points.

Adoption Rates
- Number of hectares under GM crop(s)/total hectares by crop or total arable land by country or region
- Number and share of farmers adopting GM crops (*ex post*)
- Number of farmers willing or not willing to adopt a GM crop (*ex ante*)

Typology of Adopting Farmers
- Farm characteristics (location-country/region, size, income by type of crop and livestock, ownership, organic certification)
- Farmer characteristics (education, age, sex, household income, off-farm income, time dedicated to farming)

Income Effects
- Fixed cost in €/ha
- Total variable cost in €/ha (seed, pesticides, machinery, labor, etc.)
- Composition of variable cost
- Composition of total cost
- Tonnes per ha
- Yield risk measured in annual variation in t/ha or crop insurance premiums in €/ha paid by farmers
- Quality of output: Indicator depending on quality attributes specific to crop under study
- Market price received for output (€/t)
- Subsidies received (€/ha or €/t)
- Gross margin in € per ha
- Gross margin as a percentage of turnover
- Number of farm workers and their total working hours
- Wages of employed farm workers in €/hour

Management Practices
- Type of tillage used by plot (conventional, conservation, no-till)
- Types and frequency of crops used in rotation
- Number of crops per year in the same plot
- Size of refuge areas to prevent pest resistance (share of plot area)
- Actions taken to prevent resistance of weeds/pests (time spent in h/ha)

Input Use and Efficiency
- KWh and € of energy per unit of output (or per ha)
- Liters and € of fuel per unit of output (or per ha)
- Cubic meters and € of water per unit of output (or per ha)
- Labor hours and cost in € per unit of output (or per ha)
- Land area in ha and cost in € per unit of output
- Kg and € of nitrogen, phosphorus, potassium per unit of output (or per ha)
- Kg of active ingredient of insecticide/herbicide/fungicide per unit of output (or per ha)
- Number and cost in € of insecticide/herbicide/fungicide applications per unit of output (or per ha)

- Use of machinery in hours per unit of output (or per ha)
- Costs of operating machinery in € per unit of output (or per ha), including purchase, devaluation, rental costs
- Output in € per unit of input in €

Coexistence Management
- Cost of complying with particular coexistence measures (e.g., buffer strips, compulsory training courses) in €/t and €/ha
- Compensation cost (funds, liability schemes, insurance premiums) to farmers in case of AP from GM fields in €/t and €/ha

Time Management
- Time spent on crop cultivation in h/ha and year
- Off-farm labor in hours and € (on a monthly basis to cover seasonality)
- Leisure time (h/week)
- Self-evaluation of convenience of crop management in €/ha
- Percentage of increase in productivity, which is transformed into reduction of working hours

Non-adopters. The following topics and indicators were identified for non-adopters.

Typology of Non-adopting Farmers
- Farm characteristics (location-country/region, size, income by type of crop and livestock, ownership, organic certification)
- Farmer characteristics (education, age, sex, household income, off-farm income, time dedicated to farming)

Economic Impact of GM Crop Cultivation
- Availability of varieties: Number of non-GM varieties in seed catalogues, by crop
- Price received for output (€/t)
- Crop protection spillovers measured by pest infestations
- Crop protection spillovers measured by the number of pesticide applications
- Crop protection spillovers measured by effects on yield (t/ha)
- Total segregation cost in €/t
- Loss of identity preservation rent resulting from adventitious presence in €/year
- Value and frequency of payments to farmers from national compensation schemes
- Number of disputes between farmers

Opportunity Costs of Non-adoption
- Income effects as for adopters (see above)
- Input use and efficiency as for adopters (see above)

Effects Outside the Crop Farming Sector

The cultivation of GM crops in the EU can have effects upstream and downstream of the crop-farming sector for users of GM and users of non-GM materials. Upstream, seed companies selling GM seeds and manufacturers of complementary inputs (e.g., broad-spectrum herbicides) can incur additional profit. On the other hand, providers of competitive inputs (e.g., insecticides) may lose market share. Downstream, processors of GM products (e.g., feed/food industry), as well as consumers, may be affected by changes in commodity prices and quality attributes. Furthermore, government revenues and expenses may be impacted.

Upstream. The following topics and indicators were identified for the innovation capacity of the agricultural and plant sciences, the seed industry, the agro-chemical industry, and land markets.

