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Framework for the socio-economic analysis of the cultivation of genetically modified crops

European GMO Socio-Economics Bureau
1st Reference Document

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Abstract

In the future the cultivation of genetically modified (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 European GMO Socio-Economics Bureau (ESEB) has compiled topics, indicators, methodological guidelines and potential data sources to carry out analyses of these socio-economic effects. This document provides a framework 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 Technical Working Group composed of representatives of Member States and with assistance from the European Commission's Joint Research Centre. 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. It is concluded that while methodologies are available for many of the topics and indicators, the main constraint is a lack of data.

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Executive Summary

The European GMO Socio-Economics Bureau (ESEB) was established in 2013 in order to organise and facilitate the exchange of technical and scientific information regarding the socio-economic implications of genetically modified (GM) crops between Member States (MS) and the European Commission. The mission of ESEB is to develop Reference Documents that enable a science-based assessment of these impacts in MS across the EU. This first document is a general framework that includes a list of topics that could be used in assessments, along with appropriate indicators and methods. It is based on contributions from the ESEB Technical Working Group (TWG) composed of representatives of MS and assisted by the ESEB secretariat located at the Joint Research Centre (JRC).

The introduction (Section 1) describes the background to the document, its scope, and the work process leading to its publication. The process consisted of a series of consultations and a meeting in March 2014 between the members of the TWG. They were organised by the ESEB secretariat, which also drafted the document. In collaboration with their national experts and stakeholders, TWG members proposed topics to be included in the document, which were then subjected to several selection criteria. In late 2014, the Regulatory Committee of Directive 2001/18/EC and the Advisory Group on the Food Chain and Animal and Plant Health were also given the opportunity to comment on the document.

Section 2 is concerned with the methodology for assessments. The general approach of conducting an impact assessment is presented, followed by considerations related to methods, and potential data sources. The approach consists of the definition of baseline and impact scenarios and an estimation of the value of selected indicators for each of the scenarios. The methods that can be employed vary by topics and indicators. Some topics, including many of those for farmers, can be assessed using primary data from farm surveys, and econometric techniques. Other topics, such as those concerned with downstream industries, require more aggregate economic models. Data sources include secondary data and literature reviews, although farm/industry/consumer surveys are required for most topics.

Sections 3-5 contain the topics identified by ESEB as relevant for impact assessments. The topics are introduced and complemented with the respective indicators, methodological remarks and references. The effects on crop farming (Section 3) are divided along adopters and non-adopters. Adoption rates, farmer characteristics, income and other economic effects, management practices, input use and efficiency, coexistence and time management are included among others. The effects outside the crop farming sector (Section 4) are divided into upstream and downstream industries, consumers and the government budget. They involve effects on the seed and agrochemical industries, the feed/livestock and food/retail sectors, trade, as well as consumer prices and choice, consumption, public acceptance, and government budgets. Section 5 contains the aggregate consumer and producer surplus. In the final remarks (Section 6), it is concluded that while methodologies are available for many of the topics and indicators, the main constraint is a lack of data.

Contents

1. 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 a third of the total maize area (131,538 hectares). Ninety-two 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.[3] As a result, the European GMO Socio-Economics Bureau (ESEB) was established in order to organise 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 EU. These documents are of a purely technical nature and not intended to serve any regulatory purpose.

The objective of this Reference Document is to provide a list of topics that could be included in assessments, along with indicators and methods that are appropriate for each topic. 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[4] affect the value of the selected indicator? Every assessment therefore requires a comparison between a scenario with cultivation and a scenario with no (or less) cultivation of the selected GM crop/trait.

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

The document compiles and merges contributions from the ESEB Technical Working Group (TWG) composed of representatives of Member States, with assistance of the ESEB secretariat at the Institute for Prospective Technological Studies (IPTS) of 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 in a table format (see the annex). 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[5] in late 2014 and amended as necessary.

The scope of this document encompasses impacts inside the EU. Potential impacts in third countries are excluded, with the exception of trade flows into or out of the EU.

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 12 March 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 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.

4 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)".

5 http://ec.europa.eu/dgs/health_food-safety/dgs_consultations/advisory_group_en.htm

The topics contained within this document have been selected from a more comprehensive list compiled from TWG members' contributions covering what they considered as "socio-economic" topics. However, when assessing whether or not 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.

