Methods for calculation of co-existence costs in agriculture

Guidelines of Work Package 5
Concerning Task 5.2 and 5.3
within Project SIGMEA

Methodology task force

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Table of Content

List of tables

List of figures

1 Measures to calculate sorted by crops and regions

As a starting point of analysis we decided to apply national regulations or strategies when calculating co-existence measures on farm level. Table 1 provides an overview about the distribution of work between partners for the different case studies performed within SIGMEA.

Table 1: Distribution of work

Country	Crop	National Implementation of EU Directive 2001/18/ of 12 March 2001	National Co-existence Strategy: Detailed Regulation about Co-existence Measures
France	Rape		In progress
France	Maize		
Spain	Maize		In progress
Denmark	Rape	Danish Act on Environment and Genetic Engineering, 2001 Act no. 436 of June 9, 2004	Statutory order regulating the compensation scheme (No. 220 of 31 March 2005) awaiting
Germany	Rape	German Genetic Engineering Act, Part 1, June, 2004, (Gesetz zur Regelung der Gentechnik, GenTG, Stand: Neugefasst durch Bek. v. 16.12.1993 I 2066; zuletzt geändert durch Art. 1 G v. 21.12.2004; 2005 I 186)	Statutory order regulation the Good Farming Practices awaiting
UK	Rape	Genetically modified Regulations entered into force on 17 October 2002 -Regulation Statutory Instrument (SI) -SI 2334 (animal feed) -SI 2335 (food) -SI 2412 Tracability and labeling -SI 2411 (deliberate release ,amendment) -SI 2692 (transboundary movements)	National Strategy of Co-existence awaiting at the end of 2005
Czech Republic	Rape		?

1.1 National strategy of co-existence in France

According to a recent AGRA Presse/Le Figaro, France news article from 15 September says, no regulation has apparently been finalized:

http://www.gene.ch/genet/2005/Sep/msg00060.html

The article also states that "There is good reason to bet that French regulations will be influenced by the Spanish laws." Actually, this is the only country in Europe that cultivates GM crops on a large scale (80.000 hectares of GM maize in2005), and it is where French experts, in particular from INRA (http://w3.inra.fr/), have studied the risk cross-contamination by GM crops for several years. Since observing Spanish GM field trials, the French have been constructing practical models."

1.2 National strategy of co-existence in Spain

On July 19, the Spanish government published a royal decree that regulated the co-existence of genetically modified, conventional or organic crops. It marks the desire of the Zapatero government to strictly control GM crops in Spain, in contrast to the Aznar administration – which was less strict, with laws comparable to the United States, where GM crops do not have a special status.

Spanish regulations

To start in future, the Spanish farmer - willing to cultivate GM crops - needs to warn the authorized authorities one month in advance and has to specify the variety and the introduced gene in the culture of interest. The farmer must adhere to specific rules for the preparation of the seed, the surveillance of fields, and the cultivation of the harvest. A security distance of 50 meters has to be kept between the fields of GM crops and other crops. The seeding period of the GM crops has to be declared compared to conventional varieties in order to prevent cross- pollination during blossoming. In addition, a buffer area of four rows of conventional maize that is labeled as GMO has to surround the GM field. In the case of maize resistant to the leaf-folder, 20 percent of the GM parcel has to be sown by conventional maize to hinder the development of resistance to the insect.

Additional regulations

The farmers must participate in education programs concerning GM cultivation. If a variety is deemed to be a source of contamination, it could be cancelled from the national register. Finally, the authorized persons from a region are charged with supervising whether the measures are well met.

1.3 National strategy of co-existence in Denmark

The Danish legislation distinguishes primarily between 3 different uses of genetically modified organisms: Use of GMOs for experimental purposes, use of GMOs for placing on the market and contained use of GMOs.

The use of genetic engineering is regulated in Denmark by the Act on the Environment and Genetic Engineering. The purpose of the Act is to contribute to safeguarding nature and the environment, thus ensuring sustainable social development in respect of human conditions of life and for the protection of flora and fauna. The Act shall also seek to protect human health in connection with genetic engineering.

The Danish Act on Environment and Genetic Engineering is the national implementation of EU Directive 2001/ 18/ EC of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Directive 90/ 220/ EEC. In addition to that the Act also implements EU Directive 90/ 219/ EEC on the contained use of GMO as amended by Directive 98/ 81/ EC.

The Directive on the deliberate release was latest amended in 2001. This amendment came into force on 17 October 2001. To be in accordance with the obligations in the Directive 2001/ 18/ EC, Denmark undertook a revision of the Act on the Environment and Genetic Engineering in the Spring of 2002.

Thus the regulations of GMOs in Denmark is harmonised with the regulations of other EU Member States. However, the scope of application for the Danish Act is broader as the Act also contains provisions on transport, import and the contained use of plants and animals. Three new Statutory Orders came into force together with the new Act; two Statutory Orders on the approval of production using genetically modified micro-organisms as well as plants and animals. The third Statutory Order concerns the deliberate release of genetically modified organisms. This Statutory Order contains the more detailed provisions of the Directive 2001/ 18/ EC.

The regulation of the contained use of GMOs in Denmark is also harmonised with the regulations of other EU Member States. The provisions can be found in *Statutory Order No. 829 of 3 October 2002* on the approval of production using genetically modified plants and animals, and *Statutory Order No. 830 of 3 October 2002* on the approval of production using genetically modified micro-organisms. Both Statutory Orders are based on Article 8 in the Act – *Consolidated Act No. 981 of 3 December 2002* on the Environment and Genetic Engineering in force.

In June 2002, the Danish Minister for Food, Agriculture and Fisheries took the initiative to prepare a strategy of co-existence of genetically modified, conventional and organic crops.
A Working Group (scientific expert group), a Strategy Group (legal and administrative group) and a Contact Group (stakeholders) were set up to prepare a national co-existence strategy.

