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COLLABORATIVE PROJECT

Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

D10.4 To evaluate regional cases of financial impacts on farm (viability and variability)

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Objectives

- To briefly review relevant literature
- To select and collect data on representative case study farms from across the AMIGA regions
- To model the financial impact of adopting a number of GM crops on the case study farms
- To draw overall conclusions re the financial viability of GM crops on different farm types

Introduction

Following an overall economic review submitted in sub task 10.1 we have updated some information on financial impacts of GM crops and used this as a basis to investigate the financial implications of adopting three of the currently GM crops on a range of case study farms across the EU. The report includes the results derived from a financial model when applied to 16 individual case studies farms located in six member States, using farm level data made available by AMIGA partners or from other contacts in representative countries.

Three crops were chosen for investigation as these have been successful elsewhere in the world, and the literature suggests that there could be agronomic reasons for their adoption in the EU. Indeed the first, Bt maize, has been grown in Spain, Portugal, Germany, Czech Republic and Slovakia for some years, with results that have been used to validate the model. The model has then been used to predict possible farm level financial impacts of two further crops, herbicide-tolerant oilseed rape, and herbicide-tolerant sugar beet.

The model utilises farm level information on rotations, crops grown, areas grown, input data and farmer attitudes to GM to predict the financial information on each farm. The model takes into account co-existence requirements (in relation to field size) and also allows "spill-over" effects into subsequent crops in line with findings in the literature.

1. Review of literature

In an earlier document submitted in fulfilment of task 10.1, currently available on the AMIGA webpages (McFarlane, Park and Ceddia, 2012), we reviewed economic data then available related to transgenic crops, and observed, inter alia, that even if EU farmers had open access to GM seed only some would derive a financial benefit from their growth, i.e. those where there was an agronomic benefit from the growth of GM varieties.

In this document, we present a range of case study farm businesses which are used to assess the economic benefit to that farm business of adopting a GM crop selected as a replacement within one of three groups of arable crops that are widely cultivated in two or more of the AMIGA regions, the replacement crops being:

- insect-resistant (IR) Bt maize

- herbicide-tolerant (HT) oilseed rape (OSR)

- herbicide-tolerant (HT) sugarbeet.

Regarding GM crops with herbicide-tolerance (HT) traits, there is no current experience in Western Europe on which to draw. We have extrapolated from published data for performance of HT crops in other regions of the world. We considered using the data from early experience with HT soybean crops in Romania, where adoption was rapid up to the cessation of HT soybean cultivation enforced as a condition of accession of Romania to the EU in 2007. The economic benefit was clearly demonstrated, but there are few other parts of Europe in which soybean cultivation is currently widespread, and we have not been able to find farm locations outside Romania for which there is sufficient data to use the model for soybean case studies.

In preparing these case studies, we have taken note of economic data that has been published since we prepared our earlier document; notable among recent publications are a meta-analysis of 147 GM crop impact reports that meet stringent eligibility criteria (Klümper and Qaim, 2014), and an economic review of GM crops grown in USA prepared by US Department of Agriculture Economic Research Service (Fernandez-Cornejo et al, 2014). Other relevant papers published recently include an evaluation of integrated pest management (IPM) that includes Bt maize in control of western corn rootworm (Onstad et al, 2014), a review of factors underlying the rate of spread of cereal crop pests (Bebber et al, 2014) and a review of economic implications of restrictions newly imposed within EU on the range of pesticides permitted for IPM in arable crops (Hillocks, 2012). More specific literature related to each of the selected crops is provided below:

1.1 Bt Maize

Collinge et al (2008) concluded that transgenic maize with Bt toxin genes had been widely adopted because of its ability to increase yield when there was a high insect risk. In addition, these crops were less susceptible to secondary fungal attack by Fusarium, with the result that the grain contains consistently reduced levels of mycotoxins, potentially resulting in safer food for people and safer feed for livestock. However, Gouse et al (2009), having analysed the results of a sample survey of 249 smallholders growing Bt maize in South Africa, cautioned that the results were not unambiguously favourable. There was a slight yield advantage per hectare, but average seed efficiency, in terms of yield per kg of seed, was below that for conventional seed. Further, Fernandez-Cornejo and McBride (2002) reviewed the rates of adoption in USA of Bt maize and reported a negative impact on net returns among specialized maize farms. Their analysis suggested that Bt maize may have been used on some acreage where the value of protections against the European corn borer was lower than the Bt seed premium.