Effects on Innovation Capacity of Agricultural and Plant Sciences
- Number of GM/non-GM field trials in the EU
- Number of GM/non-GM crops in the research and development and the EU regulatory pipeline
- Number of GM/non-GM varieties in the national registers
- Number and size (in €) of EU and nationally funded research projects on agricultural biotechnology and biosafety and non-GM seed technologies
- Patents issued in plant biotechnology in the EU
- Employees in plant breeding and seed industry in the EU
- Resources (in €) allocated to plant biology research in the EU

Economic Effects on the Seed Industry
- Economic welfare of seed industry (€/year)
- Production and operational costs (including cost of keeping GM and non-GM seeds separated)

Economic Effects on the Agro-chemical Industry
- Economic welfare of agro-chemical industry (€/year)
- Pesticide sales in the EU

- Number of companies producing pesticides and change over time

Land Markets
- Land purchase and rental prices
- Parcel size and number per farm
- Real estate prices

Downstream. The following topics and indicators were identified for trade effects of concerned and competing crops, processors, the feed industry, livestock producers, the food industry, other industries, and the retail sector.

Effects on Exports and Imports of Concerned and Competing Crops
- Imports and exports of competing and concerned agricultural commodities in volume (t/year) and value (€/year), by crop, GM/non-GM, and importing/exporting country/region (including internal market flows)

Effects on Costs of Segregation and Identity Preservation by Processors
- Non-GM certification cost (€/t)
- Costs associated with implementing segregation measures (€/t)

Economic Effects on Feed Industry
- Economic welfare of feed industry (€/year)
- Price of raw materials for feed industry (€/t)
- Premium on non-GM feed (€/t)
- Cost of segregating GM feed and non-GM feed (€/t)

Economic Effects on Livestock Producers
- Economic welfare of livestock producers (€/year)
- GM feed cost (€/t) per sector (e.g., poultry, dairy)
- Non-GM feed cost (€/t) per sector

Economic Effects on Food Industry
- Economic welfare (€/year)
- Price of raw materials for food industry (€/t)
- Price of certified non-GM ingredients (€/t)

Economic Effects on Other Industries
- Economic welfare of other industries (€/year)
- Cost (€/t) of raw materials/feedstock by sector (e.g. textiles, energy, chemical)

Economic Effects on Retail Sector
- Economic welfare (€/year)

Consumers. The following topics and indicators were identified for trade effects on consumer choice and range of products, consumer prices, consumption patterns, and public understanding and acceptance.

Effects on Consumer Choice, Range of Products
- Number of GM-labeled products in the EU market
- Number of not-labeled products in the EU market
- Number of GM-free-labeled products in the EU market
- Number of GM products with new characteristics (e.g., novel nutritional attributes) in the market

Effects on Consumer Prices
- Economic welfare of consumers (€/year)
- Price premium paid for non-GM (no label) or GM-free (labeled) products (€/kg)

Effects on Consumption Patterns
- Percentage of EU consumers willing and not willing to buy GM-labeled products
- Price that consumers are willing to pay for non-GM (no label) or GM-free-labeled products (by product)
- Consumption of different food categories in kg per person and year

Effects on Public Understanding and Acceptance
- Citizen beliefs about the health and environmental safety of a particular GM crop and its socio-economic impact compared to the best scientific evidence
- Share of citizens rejecting and supporting the use of a GM crop in EU agriculture

Government Budget
- Government revenue and expenditure (€/year)

Aggregate Consumer and Producer Surplus

Total economic welfare can be modeled as the sum of consumer surplus and producer surplus (i.e., aggregate economic effects). The cultivation of GM crops can have an influence on both. To further explore the distributional impacts, the Reference Document suggests the possibility to study the impact on groups with different levels of income and wealth.
- Farmers economic surplus (€/year), disaggregated by income/wealth
- Consumer and producer (including farmers) surplus (€/year), disaggregated by income/wealth

Conclusions

In the future, the cultivation of GM crops in the EU may increase, which could have a number of socio-economic consequences for farmers, upstream and downstream industries, as well as consumers. The first Reference Document of the ESEB contains a compilation of topics, indicators, methodological guidelines, and potential data sources proposed by Member States to carry out analyses of these socio-economic effects. It provides a framework applicable to any GM crop that has been or might be grown in EU Member States (and/or in Norway).

As preliminary work, the ESEB secretariat identified 49 topics as a starting point (Kathage et al., 2015). Member States were then invited to add or delete topics and to identify indicators, methodology, data sources, and scientific publications they considered appropriate to help assess the topics.