Based on the work and results from the groups a co-existence act was presented to the Parliament and the act was passed through Parliament in June 2004 with support from a broad political majority. (Act no. 436 of June 9 2004).

The Danish co-existence act contains a number of elements to full fill the national strategy:

- mandatory education of GM-growers
- authorisation of GM-growers
- registration of GM-growers
- good agricultural practices
- separation distances between GM and non GM crops
- a compensation scheme for farmers suffering losses from adventitious presence of GM crops into their non GM crops from neighbouring GM crops
- a fee of 100 DKK per hectare GM crops grown to finance the compensation scheme

The implementation of the Act is regulated by statutory order No. 220 of 31 March 2005 (growing of genetically modified crops). A statutory order regulating the compensation scheme is awaiting the final approval.

1.4 National strategy of co-existence in Germany

Germany modified the „German Genetic Engineering Act" ("Gentechnikgesetz") to ensure and implement co-existence schemes (Transgen, 2005). According to BMVEL (2005) the novel German regulation includes three main instruments:

- Precautionary obligation of the GM farmer to follow good farming practices (GFP) to avoid damages from planting GM crops.
- Registration of fields planted with GM crops
- Compensation payments for non-GM farmers in case of income losses.

According to this German regulation, farmer who use the GM technology are obliged to keep precautionary measures in order to avoid adventitious admixture of GM and conventional or organic crops in the context of Good farming practice. Details concerning the shaping of this Good Farming Practices are currently in progress and will be fixed in a special regulation which is still in progress up to now.
However, German farmer has the possibility to crop Bt maize (YieldGard – Bt maize, Monsanto) in 2005. German farmers oblige to apply Good farming practice with cropping Bt maize in a commercial way. This Good farming practice was elaborated by Monsanto and is shown in figure 1.

Figure 1: Good farming practice for Bt maize for Germany according to Monsanto (2004)

Production step Good farming practice for Bt maize (*)
Storage
Separate storage of GM and non-GM maize seed *
Seed
Registration of the Bt-field by the appropriate authority*
Cleaning the drilling machine*
Cropping
Isolation distance of 20 m to conventional maize *
Isolation distance of 300 m to organic maize fields *
Resistance management in case of a field bigger than 5 ha *
Resistance area minimum 20 % of the total maize area on farm
Maximal distance 750 m to Bt maize
Same variety, drilled on same time as Bt maize
Harvest
Cleaning of the combine *
Transport
Cleaning the transport machine*

1.5 National strategy of co-existence in the United Kingdom

The Department for Environment, Food and Rural Affairs (DEFRA) and the devolved Administrations for Scotland, Wales and Northern Ireland[1], are responsible for the implementation of EU Directives[2] on Genetically Modified Organisms (GMO's) in the UK.

There are currently no GM crops being grown in the UK. None are expected to be grown commercially before 2008. In recent years GM crops have been grown for R&D purposes at a number of sites. The main example of this has been the Farm Scale Evaluation (FSE) GM crop trials.

The UK Government and Devolved Administrations are developing a national strategy of co-existence for GM and non-GM crops. It is expected that they will publish their co-existence strategy in 2005. Before the strategy is published the UK Government and Devolved Administrations have taken actions to investigate the social, environmental and economic issues of co-existence. The Farm-scale evaluations, a GM national debate, a consultation plan with stakeholders and advice given by the Advisory Committee on Releases to the Environment (ACRE)[3] and the Agriculture and Environment Biotechnology Commission (AEBC)[4] have provided evidence base to support policy decisions on the GM issue. These actions are summarised in this section.

[1] The Devolved Administrations are: Welsh Assembly Government, Scottish Executive Environment and Rural Affairs Department and the Department of the Environment in Northern Ireland. The Department for Environment, Food and Rural Affairs (DEFRA) is a core Administration.

[2] Three key pieces of EU legislation currently regulate GMO's in the UK (directive EC 1829/2003 EC 1830/2003 and EC 1946/2003). These directives have been implemented in England through regulation Statutory Instrument (SI) 2334 on animal feed, SI 2335 on food, SI2412 on traceability and labeling, SI 2411 on deliberate release (amendment) and SI2692 on transboundary movements. In England, the Genetically Modified Organisms (Deliberate Release) Regulations 2002 entered into force on 17 October 2002. Similar regulations for Scotland and Wales came into force in December 2002 and Northern Ireland in April 2003 (Source: DEFRA [b], 2004).

[3] ACRE is an independent Advisory Committee composed of leading scientists. Its main function is to give statutory advice to Ministers in the UK and devolved administrations on the risks to human health and the environment from the release and marketing of genetically modified organisms (GMOs).

[4] AEBC was the Government strategic advisory body on biotechnology issues affecting agriculture and the environment. Its role was to provide strategic advice to Government that takes account of scientific, social and ethical considerations and identified a number of broad requirements and objectives. Further information about the AEBC can be found on its website at: http://www.aebc.gov.uk/

1.5.1 Farm scale evaluations

The Government announced the farm-scale evaluations (FSE) in 1998 as part of a set of initiatives to strengthen the process for making decisions on whether or not to allow commercial cultivation of certain GMHT crops grown and managed with their associated herbicide regimes. The FSE was a four-year programme of research by independent researchers aimed at studying the effect, if any, that the management practices associated with Genetically Modified Herbicide Tolerant (GMHT) crops might have on farmland wildlife, when compared with conventional weed control in non-GM crops.