Following a description of methodology for assessments (Section 2), the selected topics are organized into three sections that correspond to impacts on different groups in society: First, farmers and workers in the crop farming sector, including adopters and non-adopters of GM crops (Section 3), and second, people outside the crop farming sector, including upstream and downstream industries as well as consumers (Section 4). Section 5 concerns the total economic surplus and its distribution among consumers and producers (including farmers). The document concludes with a brief summary of the main results (Section 6). The annex contains the table used for submission of contributions from TWG members.

2. Methodology for assessments

Ensuring the quality of assessments of the impacts of GM cultivation requires the use of a scientific approach, reliable methods and appropriate data sources. These concepts are described in the following subsections.

2.1 Approach

There are three main steps for performing an assessment. First, a definition of the scenarios that are to be compared is needed. One scenario includes cultivation ("impact scenario") of the GM crop/trait under study, while the second represents the situation without cultivation ("baseline scenario") of the GM crop/trait. Second, the value of the indicator(s) to be assessed must be estimated for each of the two scenarios. Third, the difference between the two values ("impact") is calculated. This is illustrated in the following equation:

Impact = (value of indicator under impact scenario with GM cultivation) – (value of indicator under baseline scenario without GM cultivation)

Note that this approach implies a binary adoption decision. This is particularly suitable when considering impacts on a single plot cultivated by a farmer (either the GM crop is grown on it, or not). However, assessments usually cover more than one plot (often whole regions, countries or groups of countries) and not only adopting farmers but also non-adopting farmers and non-farming groups such as upstream and downstream industries as well as consumers. In that case, the impacts depend crucially on the (regional) adoption rate of the GM crop. Low or high adoption rates will have radically different impacts for most actors. Therefore, the impact scenario should always be described considering the actual or estimated adoption rates (between 0 and 100%). The baseline scenario will usually assume an adoption rate of 0% of the GM crop/trait under consideration, but positive adoption rates can be used, as long as it these are lower than those applied in the impact scenario. A positive adoption rate in the baseline scenario can be useful if the GM crop/trait combination under study is already grown by some farmers, but the release of new events and/or cultivars is expected to further expand its adoption rate.

The definition of the adoption rate under different scenarios can be approached in two main ways. The adoption rate can be estimated based on an explicit model (predictive), or it can be assumed in the absence of an explicit model (exploratory). In both cases, it is possible to employ varying assumptions to define multiple impact scenarios, which are then individually assessed against the baseline scenario. The use of multiple impact scenarios can provide insight into the robustness of the results.

A central question is how farmers and other stakeholders (e.g. upstream and downstream industries as well as consumers) behave under the impact and baseline scenarios. The adoption of a GM crop may lead farmers to choose different varieties or even different crops than the ones they would have grown in the absence of the GM crop, as well as modify their use of inputs and practices. Since only one scenario can be observed and the others are hypothetical, the most common approach is to compare adopters and non-adopters in the same area/region (Gómez-Barbero et al., 2008), or to compare GM and non-GM plots within the same farm (Kathage & Qaim, 2012). In both cases, the methodology should as much as possible control for the heterogeneity in environmental, economic and managerial characteristics among farmers and plots in order to avoid selection bias. The heterogeneity in farmer characteristics and behaviour also leads to heterogeneity in impacts of GM crop cultivation, which should be recognised.

Impact assessments of the cultivation of GM crops can be conducted before (*ex ante*) or after (*ex post*) cultivation takes place. Both types of analysis require a definition of the time period that shall be covered as impacts may evolve over time. Assessments should cover at least one year. For *ex ante* studies, which are likely to be constrained by the range and complexity of variables affecting crop performance, the use of multiple impact scenarios is particularly relevant.

2.2 Methods

While different topics and indicators may call for different methods, there are a number of issues that apply across almost all of them. More specific guidance on suitable methods for individual indicators can be found in the scientific publications cited in the descriptions of the associated topics in sections 3, 4 and 5 of this document.

Assessing the impact of GM cultivation on farmers typically involves using farm surveys of adopters and non-adopters.

Data from these surveys should be analysed using appropriate statistical techniques ranging from partial budgeting to econometric models specific to the indicator at hand. For *ex ante* assessments, data from field trials could be used in the absence of or in addition to the farm surveys.