Fernandez-Cornejo and Li (2005) analysed the on farm impact of adoption of Bt maize, using USDA data from a 2001 survey. They found that raw data indicated a yield improvement of 9%, but after controlling for self-selection bias (i.e. greater likelihood of adoption on well-managed farms) and other factors, they concluded ‘a

10% increase in the probability of adoption of Bt corn is associated with an increase in corn yields of 0.39%'; a small, but significantly significant increase relative to those using conventional corn varieties (Fernandez-Cornejo et al., 2006). The performance of Bt maize was also reviewed by Pilcher, Rice and Obrycki (2005), Price, Hyde and Calvin (2006), and Diffenbaugh et al (2008). Detailed descriptions of the effectiveness of Bt maize in a wide geographic spread of cereal cultivation against different insect pests were provided by Gray et al (2009), Kruger, Van Rensberg and Van den Berg (2009), Consmuller, Beckmann and Schleyer (2009), and Hutchinson et al (2010). Overall there are many indications that the use of IR can increase yields and reduce the use of pesticide, with potential knock-on environmental and financial benefits, but that caution is required in interpreting the various data.

In Europe Bt maize is the only GM crop currently planted. In Spain, the country with the greatest hectarage, yield increases obtained by Bt maize farmers have been variable. Gomez-Barbero et al. (2008) found regional differences in yield between Bt and conventional maize ranging from -1.3% to +12.1%, with the yield advantage of Bt directly related to local pest pressure. Demont et al. (2007) reported that 5.7% of maize grown in Spain during the period 1998–2003 was IR transgenic maize, delivering a net benefit of €70/ha. Both of these reports are consistent with the economic impact by country estimated by Brookes (2008) of improvement in gross margin of €86-108/ha, but only in areas of high insect infestation. Riesgo, Areal and Rodriguez-Cerezo (2012) used information from a survey conducted in 2009 of maize farmers in the Ebro Valley, Spain, to show that the partial gross margin increased by €95/ha for Bt maize.

At a farm level, Cox et al (2009) reported that field-scale studies were conducted on four farms in New York to evaluate the agronomics and economics of double-stacked hybrids, finding a range of outcomes between $89/ha net gain to $71 net loss. Whilst the engineering of multiple traits (gene stacking) is a complex procedure, it appears to be proving commercially worthwhile. Productivity analysis by Aldana et al. (2012) demonstrated the superiority of stacked varieties and found evidence of a 16% yield improvement compared to conventional varieties. Further, an ex-ante assessment of the economic performance of Bt maize with stacked traits in crop rotations in Switzerland suggested a small impact on the net margin of arable crops (Speiser et al. 2013).

1.2 Herbicide tolerant oilseed rape [Canola]

The production of GM Canola is mainly centred on the growth in Canada. Since its introduction in 1996, the area has expanded to cover about 96% (7.6 Mha) of the total area of OSR grown in Canada, and transgenic Canola has also been adopted in USA, Australia and Chile (James, 2012).

Gianessi (2008) reported that aggregate yields increased generally, and in the case of oilseed rape by about 10%. Gusta et al (2011) used farm survey data for the time period 2005-7 to calculate that the net benefit of adoption of

HT oilseed rape is in the range Can$25-28/ha, about €18-20/ha. Smyth et al (2011) reported that adoption of transgenic HT oilseed rape in western Canada enabled farmers to sow seed directly with no prior tilling, which gives significant benefit in soil conservation. Furthermore, annual carbon sequestration attributable to adoption of transgenic HT oilseed rape in western Canada had reached one million tonnes. They also estimated that the disadvantage if HT oilseed rape had not been developed and Canadian oilseed rape farmers had continued to use previous production technologies would have been that 60% more active ingredient would have been required. It should be noted that the all of the HT OSR grown in Canada is based on short season spring grown varieties, whereas much of the EU crop (more than 95%, Eurostat) is based on winter sown varieties.