The results for the three spring sown crops, maize, beet and spring oilseed rape, were published in 2003. The results for winter oilseed rape were published on 21 March 2005. With regard to the FSE results the UK Government decided that its policy on GM will be to:

- oppose EU approval for the commercial cultivation of the GM beet and oilseed rape as grown in the FSE trials
- only allow the commercial cultivation of the GM maize if restrictions are imposed on its EU marketing consent to limit herbicide use

1.5.2 GM Nation debate

Following advice from the AEBC, the UK Government promoted a public debate on the future of GMOs in the UK, which started in the autumn 2002. This debate comprised a public debate, a review of the scientific issues and a study into the overall costs and benefits of GM crops. The UK Government response to the GM debate was published on 9 March 2004[5] (DEFRA, [a] 2004).

The UK Government response accepts the public opinion on GM crops and food is generally uneasy. In addition, the debate confirmed that a range of issues and concerns shapes people's attitudes towards GM issues.

With regard to the science review, the UK Government highlighted its conclusions. The review concluded each application must be considered on a case-by-case basis. Worldwide there have been no verifiable ill effects reported from the consumption of products from GM crops over seven years. There is no evidence to suggest that current GM foods pose a greater risk to human health than their conventional counterparts. The main environmental risk with current GM crops is their potential impact on farmland biodiversity. The impact of these herbicide tolerant crops has been thoroughly investigated by the UK Farm-Scale Evaluations. The science review also acknowledged that there are some gaps in current scientific knowledge and identified areas for further research.

The UK Government highlighted the conclusions of the study on costs and benefits of GM crops. This study concluded that any economic benefit from the crops is likely to be limited in the short-term. The study also concluded that future developments in GM crops could potentially offer more significant benefits.

The UK Government has overall concluded that there is no scientific case for a blanket ban on the cultivation of GM crops in the UK, but that proposed uses need to be assessed for safety on a case-by-case basis. The Government will continue to take a precautionary approach and only agree to the commercial release of a GM crop if the evidence shows that it does not pose an unacceptable risk to human health and the environment.

1.5.3 Consultation plan with stakeholders

The UK Government is undertaking a consultation plan on the co-existence of GM and non-GM crops. This plan consists of a two-stage consultation process with stakeholders. The Devolved Administrations will contribute to these discussion workshops. The first phase started in March 2004 and comprised a series of workshops to discuss particular aspects of the overall issue, including:

- the co-existence measures needed at farm level for each crop type
- the threshold for GM presence in relation to organic production
- guidance on the possible establishment of voluntary GM-free zones

The UK Government will facilitate general co-existence arrangements at farm level based on the 0.9% EU labelling threshold for unintended GM presence. In addition, the Government will decide whether a lower threshold might apply specifically for organic production.

[5] Margaret Beckett (UK's Secretary of State for Environment, Food and Rural Affairs) set out the Government's overall policy on GM crops in a Parliamentary statement on 9 March 2004.

The second phase consists in a consultation package setting out specific proposals and/or options in line with Government's intentions.

The workshops discussed a several particular aspects of the issue. These are presented in table 3.

Table 2: Workshop discussions

Voluntary GM-free zones
What is meant by a GM-free zone? What specific points should farmers or others consider when thinking about establishing a zone? How should farmers and others pursue setting up a zone?
Regulatory burdens
co-existence framework Potential burden of the framework
Organic sector implications
EU position on GM presence in organic production Measures to minimise GM presence in organic crops Practical implications and/or constraints of aiming for a threshold below 0.9% Arguments about who should be responsible for delivering a lower organic threshold Likely economic impact of adopting a lower organic threshold
Environmental and consumers 'views
Agronomic measures for oilseed rape, maize and beet
Measures needed to manage co-existence between farms co-existence between GM and non-GM crops other than those produced for certified seed co-existence measures to ensure 0.9% threshold

The workshop on regulatory burden identified the elements, which will impact on the GM farmer, are:

(i) Notification to Government in writing of their intention to sow a GM crop;

(ii) if any neighbouring farmland falls within the recommended separation distance of the intended location of the GM crop to notify neighbouring farmers of their intention to sow a GM crop [probably by a specified date];

(iii) to observe the recommended separation distance and/or apply a barrier strip between the GM crop and any neighbouring non-GM crop of the same species.;

(iv) to control GM oilseed rape volunteers, beet 'bolters' and weed beet;

(v) to ensure that any shared cultivation or harvesting equipment used for the GM crop is cleaned before it leaves the farm; and

(vi) to keep appropriate records of some or all of the following points:

- When, who and how he notified his neighbour of his intention to sow a GM crop (if a notification is necessary)
- The field in which the GM crop is being grown
- In the case of a GM beet crop, when it was checked for possible 'bolting' plants and confirmation that any found have been destroyed
- For GM oilseed rape, the action taken to minimise 'volunteers'
- In the case of machinery hygiene, confirmation of whether shared equipment has been used on the GM crop and, if so, confirmation that it was cleaned before leaving the farm.

(Note: To minimise the burden as far as possible, it is intended to produce a pro-forma or checklist so that GM farmers can record most of these points in a simple ‘tick-box’ format and/or by entering relevant dates).

DEFRA also conducted consultation visits to farmers and agricultural contractors to investigate their views on how easy and practical it would be to apply a range of possible measures (i.e. notification, separation distances, use of machinery, volunteer control and use of a GM register) to minimise GM crops contaminating non-GM crops grown in the UK. With regard to the ability to achieve separation distance the larger the farm unit or blocks of land, the greater the ability to achieve whole field separation. Units with residential/industrial or hill land on adjacent boundaries also had greater flexibility.

1.5.4 ACRE

ACRE have provided advice to the UK Government and Devolved Administrations on the effects of the GMOs release.
ACRE is an independent advisory committee. It has advised that GM herbicide-tolerant beet and spring-sown rape should not be approved for planting on the basis of the management regimes tested under the trials. ACRE has also advised that the consent for herbicide-tolerant maize should be amended to restrict the management conditions under which it can be grown to those in the FSE; that further work be conducted to investigate the implications of the impending withdrawal of Atrazine; and that a post-market monitoring requirement be imposed to monitor the management of conventional maize for the remaining duration of the consent (expires 2006) (ACRE, 2004). The Scottish Executive accepted ACRE's advice and have agreed with the UK Government a basis for pursuing the amendment of the maize consent at EU level.