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. Economic models have been developed to estimate the aggregate welfare or macro-level impact of GM cultivation and its distribution among stakeholders (e.g. adopters and consumers) and/or regions (Europe and the rest of the world). Aggregate analyses take into account effects such as the impacts of GM crop cultivation on regional and global supply and market prices, the effects on consumers (if prices change) and the effects on prices of agricultural inputs (e.g. seeds, pesticides) as well as on land and labour. Published studies show methodological variations regarding data sources, model types and assumptions, levels of regional aggregation, applied price elasticities, price transmission along the supply chain and developments over time (Franke et al., 2011; Gómez-Barbero & Rodríguez-Cerezo, 2006). When the market of a single crop is considered, partial equilibrium models are applied, whereas general equilibrium models are used when indirect effects and spillovers to other market, sectors and stakeholders are also of interest (Qaim, 2009).

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 that are able to determine, for instance, how the operators of the chain will react to the adoption of GM crops and the exploitation of the demand for non-GM food/feed (i.e. establishing identity preserved (IP) markets and price premiums on these products). This type of analysis is still rare in the existing literature and requires primary and secondary data that are difficult to obtain (Tillie et al., 2012).

Many researchers have set out to study the preferences of consumers regarding GM/non-GM food products. Two main types of methodologies to elicit consumer preferences of GM/non-GM products can be distinguished: stated preferences are elicited in hypothetical framework, resulting in the hypothetical willingness to pay (WTP). Revealed preferences are measured in real purchase situations, resulting in the actual WTP. Revealed preferences are more appropriate as they avoid socially desirable answers. Primary data from dedicated surveys are needed for this type of analysis.

2.3 Data sources

Even with a proper methodological approach, assessments are often constrained by the availability and quality of data. These limitations are more pronounced for *ex ante* studies (Demont et al., 2008). A few topics can be examined *ex post* by relying on secondary data sources. For example, assessing the adoption rate *ex post* is facilitated by data available from the national registers required by Directive 2001/18/EC. However, even *ex post* assessment of most topics requires primary data.

Ex ante assessments usually require primary data collection, for example when predicting adoption rates (Areal et al., 2012; Demont et al., 2008). Where *ex ante* assessments utilize secondary data, such as literature reviews, appropriate consideration should be given to the predictive limitations of this type of analysis.

At this time, the data needed to estimate the values of most of the indicators described in this document are not available, and there are no initiatives at the EU level under which such data shall be collected in the future. If a country wants to obtain the required data, it is necessary to perform farm/industry/consumer surveys. These surveys should be representative of the target population, which is achieved by using adequate techniques such as random sampling. Furthermore, the establishment of panel datasets can facilitate unbiased impact assessments and the analysis of dynamics over time (Kathage & Qaim, 2012). 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.

3. Effects on crop farming

The cultivation of GM crops affects farmers that adopt and farmers that do not adopt the technology in different ways. To measure the effects of GM adoption in the EU, the overall adoption rate and the typology of adopting and non-adopting farmers should be assessed. The impacts on adopters can be divided into changes in gross margin (and its constituent costs and revenues), management practices (tillage, rotation and resistance management), input use and production efficiency (National Research Council, 2010). Further topics include coexistence management, including costs of coexistence regulations and expenses to cover the risk of adventitious presence (AP), and time management (Lusser et al., 2012). 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 (Qaim, 2009).[6]

3.1 Adopters

3.1.1 Adoption rates

Adoption rates can be expressed in several ways; most commonly as the number of hectares that are cultivated under GM crops and the share of these hectares among the total cultivated area under these crops (James, 2014). Another indicator is the number of farmers using GM crops on at least a part of their land and their share among all farmers. The number of farmers willing to adopt or not to adopt a particular GM crop can be used as an estimate (*ex ante*) of its potential adoption or diffusion (Areal et al., 2012; Areal et al., 2011). A different approach of predicting adoption rates is based on a utility model according to which a farmer will adopt a GM crop if the expected benefits of adoption exceed the expected costs (Demont et al., 2008).

Proposed indicators:

- 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*)

3.1.2 Typology of adopting farmers

A starting point for the analysis of the impacts of GM crop cultivation on adopting farmers is their characterisation in terms of farm location, size, income, crop and livestock operations and ownership status (Gómez-Barbero et al, 2008; Kathage & Qaim, 2012). Also, demographic characteristics of the farm manager such as education, age, sex, income and occupational status should be collected. These characteristics provide information on which groups or types of farmers are directly impacted by GM cultivation. Furthermore, some of these characteristics may themselves change as a result of adoption.