Hasan et al (2006) reviewed the gene pool represented by a broad range of winter and spring varieties, and suggested the use of molecular markers for marker-assisted transfer of these traits between these varieties. The likelihood is that if a transgenic winter sown variety were accessible then there could be significant herbicide benefits on the 6.2 Mha (Eurostat) grown across the EU in 2010. This extent of OSR production is comparable with the production of spring Canola in Canada, where the GM proportion reached 50% within four years after it became available (James, 2012).

1.3 Herbicide tolerant sugar beet

Transgenic herbicide tolerant sugar beet has had a very rapid adoption in the US; reaching 95% adoption within two years of its commercialisation in 2007. Model simulations show that the annual benefits for GMHT sugar beet farmers in the USA average around $257/ha (Dillen et al, 2013). The impact of a hypothetical introduction of herbicide tolerant sugar beet to the EU has been modelled and the outputs indicated there would be significant gains to farmers and consumers, arising primarily from savings in expenditure on herbicide required for conventional sugar beet, which exceed the technology fee of €90-106/ha paid by growers in the USA (Dillen et al. 2009a). The economic advantage of adopting HT sugar beet throughout the EU was estimated to be in the region of €300 million per annum to the EU as a whole, based on data from USA (Dillen et al, 2009b). No varieties are approved for growth in the EU but sugar beet is widely cultivated in many regions of Europe, and HT sugar beet attracts keen interest among EU farmers.

Overall the above brief overview of economic impacts of the three traits suggests that in many cases where agronomic issues can be targeted by GM crops, farmers are deriving benefits from growing GM crops and that this is true for a range of countries outside of the EU. (this is also evidenced in the more substantive review undertaken in sub-task 10.1). The only substantive data related to the EU concerns maize in Spain and it is clear that some farmers grow GM crops year on year because they believe there is a financial benefit to doing so. Literature reviews suggest that this benefit is variable across different geographies. farms and agronomic situations and hence in this report specific cases have been investigated to evaluate the predicted financial impact of growing GM on a range of different farm types across the EU.

2. Selection of case study farms

2.1 Overview

To evaluate the financial variability across the EU requires reasonably detailed data on individual farms, which is not always easy to obtain. Initially we proposed to undertake surveys on individual farms, but it became clear that this was not practical within the timeframe and resources available. This we adopted an approach based on the use of secondary data, which in turn could be used within a model modified from the broader economic model described in sub-task 10.2.

Farm level data was accessed from various sources, including data sets made available by AMIGA partners and by partners in the EU FP7 PRICE consortium, plus data from FADN. Having collected a range of farm-level data we selected a small group of case study farms based on size, rotation and potential agronomic usefulness of utilising GM. Table 2.1 illustrates the broad characteristics of the selected farms these falling into 2 groups: all-arable or mixed farms in different geographic regions as defined in AMIGA project. Actual rotation patterns vary between biogeographic regions of Europe, and we have taken this into account in choosing examples for the study. We have selected two or more typical arable farms in each country, from the large numbers of farms that have submitted data in response to farm surveys specifically designed to discover farms which may benefit from including one of more of the small set of GM crops mentioned above in their preferred crop rotation.

In each case, we assessed the likely financial impact for the farms of adoption of MON810 Bt maize, and varieties of HT oilseed rape and HT sugar beet that may be suitable for cultivation if regulations were to allow then to be cultivated. Although we could draw on experiences to date within the EU for the small amounts of Bt maize grown it is accepted that the results can only give an indication, particularly for the HT varieties. A clear weakness is the difference between how farmers suggest they may behave if GM crops were available and how they would actually behave. Also from the individual farm/farmer perspective it is also quite difficult to predict how the growing of GM will influence overall farm practice and rotation.