Almost 100 indicators, which range from farm adoption rates to consumer surplus, have been identified by the ESEB Technical Working Group. The document contains impacts for all major groups in society that might be impacted by the cultivation of GM crops in the EU—adopting and non-adopting crop farmers, upstream industries such as the seed and agro-chemical industries, downstream industries such as feed and livestock producers, the food and retail sector, consumers, and the government budget. It also proposes consumer and producer surplus as an aggregate indicator.

According to the document, evidence of impacts in the EU already exists for some crop/trait combinations both *ex post* and *ex ante*, but for most topics it is very limited. Methodologies have been developed by the scientific community for many of the topics and indicators (from simple partial budget analysis to complex aggregated models). However, the main constraint concerns the lack of data to conduct the analyses. Surveys of farmers, industry, and consumers are necessary to assess the majority of topics. Fewer topics can be analyzed by compiling secondary data from existing sources.

While the first ESEB Reference Document represents a very general framework with potential applicability to various GM crops, the goal of the next Reference Document is a detailed focus on Bt maize, the first and currently only GM crop grown in the EU.

References

Areal, F.J., Riesgo, L., & Rodríguez-Cerezo, E. (2013). Economic and agronomic impact of commercialized GM crops: A meta-analysis. *Journal of Agricultural Science*, *151*, 7-33.

Brookes, G., & Barfoot, P. (2015). *GM crops: Global socio-economic and environmental impacts 1996-2013*. Dorchester, UK: PG Economics Ltd.

Carpenter, J.E. (2010). Peer-reviewed surveys indicate positive impact of commercialized GM crops. *Nature Biotechnology, 28*, 319-321.

Carpenter, J.E. (2011). Impact of GM crops on biodiversity. *GM Crops*, *2*, 7-23.

Carpenter, J.E. (2013). The socio-economic impacts of currently commercialised genetically engineered crops. *International Journal of Biotechnology, 12*, 249-268.

COGEM (The Netherlands Commission on Genetic Modification). (2009). *Social-economic aspects of GMOs* (COGEM Report CGM/090929-01). Bilthoven, The Netherlands: Author.

COGEM. (2014, December). *Building blocks for an assessment framework for the cultivation of genetically modified crops* (COGEM Report CGM/141222-01). Bilthoven, The Netherlands: Author.

European Commission. (2011, May). *Report from the Commission to the European Parliament and the Council on socio-economic implications on the basis of Member States contributions, as requested by the Conclusions of the Environment Council of December 2008* (SANCO/10715/2011 Rev. 5). Brussels: Author.

European Commission. (2015). Directive (EU) 2015/412 of the European Parliament and of the Council of 11 March 2015 amending Directive 2001/18/EC as regards to the possibility for the Member States to restrict or prohibit the cultivation of genetically modified organisms (GMOs) in their territory (Text with EEA relevance). *Official Journal of the European Communities*, *L68*, 1-8.

Finger, R., El Benni, N., Kaphengst, T., Evans, C., Herbert, S., et al. (2011). A meta analysis on farm-level costs and benefits of GM crops. *Sustainability, 3*, 743-762.

Fischer, K., Ekener-Petersen, E., Rydhmer, L., & Edvardsson Björnberg, K. (2015). Social impacts of GM crops in agriculture: A systematic literature review. *Sustainability, 7*, 8598-8620.

Franke, A.C., Breukers, M.L.H., Broer, W., Bunte, F., Dolstra, O., et al. (2011, April). *Sustainability of current GM crop cultivation* (Report 386). Wageningen, The Netherlands: Plant Research International.

James, C. (2014). *Global status of commercialized biotech/GM crops: 2014* (ISAAA Brief No. 49). Ithaca, NY: International Service for the Acquisition of Agri-biotech Applications (ISAAA).

Kathage, J., Gómez-Barbero, M., & Rodríguez-Cerezo, E. (2015). *A framework for the socio-economic analysis of the cultivation of genetically modified crops: European GMO Socio-Economics Bureau 1st Reference Document* (Technical Report EUR 27241 EN). Seville, Spain: Joint Research Centre, Institute for Prospective Technological Studies.

Klümper, W., & Qaim, M. (2014). A meta-analysis of the impacts of genetically modified crops. *PLoS ONE*, *9*, e111629.

Kouser, S., & Qaim, M. (2013). Genetically modified crops and food security. *PLoS ONE, 8,* e64879.

Ludlow, K., Smyth, S., & Falck-Zepeda, J. (2014). *Socio-economic considerations in biotechnology regulation.* New York: Springer.

National Research Council. (2010). *The impact of genetically engineered crops on farm sustainability in the United States*. Washington, DC: National Academies Press.

Authors' Notes

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