- 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)

3.1.3 Income effects

GM crop adoption can have an impact on variable and fixed cost, cost structure, yield and yield risk, quality of output, output price, subsidies and gross margin (Franke et al., 2011; Gómez-Barbero et al., 2008; Kathage & Qaim, 2012; National Research Council, 2010). Coexistence costs should be counted as a part of the variable cost (further detailed in topic 3.1.6). Adoption could also have an impact on fixed cost (e.g. if separate storage facilities are needed). Fixed and variable costs should be measured in Euros per hectare. The cost structure is indicated by the composition of variable cost (e.g. seed cost as a share of variable cost) and of total cost (i.e. variable cost as a share of the total cost). Yield should be captured in tonnes per hectare, and yield risk expressed in annual yield variation or, if available, crop insurance premiums paid by adopters. Quality of output can be measured by a variety of indicators, such as the content of particular nutrients (e.g. protein) and/or contaminants (e.g. mycotoxins). Output price should be reported as the price in Euros per tonne at the farm gate. Subsidies, the eligibility of which might change with GM cultivation, and gross margins should be measured in Euros per hectare. In addition to

6 Note that several indicators in this document may be repeatedly mentioned under different topics. This is not considered a problem since aggregation across topics is not intended.

income effects for farmers, the impact on farm workers' employment and wages may be assessed.

3.1.3.1 Fixed cost

- Fixed cost in €/ha

3.1.3.2 Variable cost

- Total variable cost in €/ha (seed, pesticides, machinery, labour, etc.)

3.1.3.3 Cost structure

- Composition of variable cost
- Composition of total cost

3.1.3.4 Yield and yield risk

- Tonnes per ha
- Yield risk measured in annual variation in t/ha or crop insurance premiums in €/ha paid by farmers

3.1.3.5 Quality of output

- Indicator depending on quality attributes specific to crop under study (e.g. protein content, oil composition, level of mycotoxins, pesticide residues, etc.)

3.1.3.6 Price received for output

- Market price (€/t)

3.1.3.7 Subsidies

- Subsidies (€/ha or €/t)

3.1.3.8 Gross margin

- Gross margin in € per ha
- Gross margin as a percentage of turnover

3.1.3.9 Employment and wages

- Number of farm workers and their total working hours (on a monthly basis to cover seasonality)
- Wages of employed farm workers in €/hour

3.1.4 Management practices

GM crop cultivation may impact the choice of tillage operations, rotation and pest resistance management (Bonny, 2008; Frisvold & Reeves, 2008; National Research Council, 2010). For tillage the recommended indicators are the frequency of conventional, conservation and zero tillage on a given plot. The impact on rotations should be measured by the number and types of crops cultivated over time in the same field. Resistance management are actions taken by farmers to prevent pest/disease/weed resistance and can be measured in the size of refuge areas and time efforts (e.g. extra time for sowing/harvesting of a refuge variety).

3.1.4.1 Tillage

- Type of tillage used by plot (conventional, conservation, no-till)

3.1.4.2 Crop rotation

- Types and frequency of crops used in rotation
- Number of crops per year in the same plot

3.1.4.3 Resistance management

- Size of refuge areas (share of plot area)
- Actions taken to prevent resistance (time spent in h/ha)

3.1.5 Input use and efficiency

The adoption of GM crops can have effects on the use of energy, fuel, water, labour, land, fertilizer, insecticides, herbicides, fungicides, and machinery (Carpenter, 2011; Dinu et al., 2010; Franke et al., 2011; Gómez-Barbero & Rodríguez-Cerezo, 2006; Lusser et al., 2012; National Research Council, 2010). Of high importance for impact assessments are the use of pesticides and overall production efficiency, but also labour, land, water, fertiliser and fuel, all of which might decrease or increase depending on the GM trait. For example, farmers might reduce pesticide use due to Bt crops, or use more land or fertilizer in the cultivation of a crop because it could become more profitable with a GM trait (Burrows et al., 2014).

Input use can be reported by unit of area or unit of output. Since a GM crop might have a different output per hectare than the relevant comparator and land is itself an input, it is recommended that input use is reported per unit of output (e.g. per tonne).

Overall production efficiency is considered a very important topic. It can be indicated by revenue divided by total input costs.