Table 2.1: Overview of the 16 farm businesses selected as case studies

Country		Region	Farm-size ha	Area of GM (ha)	Crop(s) with GM potential	Selected rotation
Czech Republic		**3**				

	CZ1	Dairy farm in west of Czech Republic		487	15	Bt maize	continuous forage maize
	CZ2	All-arable farm in west of Czech Republic		1300	30	Bt maize	wheat/maize/spr barley/rape
Germany			**3**				
	DE1	All-arable farm in Brandenburg		900	60	Bt maize, HT rape	wheat/maize/spr barley/rape
	DE2	Mixed farm in Saxony		2500	50	Bt maize	wheat/maize/spr barley
Slovakia			**3**				
	SK1	Large arable farm complex close to Nove Zamky		5550	70	Bt maize	maize/maize/spr barley
	SK2	Arable farm at Vrable close to Nitra		2430	60	Bt maize	sunflower/wheat/maize/spr barley
	SK3	Cooperative farm complex at Hlohovec		3500	20	Bt maize, HT rape	rape/wheat/maize/wheat
Spain			**1**				
	ES1	Arable farm in Los Monegros, Aragon		330	30	Bt maize	maize/maize/spr barley
	ES2	Mixed farm in la Hoya de Huesca, Aragon		40	10	Bt maize	maize/maize/sunflower
Sweden			**5**				
	SW1	Small all-arable farm in Scania		103	10	HT rape	wheat/spr barley/rape
	SW2	Large arable farm in Scania		673	50	HT beet, HT rape	wheat/spr barley/beet/rape
	SW3	Medium size arable farm in Scania		356	40	HT beet, HT rape	wheat/beet/rape
UK			**4**				

	UK1	Mixed farm in South-west of England growing continuous maize for on-farm use		90	10	Bt maize	continuous silage maize
	UK2	All-arable farm in the South-west of England		236	50	Bt maize	wheat/wheat/barley/maize
	UK3	Arable farm in the East of England, all arable crops including sugar beet and oilseed rape		240	25	HT beet, HT rape	beet/rape/wheat/winter barley/spr barley
	UK4	Arable farm in the East of England, all arable crops including oilseed rape		400	50	HT rape	rape/wheat/winter barley/spr barley

2.2 Details of selected farms

Czech Republic (region 3)

CZ1 - Dairy farm in west of Czech Republic

This is a 487 ha dairy farm, small by Czech standards, on a plain in west of Czech Republic, close to the Danube (which forms the border with Austria). It operates as a limited company, with 10 employees. The CEO is 58, with a degree in agriculture. At the time of the survey, they were growing 106 ha of conventional forage maize in 7 parcels, and 118 ha of Bt forage maize in another 7 parcels, all used on-farm.

They grow Bt grain maize in rotation to alleviate pest pressure, but find compliance with coexistence measures somewhat burdensome. The main incentive is convenience of management and pest management, they see little economic advantage.

CZ2 - All-arable farm in west of Czech Republic

This is a 1300 ha all-arable farm, medium size by Czech standards, on a plain in west of Czech Republic, very close to the Danube (which forms the border with Austria). It operates as a limited company, with 19 employees. The CEO is 60, with degree in agriculture. At the time of the survey, they were growing 504 ha of conventional grain maize in 16 parcels, on contract.

They are aware of some potential benefit if they were to adopt Bt maize, but they are doubtful of acceptability to their market. They do think that farmers should be allowed the option to grow GM crops, and that GM will be beneficial in the long term. An assessment of the possible benefit of adopting HT rape, if a suitable variety becomes available, is included in this case study.

Germany (region 3)

DE1: All-arable farm in Brandenburg

This is a 900 ha all-arable farm, with 1.5 km of border shared with nine neighbouring farms, with whom the business is on good terms. The quality of the soil is not ideal, and there are some topographic constraints, but the greatest concerns arise from water availability and weed pressure. There is also a growing concern about ECB damage to the maize crop. In 2012 the farm cultivated 15 ha of grain maize and 65 ha of silage maize, the whole quantity being sold on contract. The business considers that there may be difficulty in obtaining contracts sell Bt maize even if they were allowed to grow it.