1.6 Common measures independent from national strategies and regulations

The commission guidelines, which take the form of non-binding recommendations addressed to the Member States, intend to help them develop national strategies and approaches. Their scope extends from agricultural crop production on the farm up to the first point of sale, i.e. ‘from the seed to the silo’.

Focusing mainly on technical and procedural aspects, the guidelines provide a list of general principles and elements to aid Member States in establishing best practices for co-existence. Table 1 shows such measures which farmers could apply on-farm proposed by European Commission (2003).

Table 3: Indicative catalogue of on-farm measures for co-existence according to Commission of the European Communities (2003)

Measures to prevent pollen flow to neighbouring fields		
On farm measures	Preperation for sowing, planting and soil cultivation	Isolation distance
		Buffer zones
		Pollen traps or barriers e.g. hedgerows
		Suitable crop rotation systems
		Planning crop production
		Reducing size of the seed bank through adequate soil tillage
		Managing populations in field borders through appropriate cultivation methods, use of selective herbicides
		Choosing optimal sowing dates
		Careful handling of seeds to avoid admixture
		Using varieties with reduced pollen production or male sterile varieties
		Cleaning of seed drills
		Sharing seed drills only with farmers using the same production type
		Preventing seed spillage when travelling to and from the field
		Control/destruction of volunteers
	Harvest and post-harvest field treatment	Saving seeds only from suitable fields and field areas
		Minimising seed loss during the harvest
		Cleaning of harvesting machinery
		Sharing harvesting machinery only with farmers using the same production type
		Seperatly harvesting of field margins
	Transport and storage	Ensuring the physical segregation
		Adequate Seed storage arrangements and practices
		Avoiding spillage during transport
	Field monitoring	Monitoring of seed spillage sites, fields and field margins for volunteer development

2 Methodology of cost calculation

2.1 State of art – literature review

There is some literature focussing on the economics of genetically modified plants. Recent research in economics of GM organisms has mainly concentrated on the identification of impacts of GM crops on farmers' gross margin defined as the difference between revenues and variable costs (Sacasta & Wesseler, 2004). The impact of GM crops on revenues is mostly investigated through impacts on yields whereas the impact on variable costs is investigated through impacts on costs for seeds, technology, pesticides/herbicides, fertilizer, machinery and labour. One of the shortcomings is that most studies do not consider identify preservation or segregation costs which implies additional costs at all stages of food and feed chain and which especially occur by avoiding adventitious admixture between GM and non-GM crops on farm level. However, there are some studies which quantified labelling respectively IP costs on farm level (table 2).

Table 4: Studies dealing with segregation costs modified according to Jones, S. et al, 2001

Author	**Country**
Buckwell et al (1999)	Canada, USA, EU
Bullock, David et al (2000)	USA
Directorate-General for Agriculture (2000)	EU
Jones, S. et al (2001)	UK
Bock, Anne-Katrin et al (2002)	France, Italy, Germany
Brooks, Graham (2003)	EU
Tolstrup, Karl et al (2003)	Denmark
Golder G., (2000)	Canada
Deams, W., M. Demont et al (2005)	EU
Strategy Unit, UK (2003)	UK

There is no common methodological approach used in these studies. Bock, A-K. et al (2002) mainly concentrate on the question how different measures influence thresholds under special regional conditions and assess the additional costs whereas Tolstrup, K. et al. (2003) calculate different scenarios based on the report of Bock, A-K. et al (2002) under Danish conditions without simulation any measures and their impact on the level of contamination. Jones, S. et al. (2001) and DG Agri (2000) used the welfare approach to estimate the economic impacts of genetically modified crops on agri-food-sector.

Concerning our methodology guidelines the working paper of Deams, W., M. Demont et al (2005) is the most useful paper. Deams, W., M. Demont et al (2005) describe as detailed and realistic as possible, the potential economic costs of co-existence at the farm level in a whole model.

According to Deams, W, M. Demont et al (2005) following captures give an overview of possible co-existence measure costs calculation.

2.1.1 Costs of co-existence

(1) $$C_{cox} = C_{gfp} + \mathrm{C_c} + \mathrm{C_{sf}}$$

C_{cox} = Costs of co-existence

C_{gfp} = Costs of Good Farming Practice

$\mathrm{C_c}$ = Costs of Control

$\mathrm{C_{sf}}$ = Costs of system failure

2.1.2 Costs of Good farming practice

(2) $$C_{gfp} = C_{bz\,g} + C_{ti} + C_{cr} + C_{dr} + C\ldots$$

C_{gfp} = Costs of Good farming practice

$C_{bz\,g}$ = Buffer zone

C_{ti} = time isolation – different flowering varieties

C_{cr} = crop rotation

C_{dr} = daily routines

2.1.3 Area of isolation in case of border seed

(3) $$a_{iso\ bs} = a^2 - (a - 2d)^2$$

$a_{iso\ bs}$ = Area of isolation - border seed

Note: According to WP 5 meeting in November 2005 “border seed” is now called “buffer strips” or “non-GM strips”. They are on GM fields whereas “discard width” is on non-GM field. Both are out of non-GM maize.