3.1.5.1 Energy

- KWh and € per unit of output (or per ha)

3.1.5.2 Fuel

- Litres and € per unit of output (or per ha)

3.1.5.3 Irrigation

- Cubic metres and € per unit of output (or per ha)

3.1.5.4 Labour

- Labour hours and cost in € per unit of output (or per ha)

3.1.5.5 Land

- Land area in ha and cost in € per unit of output

3.1.5.6 Fertilizer

- Kg and € of nitrogen, phosphorus, potassium per unit of output (or per ha)

3.1.5.7 Pesticides

- 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)

3.1.5.8 Machinery

- 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

3.1.5.9 Production efficiency

- Revenue divided by total input costs

3.1.6 Coexistence management

Depending on the regulatory system, adopters of GM crops may have to cope with the costs of implementing coexistence regulations, which can consist of technical (e.g. isolation distances, buffer strips) or administrative measures (e.g. compulsory training courses) (Areal et al., 2011; Areal et al., 2012; Czarnak-Klos & Rodríguez-Cerezo, 2010; Devos et al., 2009; Devos et al., 2005; Messean et al., 2006). The costs of complying with regulations depend on their exact specifications but could for example be the opportunity costs of not cultivating the GM crop on buffer strips. There may be costs to cover the risk of adventitious presence, e.g. through insurance premiums or levies GM crop farmers pay. The costs of coexistence management should be indicated per tonne of produced output and per hectare.

3.1.6.1 Cost of coexistence regulations

- Cost of complying with particular coexistence measures (e.g. buffer strips, compulsory training courses) in €/t and €/ha

3.1.6.2 Cost to cover risk of adventitious presence (AP)

- Compensation cost (funds, liability schemes, insurance premiums) to farmers in case of AP from GM fields in €/t and €/ha

3.1.7 Time management

GM crop adoption may affect the time management of farmers (Gómez-Barbero & Rodríguez-Cerezo, 2006; Mannion & Morse, 2013; National Research Council, 2010). Time availability is indicated by the hours or days spent on the management of a crop, the time and income derived from off-farm income and farmers monetary evaluation of leisure time and convenience (e.g. ease and flexibility of pest management). The quality of life of farmers might be improved through reduced working time (Omann & Spangenberg, 2002).

- Time spent on crop cultivation in h/ha and year

- Off-farm labour 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

3.2 Non-adopters

3.2.1 Typology of non-adopting farmers

Non-adopters should be characterized using the same indicators as adopters (see topic 3.1.2).

3.2.2 Economic impact of GM crop cultivation

The cultivation of GM crops can have effects on the availability of non-GM crop varieties, the prices received for non-GM crops, crop protection spillovers and segregation costs due to private standards (Demont & Devos, 2008; Demont et al., 2009; Devos et al., 2009; Franke et al., 2011; National Research Council, 2010).

The availability of non-GM crop varieties can be indicated by their number as recorded in national seed catalogues. Output prices should be measured in Euro per tonne.

Crop protection spillovers can consist of regional pest reductions brought about by the cultivation of insect-resistant GM crops, and potentially also of a reversal of insect resistance to synthetic insecticides (National Research Council, 2010). Spillovers should be indicated in changes in pest infestations, pesticide applications and yields. One potential method to estimate these changes is to record pesticide use and yields of non-GM crops grown in rotation with GM crops and compare these to the pesticide use and yields of non-GM crop grown in rotation with non-GM crop comparators.

Farmers growing IP non-GM or organic crops often receive a price premium for their products. In case of cross-pollination, these products might lose their IP status (e.g. organic certification), the corresponding premium and potentially also subsidies associated with that status (e.g. subsidies for organic production) (Consmüller et al., 2010). Non-GM IP crop producers may also implement segregation measures and the cultivation of GM crops might increase the costs of these measures. Payments received from compensation schemes can be another indicator of the cost of coexistence. Coexistence also has the potential to lead to disputes between neighbouring farmers due to the various externalities that may or may not be covered by legislation.

3.2.2.1 Availability of non-GM crop varieties for non-adopters

- Number of non-GM varieties in seed catalogues, by crop

3.2.2.2 Price received for output

- Price (€/t)

3.2.2.3 Pest reductions and reversal of resistance to synthetic pesticides

- Pest infestations

- Number of pesticide applications

- Yield (t/ha)

3.2.2.4 Segregation and adventitious presence (due to private standards)

- Total segregation cost in €/t

- Loss of IP rent resulting from adventitious presence in €/year

- Value and frequency of payments to farmers from national compensation schemes

- Number of disputes between farmers

3.2.3 Opportunity costs of non-adoption

Non-adopters might want to grow GM crops but be unable to do that because the GM crops are either not yet approved for cultivation or under temporary national bans (Park et al., 2011; Pray et al., 2005). In addition, uncertainty about future regulatory decisions represents an institutional risk for farmers (Franke et al., 2011). Potential opportunity costs caused by this non-availability of GM crops should follow the same topics and indicators as those mentioned under income effects, input use and efficiency for adopters.