The possibility of this farm adopting HT rape in the rotation has accordingly been assessed, alongside an assessment of adoption of Bt maize, in a rotation sequence wheat/maize/spring barley/rape.

DE2: Mixed farm in Saxony

This is a 2500 ha farm, of which 2000 ha are rented. The farm focus is on cereals. In 2012, 650 ha of maize was grown, of which 250 ha was forage maize for on farm use; 400 ha of grain maize was sold on contract. This large farm has 15 farm neighbours, all on good terms. The farm is a member of a co-operative scheme. Use is made of government extension facilities and of commercial advisory services.

A proportion of the 2012 silage maize was Bt maize (50 ha, in one parcel) with average yield of 39 t/ha, compared with 36 t/ha for conventional silage maize. Conventional silage maize was confined to 16 smaller parcels. The Bt silage maize was of significantly better quality, with reduced pest damage. The crop rotation in this 50 ha parcel is wheat/maize/spring barley/rape. Segregation of GM seed is considered a mild burden; coexistence costs are acceptable if separation distances are not greater than 150m.

The business is strongly of the opinion that farmers should be allowed to use GM crops if they so decide, and that this farm would certainly adopt other GM crops if permitted; any risk to the environment can be managed, and there is no risk to human health. The business is of the opinion that lack of access to GM crops is making EU uncompetitive in world markets.

Slovakia (region 3)

SK1: Large arable farm complex close to Nove Zamky

This 5550 ha farm is operated as a limited company, with 80 employees. The complex has 200 km boundary, parts of which adjoin 10 neighbouring farms. The primary crop is winter wheat, with 1800 ha grown in 2013. Among a number of arable crops grown in rotation with the wheat, the business already grows some Bt maize, for sale as both grain and silage. Their good experience with Bt maize means that they are keen to cultivate HT crops when permitted. They typically grow about 600 ha of rape and 400 ha of sugarbeet each year.

SK2: Arable farm at Vrable close to Nitra

This 2430 ha farm is about 100 km east of Bratislava, close to the old city of Nitra at the foothill of the Zobor mountain (587 m), and is located in the warmest and driest part of Slovakia. The annual rainfall is 50-60 cm. The farm grows mainly wheat and maize, with sunflower as the preferred break crop. They have not so far grown Bt maize, but they are interested in the possibility.

SK3: Cooperative farm complex at Hlohovec

This 3500 co-operative lies to the north of Nitra, at the foot of the Považský Inovec mountains, between the historical cities Trnava and Nitra. They grow wheat, maize, barley and rape; they have not so far considered growing GM crops, but with 800 ha of maize and 400 ha of rape, grown typically in rotation with winter wheat, they could probably obtain significant economic benefit from Bt maize, and perhaps HT rape also.

Spain (region 1)

ES1: Arable farm in Los Monegros, Aragon

This is a 330 ha all-arable farm in the central part of the autonomous community of Aragon in north-east Spain, where Bt maize has been cultivated with economic success for more than a decade. This is an arid locality, and the farm has installed a sprinkler irrigation system which maintains crop yield with efficient use of water during months affected by severe drought. The sprinkler system is also used to apply fertiliser prior to seeding.

The cropping system is maize-based, and a three crop rotation grain maize/ silage maize/ spring barley is spread over two years, with legumes or oilseeds grown as break crops in other years .

ES2: Mixed farm in la Hoya de Huesca, Aragon

This is a 40 ha mixed farm in the northern part of the autonomous community of Aragon in north-east Spain, where Bt maize has been cultivated with economic success for more than a decade. The farm still uses a traditional surface irrigation system, pending investment in a sprinkler system. Surface irrigation is installed for approximately 40% of the farm area. In this district water delivery is available based on previous water consumption.

An eight hectare parcel is used for grain maize followed by silage maize and barley, with oilseed rape as an occasional break crop which is not irrigated.