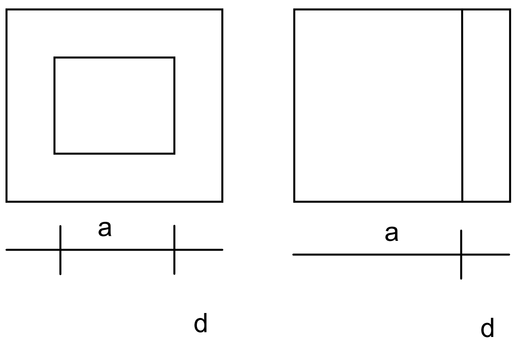
2.1.4 Area of isolation in case of buffer zone

(4) $$a_{iso\,bz} = a^2 - (a - d)^2$$

$a_{iso\ bz}$ = Area of Isolation - buffer zone

a = Area
d = Isolation Distance

(1)	(2)
Buffer strips non-GM-stripes Former border seed	Discard width former buffer zone



Note: According to WP 5 meeting in November 2005 “border seed” is now called “buffer strips” or “non-GM strips”. They are on GM fields whereas “discard width” is on non-GM field. Both are out of non-GM maize.

2.1.5 Costs of border seed on GM field

(5) $$C_{bs\,g} = a_{isobs}\left(y_g\, p_g - I_g\right)$$

$C_{bz\,g}$ = Costs of border seed on Gm field

a_{isobs} = Area of Isolation – border seed

I $_g$ = Input costs GM crop
y_g = Yield of GM crop

p_g = Price of GM crop

Note: According to WP 5 meeting in November 2005 “border seed” is now called “buffer strips” or “non-GM strips”. They are on GM fields whereas “discard width” is on non-GM field. Both are out of non-GM maize.

2.1.6 Costs of buffer zone on GM-field

(6) $$C_{bz\,g} = a_{isobz}\left(y_g\, p_g - I_g\right)$$

$C_{bz\,g}$ = Costs of buffer zone on GM field

a_{isobz} = Area of Isolation – buffer zone

I_g = Input costs – GM farmer

Note: According to WP 5 meeting in November 2005 “border seed” is now called “buffer strips” or “non-GM strips”. They are on GM fields whereas “discard width” is on non-GM field. Both are out of non-GM maize.

2.1.7 Costs of time isolation (difference in flowering date of different varieties)

(7) $$C_{ti\,g} = \left(y_{lf}\, p_{lf} - I_{lf}\right) - \left(y_{ef}\, p_{ef} - I_{ef}\right)$$

or

(8) $$C_{ti\,g} = \left(y_{lf} - y_{ef}\right)\left(p_{lf} - p_{ef}\right)$$
$$y_{lf} \geq y_{ef}$$

y_{lf} = Yield late flowering variety

y_{ef} = Yield early flowering variety

$C_{ti\,g}$ = Costs of time isolation GM farmer

Early varieties are less productive than late varieties. This yield loss accounts for the GM maize variety. Thus a cooperative has to be established between GM maize growers and non-GM maize growers. Late varieties are more productive than early varieties but are subject to another type of commercial risk: in cold and/or rainy years, harvesting of late varieties may be difficult (potential losses).

2.1.8 Costs of daily routines

(9) $$C_{dr} = C_{cm} + C_{vc}$$

C_{dr} = Costs of daily routines
C_{cm} = Cleaning machineries
C_{vc} = Volunteer Control

2.1.9 Costs for cleaning machinery (Machinery is not used 100 %)

(10) $$C_{cm} = (x-1)(t_{cm} I_{wph})$$

x-1 = Cleaning the machinery one time is current practice.

2.1.10 Costs for cleaning machinery (Using machinery 100 %)

(11) $$C_{cm} = (x_{cm} - 1)(t_{cm} I_{wph}) + (\frac{I_{lea}}{t_u} \times t_{cm})$$

For Machineries, which has been used all the time in season? Due to this fact opportunity costs could occur.

2.1.11 Costs for cleaning drilling machine

(12) $$C_{cs} = (f_s - 1)(tw)$$

Ccs = Costs for cleaning drilling machine
fs = number of times of cleaning
t = time spend on cleaning
w = hourly wage

2.1.12 Costs for cleaning harvest machineries by flushing

(13) $$C_{ch} = \left(f_h - 1\right)\left[tw + q_f\left(p_n - \left(1 + \varsigma\right)p_g\right)\right]$$

f_h = number of cleaning operations
t = time needed to clean machinery
w = hourly wage of labour
q_f = amount of crop that is needed for flushing
ς = price effect of selling a small lot of the harvested crop with GM presence
p_n - p_g = price premium that will be lost on the non-GM crop by using it as flushing material

2.1.13 Costs of volunteer control – by hand

(14) $$C_{vch} = x_{vc}\left[I_{wph}\left(t_{vc} a_g\right)\right]$$

C_{vch} = Cost for volunteer control $[€/ha]$
t_{vc} = time for volunteer control $[h/ha]$
a_g = area of former GM-field $[ha]$
I_{wph} = Input Costs for wage per hour $[€/h]$
x_{vc} = number of volunteer control treatment

2.1.14 Costs of volunteer control – by machinery

(15) $$C_{vcm} = x_{vcm}\left\{a_g\left[\left(I_m + \left(p_h \times x_h\right)\right) + \left(I_{wph} t_{vcm}\right)\right]\right\}$$

C_{vcm} = Costs of volunteer control by machinery $[€/ha]$
x_{vcm} = number of volunteer control by machinery
a_g = area of GM-field, which has to be treated with herbicide $[ha]$
I_m = variable costs for machinery $[€/ha]$
$p_h \times x_h$ = Costs for herbicide (price and amount per ha) $[€/ha]$
I_{wph} = Costs for wage per hour $[€/h]$
t_{vcm} = time for volunteer control by machinery $[h/ha]$

3 Databases and data sources

3.1 Gross margin of GM crops - Methodology of farm level impact estimation

The *ex ante* evaluation of the farm-level impact of transgenic crops in the European Union (EU) is subject to uncertainty. First, the absence of commercial-scale adoption implies that (i) no farm-level data is available on yield boosts or cost reductions due to the changed mix of production factor use and (ii) no evidence is available on the potential adoption pattern of the new technology. Secondly, the absence of a market for transgenic seed implies that no information is available on the price of the new technology, the so-called ‘technology fee’ or ‘price premium’.
These two factors determine the impact estimates for more than 80%, the other 20% is explained by structural parameters, such as e. g. yield, production, area, elasticity’s (for aggregate studies). The impact of co-existence will also introduce new uncertainties on the first three factors discussed. Therefore, the only methodology that makes sense for *ex ante* impact analysis under co-existence in the EU is one that is simple, clear and very transparent. Therefore, we recommend the use of the following simple methodologies for insect resistant (Bt maize) and herbicide tolerant (HT oilseed rape) crops.