- Income effects (see 3.1.3)

- Input use and efficiency (see 3.1.5)

4. 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 (Lusser et al., 2012). Furthermore, government revenues and expenses may be impacted.

4.1 Upstream

4.1.1 Effects on innovation capacity of agricultural and plant sciences

The adoption of GM crops in the EU can have an impact on the innovation capacity of agricultural and plant sciences in the EU. For example, GM adoption might increase Research and Development (R&D) investments in agricultural biotechnology, plant sciences and biosafety in the EU and thereby result in technological spillovers to other sectors (e.g. health care) (Anderson, 2010). The size of these spillovers will depend, among other things, on the ownership of the technology (FAO, 2011). At the same time, the cultivation of GM crops may increase the concentration of the seed industry, which could in turn reduce investments in new seed technologies (Anderson 2010; Franke et al., 2011).

An increase in GM cultivation could also have an impact on GM events that are in the regulatory pipeline for cultivation in the EU or at an advanced stage of development (Graff et al., 2009). The number of field trials in the EU may be affected in a similar way.

The fact that seed companies can often charge higher prices for GM seeds (technology fee) may affect future R&D investments. In contrast, high regulatory costs (to companies and authorities) usually act as barriers to R&D and commercialisation (Wield et al., 2010).

Proposed indicators:

- Number of GM/non-GM field trials in the EU
- Number of GM/non-GM crops in the R&D 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

4.1.2 Economic effects on the seed industry

GM cultivation could have an impact on the seed industry in the EU. The seed industry normally receives a price premium for GM seeds (i.e. technology fee) relative to conventional seeds (Gómez-Barbero et al., 2008; Gómez-Barbero & Rodríguez-Cerezo, 2006). GM adoption might reduce the demand for farm-saved seeds and thus increase seed market prices. An increasing market share of GM crops could also strengthen the market power of seed companies, either due to higher concentration in the GM seed sector, or an increase in market power at the expense of other input industries, and thus have an impact on seed prices. All these elements may increase the economic welfare captured by seed companies supplying GM seeds (Qaim et al., 2005).

On the one hand, with rising GM crop adoption, benefits may shift from conventional to GM seed producers. This could also translate into a shift of R&D strength between these sectors (Lusser et al., 2012). On the other hand, non-GM seed producers might benefit from specializing in a niche market, for example organic seeds.

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

4.1.3 Economic effects on the agro-chemical industry

As in the case for the conventional seed producers, the adoption of GM crops may shift benefits from the producers of competitive pesticides (e.g. synthetic insecticides) to the producers of GM seeds and complementary products such as broad-spectrum herbicides (Desquilbet et al., 2001; Lusser et al., 2012).

- Economic welfare of agro-chemical industry (€/year)
- Pesticide sales in the EU
- Number of companies producing pesticides and change over time

4.1.4 Land markets

An expansion in the cultivation of GM crops might affect land prices through changes in the profitability of the crops grown. Changes in prices, together with the possibility of certain GM traits not being scale-neutral, could also affect parcel structure. Furthermore, land market effects may extend to the real estate market.

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

4.2 Downstream

4.2.1 Effects on exports and imports of concerned and competing crops

The EU is highly dependent on imported vegetable protein as an ingredient for livestock feed and this protein is increasingly derived from GM crops in terms of area and the number of crop/trait combinations (Nowicki et al., 2010). At the same time, there is a segmentation of agricultural commodity markets due to GM crop regulations (e.g. labelling regulations in the EU) and private standards resulting from market demand for non-GM feed/food.

If more GM crops are cultivated in the EU the overall imports of concerned and competing crops may decrease. Export might go up because the EU produces more domestically, or may go down because of trading partners demanding non-GM products. Similar considerations apply to trade patterns between EU countries within the internal market.

- 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)

4.2.2 Effects on costs of segregation and identity preservation by processors

When a GM crop is cultivated in the EU, processors that want to capitalize on the demand for non-GM crops have to maintain a segregation system preventing admixture with GM products through the food/feed chain (Franke et al., 2011).