Sweden (region 5)

SW1: Small all-arable farm in province of Scania (southernmost province).

This is a 103 ha family farm, 22 ha of which is rented land. The province of Scania is at the southern tip of Sweden, and contains two plains of highly-fertile agricultural land, with mild climate – snow is relatively uncommon. At this farm they grow wheat and barley, with about 10 ha of rape. They may consider HT rape when available.

SW2: Large arable farm in Scania

This 673 ha owner-occupied arable farm employs one additional full-time worker. They grow about 100 ha of sugar beet and about 60 ha of rape alongside about 400 ha of cereals. They use advanced farming methods, and achieve winter wheat yields of almost 8 t/ha. It may be well-worthwhile adopting HT sugar beet when available, and perhaps HT rape as well.

SW3: Medium size arable farm in Scania

The 358 ha family farm with two additional employees also uses modern soil management techniques to achieve yields of 7.4 t/ha of winter wheat and 6.5 t/ha of barley. They grow about 65 ha of sugar beet in rotation with wheat and rape, and are very likely to welcome an opportunity to adopt HT sugar beet, and perhaps HT rape as well.

UK (region 4)

UK1: Mixed farm in South-west of England growing continuous maize for on-farm use

This is a mixed farm of 90 ha in Wiltshire. The farm cultivates continuous maize, all for on-farm use. Field size is constrained by topographic features.

The farm has 6 immediate neighbours, and the farmer expects that there would be additional costs in complying with coexistence regulations, but is confident of amicable relations with neighbours; he has some concern about attitudes of bee keepers.

UK2: All-arable farm in the South-west of England

This is an all-arable 236 ha farm in Somerset, the owner is 74 years old, and works the farm himself with 4 full-time staff. The farm is partially south facing, and in those parts of the farm the soil is sufficiently warm in the spring for cultivation of grain maize. The maize is ripe by mid-October, when it is cut at 30-35% moisture, and sent for off-farm drying.

The farm grows wheat, barley and maize in rotation, and suffers moderate to severe pest pressure. 50 ha of maize are grown annually, all under contract.

UK3: Arable farm in the East of England growing all arable crops including sugar beet and oilseed rape

This is a reasonably large farm in Cambridgeshire on high quality grade 1 and 2 land. The farmer is around 50 years of age and has been farming at this location for about 30 years. The farm operates a five year rotation which is normally wheat, wheat, sugar beet, winter barley and oilseed rape. The overall arable area of the farm is 240 hectares of which about 10% each year is grown to sugar beet.

The farm is not ring fenced and thus the different parcels of land mean the farm has 11 immediate neighbours. This makes co-existence measures a challenge, although the owner does not have serious concerns about cross contamination with neighbours.

The main management issues the farm faces are in relation to high weed burdens and occasional summer drought. The latter requires irrigation of the sugar beet in some years. The farmer would grow GM crops if allowed to help combat continued weed pressure. The main GM options that could be available in the near future are HT sugar beet and HT oilseed rape. The advent of drought tolerant GM varieties in the future could offer an additional benefit. The farmer is very positive about the adoption of GM if available and would adopt, providing there was a clear market for the products.

UK4: Arable farm in the East of England growing all arable crops including oilseed rape

This is a 400 ha all-arable farm in Norfolk, with 3 full-time staff. The farm operates a four year rotation which is normally wheat, second wheat, OSR, barley, with 100ha of OSR grown each year under contract.

The farm has 3km of border with 7 immediate neighbours.

The main GM option that could be available in the near future is HT oilseed rape. The farmer is very positive about the adoption of GM if available and would adopt providing there was an amicable arrangement with neighbouring farms.

3 Model description and use

3.1 Model construction

In sub-task 10.2 we described an ex ante economic model constructed to evaluate the regional impacts of growing GM crops. We have described this model in McFarlane, Park and Ceddia (2014) a simulation tool called Model of Economic consequences of Transgenic crops in the EU (METE). This has been adapted so that it can be utilised to evaluate the financial impacts of growing GM crops on individual farms. A key feature of the model is that it includes simulation of the effects of crop rotation, particularly the effect of the continuing level of weed pressure in systems using no-till or minimum-till soil preparation. It also simulates the benefit of break crops in the main crop rotation.