Insect resistant crops (Bt maize)

Model
The simplest way to estimate the impact of Bt maize is the method of Ostlie, Hutchison, and Hellmich (1997). It is assumed that maize borer infestation decreases yield proportionally to the damage incurred despite pest control technology k. The technology k can be: absent ($k = 0$), conventional through insecticides ($k = c$) or biotechnological through Bt maize ($k = g$). The observed yield y_{jk} (t/ha) can be expressed as:

$$y_k = y_m \, [1 - (1 - \alpha_k) \, s] \qquad (1)$$

with y_m (t/ha) the theoretical maximum yield attained under hypothetical absence of corn borers, α_k the efficacy of technology k, measured by the proportion of larvae killed before affecting yield, and s_j the theoretical average proportional loss caused by corn borers in year j under absence of treatment. The profit per hectare π_{jk} (€/ha) of the farmer using technology k in year j is:

$$\pi_k = p \, y_k - w_k - c = p \, y_m \, [1 - (1 - \alpha_k) \, s] - w_k - c \qquad (2)$$

with p (€/t) the maize price, w_k (€/ha) the cost of technology k to combat corn borers and c (€/ha) all other costs that are independent of the choice of technology k, including the cost of conventional seed. In the case of an insecticide treatment ($k = c$) w_k comprises the cost of the product and the spraying application. For biotechnological crop protection ($k = g$), w_k represents the technology fee. In case of no treatment ($k = o$), $w_k = 0$.
The first assumption that needs to be investigated is the benchmark. Are farmers using insecticides or not? If yes, the best assumption is that Bt maize adopters were insecticide users before adoption. This provides a conservative impact estimate.[6] Only if you can argument the insignificance of insecticide use in the analysed region, you can assume that farmers switch from no treatment to Bt maize.
Depending on the assumption made in the previous step, you can estimate the farm-level impact through the difference in per-hectare profits $\Delta\pi_k = \pi_g - \pi_k$ where π_k is the profit under chemical crop protection ($k = c$) or no treatment ($k = o$). This assumption implies that the benefits from adopting Bt maize are generated by two factors: the difference in efficacy of corn borer control and the cost difference between both technologies.

Data
Data collection is still in progress and will be finished in the coming months in the project SIGMEA. However, some data are still available.

[6] Our null hypothesis asserts that farmers are not benefiting from Bt maize. If no survey data is available about the share of Bt adopters who were non-insecticide users before, by making this assumption a type II error is avoided, in which the null hypothesis is rejected by overestimating farmers’ benefits. Choosing conservative assumptions is very common in impact assessments of agricultural research since Griliches’ (1958) seminal paper, stating: “At almost every point at which there was a choice of assumptions to be made, I have purposely chosen those that would result in a lower estimate” (p. 426).

Efficacy of insecticide

Estimates of the efficacy of insecticides to control corn borers vary considerably. Ostlie, Hutchison, and Hellmich (1997) report an efficacy of 80% against first generation borers and 67% against second generation. Labatte *et al.* (1996) observe an average efficacy of 72% in case of suboptimal timing. Degenhardt, H.; Horstmann, F. and N. Mülleder (2003) examined the impact of every existing pest management against the European Corn Borer and estimated them regarding to their efficiency. Compared to biological and chemical pest management methods, Bt maize made the highest impact on larvae with efficiacy of nearly 100 % of the European Corn Borer.

Cost calculation of Degenhardt, H.; Horstmann, F. and N. Mülleder (2003) results in benefits of between 84-93 €/ha for Bt maize cultivators by considering higher yields in the range of 14 – 15 % and seed costs of plus 35 € per hectare comparing to conventional seeds[7]. Common insecticide users gain between € 18 – € 55 per ha by applying common insecticide management methods. Non-insecticide users do not benefit from their ecological insecticide treatment (trichogramma application) in case of high infestation levels. Their losses account for 52 - 57 €/ha.

Costs for technology fee

The 'technology fee' or 'price premium' reflects the per-hectare increase of seed costs of the transgenic variety. We suggest using a fixed technology fee. The technology fee for Bt maize in Europe is now more or less established. For Syngenta's Compa CB, Brookes (2002) reported a technology fee of €29-31/ha in Spain. This price is recommended by the seed industry but many farmers pay lower prices through local cooperatives, i.e. €18-19/ha, capturing 70% of the Spanish maize seed market[8]. In the Czech Republic, a technology fee of €31/ha is used. Monsanto CZ claimed that they will use more or less the same technology fee in other EU regions, with a variation of 10%, depending on the region. Therefore, €31/ha is a good and rather conservative benchmark.

Costs for seed

Based on a telephone interview a German seed retailer there are seeds charges of 95 € per unit (which is 50 000 seeds) for a Bt maize variety. This price is 24 € higher compared to a conventional variety in 2006.