- Non-GM certification cost (€/t)
- Costs associated with implementing segregation measures (€/t)

4.2.3 Economic effects on feed industry

The feed industry might benefit from lower prices for raw materials if an expansion of GM cultivation in the EU leads to lower market prices (Lusser et al., 2012). Most of the EU feed industry accepts GM raw materials which tend to be cheaper than their conventional counterparts. At the same time, a segment of the EU feed industry may capitalize on the demand for non-GM feed.

- 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)

4.2.4 Economic effects on livestock producers

The livestock sector may benefit from less expensive feed and feedstuffs if GM cultivation expands in the EU. At the same time, livestock producers capitalizing on the demand for non-GM products may have to pay a higher premium if more GM crops are cultivated (Lusser et al., 2012).

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

4.2.5 Economic effects on food industry

The EU food industry could benefit from less expensive and/or better quality of raw materials which may result from the increase in the cultivation of GM crops in the EU. However, parts of the industry are hesitant to accept GM products and willing to bear higher costs to avoid mandatory GM labelling. This policy can be achieved by sourcing ingredients from certified non-GM markets (at higher costs) and separating GM and non-GM ingredients in their processing facilities (Lusser et al., 2012).

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

4.2.6 Economic effects on other industries

GM crops may be used as feedstock for EU industries other than food/feed production (e.g. GM cotton for textile, GM maize for ethanol, GM potato for industrial starch). These crops may have a single purpose (e.g. amylase maize for bio-ethanol production) or more than one (Bt maize for animal feeding and/or bio-ethanol). Therefore, non-food/feed industrial sectors such as the energy, textiles or chemical industry can be affected by the cultivation of GM crops whether they are genetically engineered for those specific purposes or not.

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

4.2.7 Economic effects on retail sector

The retail sector faces the same challenges as the food sector regarding the impacts of GM cultivation in the EU. It could benefit from less expensive products or it may have to pay a higher price for non-GM certified products.

- Economic welfare (€/year)

4.3 Consumers

The cultivation of GM crops may affect consumers through changes in the price, quality and variety of food and consumer products (Franke et al., 2011). Furthermore, it may modify consumer understanding and acceptance of GM crops and products.

4.3.1 Effects on consumer choice, range of products

Freedom of choice can be related to the freedom of consumers to choose GM or non-GM products (Franke et al., 2011). The possibility to cultivate GM crops with new characteristics may alter the range of products offered to consumers (Devos et al., 2005). However, the EU mandatory labelling requirements may prevent products from GM crops cultivated in the EU from appearing at the retail level (Carter & Gruére, 2003).

- Number of GM labelled products in the EU market
- Number of not labelled products in the EU market
- Number of GM-free labelled products in the EU market
- Number of GM products with new characteristics (e.g. novel nutritional attributes) in the market

4.3.2 Effects on consumer prices

GM crop products may be supplied at different prices than those from conventional crops (Franke et al., 2011; Sexton & Zilberman, 2012). This fact may have different impacts on consumers depending on their choices, GM, non-GM (no label) or non-GM labelled products. Final consumers of GM products may benefit from lower prices when they are transmitted to them, which results in gains of consumer surplus. The overall consumer surplus will depend on consumer attitudes towards GM crops, the cost of segregating GM and non-GM crops, the pricing strategies of life science companies (i.e. the greater the share of the seed industry in the economic welfare surplus the smaller may be the gains to consumers) and the availability of GM products versus non-GM products on the shelf, amongst other factors. Finally, some consumers may be willing to pay price premiums for non-GM products or non-GM labelled products.

- Economic welfare (€/year)
- Price premium paid for non-GM (no label) or GM-free (labelled) products (€/kg)

4.3.3 Effects on consumption patterns

Many studies have explored the acceptability of GM foods to consumers, and some have concluded that much depends upon whether consumers see a clear benefit (Hossain et al., 2003). Consumer preferences regarding GM/non-GM food products are measured by the WTP (Lusser et al., 2012). The adoption of GM crops might also influence consumption of different food categories (e.g. meats, fruit and vegetables) by inducing price changes.

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

4.3.4 Effects on public understanding and acceptance

There is a growing body of scientific literature on the public understanding and acceptance of GM crop cultivation globally (Costa-Font et al., 2008; De Groote, 2011; Frewer et al., 2011; Lusk et al., 2005; Smale et al., 2009). Existing evidence shows that when people are confronted with a real GM product, they switch from a general mode of acceptance or rejection of the technology to a more differentiated mode assessing the particular qualities and the price of the product (Aerni et al., 2011). At the same time, it can be concluded that public attitudes and perceptions towards GM plants and crops vary with time (and the occurrence of new events) and in different countries and cultures (Frewer et al., 2011). Therefore, the cultivation of GM crops and their dissemination in the EU may lead to a smaller or greater public understanding and acceptance of GM crops among citizens.

- 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

4.4 Government budget

GM crop cultivation might influence government revenue and expenditures, depending on the level of regulation foreseen. For example, controls might be required and their total cost increase when the area under GM crops expands. At the same time, public revenues might increase through taxation of companies and farmers (e.g. sales taxes, corporate taxes and individual income taxes) (Mankiw, 2014).

- Government reve nue and expenditure (€/year)

5. Aggregate consumer and producer surplus

Total economic welfare can be modelled as the sum of consumer surplus and producer (including farmers) surplus (i.e. aggregate economic effects). The cultivation of GM crops can have an influence on both. Depending on the relative gains or losses, certain producers or consumers might be more affected than others (e.g. small farmers may benefit more from the adoption of a GM crop in developing countries; Lusser et al., 2012). To further explore the distributional impacts, it is possible 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

6. Final remarks

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 European GMO Socio-Economics Bureau (ESEB) has compiled topics, indicators, methodological guidelines and potential data sources proposed by Member States to carry out analyses of these socio-economic effects. This first document provides a framework applicable to any GM crop that has been or might be grown in EU Member States.

As preliminary work, The ESEB secretariat identified 49 topics as a starting point (see the annex). Members of the ESEB Technical Working Group (TWG) were then invited to add or delete topics and to identify indicators, methodology, data sources and scientific publications they consider appropriate to help assess the topics.

Almost 100 indicators, which range from farm adoption rates to consumer surplus, have been identified by the TWG.

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 analysed by compiling secondary data from existing sources.

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ANNEX: Table for submission of contributions						
General framework for the socio-economic assessment of GM crops Topics related to the benefits and costs of cultivating GM crops in Europe						
Item #	**List of relevant topics**	**Priority – (high/low)**	**Indicators for the assessment**	**Methodologies for the assessment**	**Data Sources for the assessment**	**References**
1	**1. Effects on Farmers**					
1.1	**1.1 Adopters of GM crops**					
1	Adoption rates					
2	Typology of adopting farmers					
	Partial budget analysis (GM vs. conventional variety):					
3	Fixed cost					
4	Variable cost					
5	Seed cost (technology fee)					
6	Pesticide cost					
7	Cost structure					
8	Yield					
9	Quality of output					
10	Price received for output					
11	Gross margin					
	Changes in management practices due to adoption:					
12	Tillage					
13	Rotation schemes					
14	Resistance management					
	Changes in input use due to adoption:					
15	Energy					
16	Fuel					
17	Water					
18	Labour					
19	Land					

20	Fertilizer					
21	Insecticides					
22	Herbicides					
23	Fungicides					
24	Machinery					
25	Production efficiency (output per unit of input)					
	Coexistance management (at farm level):					
26	Cost of coexistance regulations					
27	Cost to cover risk of adventitious presence (e.g. insurance, funds)					
	Non-pecuniary effects:					
28	Health effects related to input use (e.g. pesticides)					
29	Time availability for off-farm labour					
	1.2 Nonadopters of GM crops					
30	Typology of nonadopting farmers					
31	Availability of non-GM crop varieties					
	Economic effects of GM cultivation on nonadopters:					
32	Price received for output (for same use)					
33	Crop protection spillovers from GM cultivation (e.g. areawide pest suppression)					
34	Segregation cost (according to market demand)					
	2. Effects on Nonfarmers					
	2.1 Upstream					
35	Innovation capacity of agricultural and plant sciences					
	Economic effects on:					
36	Seed industry					
37	Agro-chemical industry					
2.2	**2.2 Downstream**					
38	European exports and imports of concerned and competing crops					
39	Costs of segregation and identity preservation by processors					

	Economic effects on:					
40	Feed industry					
41	Livestock producers					
42	Food industry					
43	Retail sector					
	2.3 Consumers					
44	Consumer choice, range of products					
45	Consumption prices					
46	Consumption patterns					
47	Nutritional quality					
48	Food safety and health care costs					
49	Global food security					
Please enter any additional topics below (along with priorities, indicators, methodologies, data sources and references)						

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