Herbicide tolerant crops (HT oilseed rape)

Model

There is one problem with the estimation of the farm-level impact of HT crops. Since HT technology has a relatively uniform value for a large segment of farmers, HT crops are competitively priced with conventional ones. This means that, on average, there are no large differences in gross margins between adopters and non-adopters. Especially in the case of HT crops, different authors stress the importance of taking into account heterogeneity of farmers and farms in assessing the impact of this biotechnology innovations in agriculture (Fulton and Keyowski, 1999, Desquilbet, Lemarié, and Levert, 2001, Bullock and Nitsi, 2001, Fulton and Giannakas, 2004). However, taking into account heterogeneity requires a lot of data since not only average weed control program costs have to be estimated, but also the standard deviation. The standard deviation determines which proportion of the farmers is situated on the right tail of the statistical distribution of herbicide costs, i.e. farmers that face weeding costs higher than the sum of the technology fee and the cost of the replacement program. Strictly spoken, only those farmers are potential adopters and only gross margins of those farmers have to be compared. In reality, such data is not available. Therefore, the analysis can only be done by simply comparing gross margins, knowing that this is not entirely correct.

Data

Regarding the technology fee of HT oilseed rape, the only indication from literature is a premium of about 23 €/ha reported for HT canola in Canada in 1999 (Fulton and Keyowski, 1999, Phillips, 2003). Based on a comparison of seed prices, the total price premium is about 32 €/ha. It is suggested taking a technology fee of 25 €/ha for HT oilseed rape. The replacement program for HT oilseed rape is a recommended glyphosate rate of 2.5 l/ha. The average glyphosate price for generic herbicides and Roundup is around €4 to 6/l.

In literature, there is some discussion about the yield effects of HT crops. Some advocate that HT crops should be compared with their isogenic[9] counterparts (Marra, Pardey, and Alston, 2002). Recent

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[7] No technology fee is considered in this calculation.

[8] As a comparison, the technology fee of Bt maize in the USA was estimated at €26/ha in 1997, €22/ha in 1998 and 1999 and €16-17/ha in 2001 (Gianessi *et al.*, 2002), while Benbrook (2001)┴ estimated this fee to be higher, i.e. €25/ha during the same period.

[9] Isogenic varieties have exactly the same genetic composition with the exception of the inserted gene.

research on North Carolina's farmers did not reveal any statistically significant yield differences at the 95% level between HT maize, cotton and soybeans and their conventional counterparts (Marra, Piggott, and Sydorovych, 2004, p. 43). Likewise, European field trials showed no increase in any HT crop (Schütte, 2003). Therefore, it is recommended assuming a 0 yield boost for HT crops.

3.2 Data collection

As a starting point, tables should be used for national evaluations and "national" tables should be worked out based on the (for most countries limited) available data.
After that crop budgets for GM crops including "coex-costs" should be compared to a baseline non GM crop budget. As we in most countries only have limited or none practical an experience with growing of GM crops it should be used:

a) sensitivity approach and/or - assumptions
b) conclusion by analogy approach – data from other countries

Table 5: Studies dealing with economic impacts of genetically modified maize

Impact on:	Trait	Impact	Author	Titel	Country
Gross margin	IR	↑	Marra et al. (1998)	Economic impacts of the first crop biotechnologies	USA
	IR	↑ (if infestation is high)	Rice and Pilcher (1998)	Potential benefits and limitations of transgenic Bt corn for management of the European corn borer	USA
	IR	↓	Fernandez-Cornejo, J. and W.D. McBride (2002):	Adoption of bioengineered crops, USDA, 2002	USA
	HR	↑	Fernandez-Cornejo, J. and W.D. McBride (2002):	Adoption of bioengineered crops, USDA, 2002	USA
	IR	↓ (1998-1999)	Carpenter and Gianessi (2001)	Agricultural Biotechnology : updated benefits estimates	USA
	IR	↑ (1997)	Carpenter and Gianessi (2001)	Agricultural Biotechnology : updated benefits estimates	USA
	IR	↑ (if area with high infestation levels)	Hyde, J., Martin, M.A., Preckel, P.V., Edwards, C.R. (1999):	The economic of Bt-corn: valuing protection from the European corn borer	?
	IR	↔ (if area with low to medium infestation levels)	Hyde, J., Martin, M.A., Preckel, P.V., Edwards, C.R. (1999):	The economic of Bt-corn: valuing protection from the European corn borer	?
Yield					
	IR	1.8-2.5 ↑ (%)	Brookes, G. (2002)	The farm level impact of using Bt maize in Spain	Spain
	IR	5 ↑ (%)	Brookes, G. (2002)	The farm level impact of using Bt maize in Spain	Spain
	IR	↑ (if infestation is high)	Rice and Pilcher (1998)	Potential benefits and limitations of transgenic Bt corn for management of the European corn borer	USA
	IR	↑	Carpenter and Gianessi (2001)	Agricultural Biotechnology : updated benefits estimates	USA
	IR	↑	Hyde, J., Martin, M.A., Preckel, P.V., Edwards, C.R. (1999):	The economic of Bt-corn: valuing protection from the European corn borer	
Herbicide	HR	↓ (1996-2001) ↑ (2002-2003)	Benbrook, C. (2003)	Impacts of genetically engineered crops on pesticide use in United States: the first years, Benbrook Consulting Services, Idaho, 2003	USA
Insecticide					
	IR	0-100 ↑ (%)	Brookes, G. (2002)	The farm level impact of using Bt maize in Spain	Spain
Herbicide + Insecticide	IR+HR	↓ (1996-2001) ↑ (2002-2003)	Benbrook, C. (2003)	Impacts of genetically engineered crops on pesticide use in United States: the first years, Benbrook Consulting Services, Idaho, 2003	USA
	IR + HR	↓	Fernandez-Cornejo, J. and W.D. McBride (2002):	Adoption of bioengineered crops, USDA, 2002	USA
	IR	↔	Carpenter and Gianessi (2001)	Agricultural Biotechnology : updated benefits estimates	USA
Costs for Seed	IR	30-35 ↑ (%)	Charles M. Benbrook, Benbrook Consulting Services, Sandpoint Idaho	When does it pay to plant Bt-corn - farm level economic impact of bt-corn 1996-2001	USA, Kanada

↑ = higher for GM crops than for conventional crops
↔ = same for GM crops as for conventional crops
↓ = lower for GM crops than for conventional crops

3.3 Structure of data - Prices, yields and gross margins

As a general principle, we should use data out of the region we analyse. Ideally, averages of the recent three years (2003-2005) should be applied. The structure of gross margin calculation (which forms the baseline of many of the analyses) should be as follows Table 6):

Table 6: Structure of gross margin calculation

Parameter for the specific crop (e. g. maize, rapeseed)	**Dimension**
Yield Price	tonnes/ha €/tonne
Total income	**€/ha**
Costs of seed (i) Costs for machinery (ii) Costs of seed **Crop protection** (iii) Costs for machinery (iv) Costs for insecticide/herbicide/fungicide etc. **Fertilizer** (v) Costs for machinery (vi) Costs for fertilizer **Harvest** (vii)Costs for machinery **Miscellaneous Costs like:** Hail insurance Costs for special equipment Cost for e.g. drying, Irrigation	
Variable costs	**€/ha**
Gross margin I	**€/ha**
Compensation payments	€/ha
Gross margin II	**€/ha**

The detailed the information about the costs of production (material plus machinery) the much the better. Additional information about time for each single production step could be very useful like time and amount of insecticide use in case of Bt maize.

Gross margin of GM crop

(1) $GM_g = \left(y_g p_g - I_g\right)$

(2) $I_g = (I_h + I_s + I_f + I_{cp} + I_{mis}) + C_{gfp}$

GM_g = Gross margin GM
I_g = Input costs of GM crop

I_h = Input cost - harvest
I_s = Input cost - seed
I_{cp} = Input cost - crop protection
I_f = Input cost - fertiliser
I_{mis} = Input cost - others like insurance, special machinery, drying
C_{gfp} = Costs of Good Farming Practices

Gross margin of non-GM crop

(1) $GM_c = (y_c p_c - I_c)$

(2) $I_c = (I_h + I_s + I_f + I_{cp} + I_{mis})$

GM_c = Gross margin conventional crop
I_c = Input cost conventional crop
I_h = Input cost - variable machinery costs
I_s = Input cost - seed
I_{cp} = Input cost - crop protection
I_f = Input cost - fertilizer
I_{mis} = Input cost - others like insurance, special machinery, drying
I_{cp} = Input Cost - crop protection
I_f = Input Cost - fertilizer
I_{oth} = Input Cost - Others like insurance

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Annex 1: Abbreviations

Area		
a_0	Common cultivated area	ha
$a_{iso\ bz}$	Isolation area as buffer zone	ha
$a_{iso\ bs}$	Isolation area as border seed	ha
a_g	Area GM crop	ha
Price		
p_g	Producer price, GM –	€/tonne
p_c	Producer price, Conventional	€/tonne
p_{or}	Producer price, Organic,	€/tonne
p_{ef}	Price, early flowering	€/tonne
p_{lf}	Price, late flowering	€/tonne
p_h	Price, for herbicide	€/liter
p_{sg}	Price for seed, genetically modified	€/tonne
Yield		
y_g	Yield, GM	tonnes/ha
y_c	Yield, conventional	tonnes/ha
y_{or}	Yield, organic	tonnes/ha
y_{ef}	Yield, early flowering	tonnes/ha
y_{lf}	Yield, late flowering	tonnes/ha
Input Costs		
I_g	Input costs, GM	€/ha
I_c	Input costs, conventional	€/ha
I_{or}	Input costs, organic	€/ha
I_{wph}	Input costs - wage per hour	€/h
I_{lea}	Input costs - leasing costs	€/ha
I_m	Input cost - variable machinery costs	€/ha
Gross margins		
GM_g	Gross margin, GM	€/ha
GM_c	Gross margin, conventional	€/ha
GM_{or}	Gross margin, organic	€/ha
GM_{sa}	Gross margin, set-aside	€/ha
GM_{ac}	Gross margin, alternative crop	€/ha
GM_{ef}	Gross margin, early flowering	€/ha
GM_{lf}	Gross margin, late flowering	€/ha
Costs of co-existence measures		
C_{coex}	Costs of Coex measures	
C_{gfp}	Costs of Good Farming Practice	
C_c	Costs of control	
C_{cr}	Cost of crop rotation	€/ha
C_{vc}	Costs of volunteer control	€/ha
$C_{vc\ h}$	Costs of volunteer control by hand	€/ha
$C_{vc\ m}$	Costs of volunteer control by machinery	€/ha
C_s	Costs of sampling	€/ha

C_a	Costs of analysis	€/ha
C_{sf}	Costs of system failure	
C_{bz}	Costs of buffer zone	€/m
$C_{bz\ g}$	Costs of buffer zone, GM-farmer	
C_{bs}	Costs of border seed	€/m
$C_{bs\ g}$	Costs of border sowing, GM-farmer	
C_{ti}	Costs of temporal isolation	
$C_{ti\ g}$	Costs of temporal isolation, GM-farmer	
$C_{ti\ c}$	Costs of temporal isolation, conventional farmer	€/m
C_{cm}	Cost for cleaning machinery	€/cleaning
C_{lea}	Costs for leasing	€/ha
C_l	Cost for labour	€/h
Time		
t_{vc}	Time for volunteer control	h/ha
$t_{vc\ h}$	Time for volunteer control hand	h/ha
$t_{vc\ m}$	Time for volunteer control machinery	h/ha
t_{cm}	Time for cleaning machinery	h
t_u	Time using machinery for production step	h/ha
Production types		
G	GM-farmer	-
C	Conventional farmer	-
O	Organic farmer	-
Amounts		
x_{cm}	Number of cleaning processes	number
x_{vc}	Number of volunteer control treatment	number
x_h	Amount of herbicide	litre/ha
x_{fss}	Amount of farm-saved seed	%
Others		
d	Isolation distance	meter