Each simulation produces, first a set of results for gross margin when the conventional crop is grown, which can be approximately verified from published data of crop performance, and then, secondly, the gross margin outcome predicted if a GM crop is introduced in place of a conventional equivalent. For the case studies from Spain, we are able to compare the predicted outcomes with actual reports of the performance of GM MON810 maize at known levels of pest pressure in particular growing seasons. For all the other maize examples in the case studies, we have extrapolated from the Spanish data in simulation of adoption of GM MON810 maize.

The model uses economic parameters taken from sources that collect data in a consistent manner for the arable crops included in the rotations, primarily Brookes (2012), supplemented by the data for UK given in Nix (2015). The gross margin benefits of adopting Bt maize, with due allowance for refuge areas recommended to delay onset of resistance (Huang et al, 2011; Siegfried and Hellmich, 2012), are based on Gómez-Barbero et al (2008). There is no European experience of growing HT oilseed rape, and no winter variety of HT rape has yet been made available by the suppliers; there is however a large body of evidence from the spring variety of HT Canola widely adopted in Canada (Smyth et al, 2010; Gusta et al, 2011), where the crop is cultivated in rotation with milling wheat, as it would be in the European farms selected for case studies. The model outcomes are based on conservative extrapolation of Canadian data.

There is a similar lack of European experience of cultivation of HT sugarbeet. A comprehensive record of annual surveys of farms cultivating HT sugarbeet in North Dakota is available (Stachler et al, 2012) made every year from 2005 to 2010, including 112 growers and 28 kha in the 2010 survey. The performance of HT sugarbeet on case study farms in northern Europe is predicted using this data. Crop rotation is one of strategies recommended to limit the impairment of, particularly, yield of winter wheat in southern UK by the spread of *Alopecurus myosuroides* (blackgrass), which has become resistant to some treatments (HGCA, 2009; Moss et al, 2011). In further use of our model, we predict savings in cost of control to protect yield of winter wheat or feed wheat as an ongoing benefit following HT oilseed rape or HT sugar beet in a crop rotation.

Specific economic and management data for each farm were used to obtain from the model the predicted benefit of adopting one or more of Bt maize, HT sugarbeet and HT rape in place of the conventional equivalent crop in the crop rotation sequence or sequences reported as being in use at that farm. The full results are shown in detail in the appended case studies and a summary of the results is presented below in the main text.

3.2 Sensitivity issues

There are three major sensitivity issues. The first is the volatility of the crop prices used in the simulations. This is the greatest source of variability in the economic parameters applied in the model, but it has a slightly reduced effect in the model outcome, as the model predictions are primarily concerned with the difference in gross margin between GM and equivalent conventional crops. For instance, the Agriculture and Horticulture Development Board (AHDB) of the UK Home-Grown Cereals Authority (HGCA) has published an estimate of the extent to which a change in wheat price affects the penalty of 1% yield loss affects the gross margin available from winter wheat (Watts, 2014); the penalty is equivalent to €211/ha at a wheat price of €220/t, and €160/ha at a wheat price of €158/t – a 27% price fall reduces the value of 1% yield saving by 24%.

The second sensitivity issue is the premium which the food chain might be willing to pay to obtain non-GM maize, oilseed rape or sugar beet. There is no difference whatever in crystalline sucrose from any source, cane or beet, GM or non-GM; vegetable oil refining similarly removes most traces of the source of the oil, and there has been no publication of any claim that a blind tasting panel can distinguish GM from non-GM maize. Nevertheless, lingering public concerns for the concept of genetic engineering of food products may be sufficient to achieve a small premium for non-GM products, or a depressed price for GM derived products. However, it should be noted that prices in the EU for broad-acre crops are governed to a large extent by prices on world-markets. For instance, a product yielding on average 6 t/ha and selling for €200/t provides revenue of €1200/ha, and if variable costs are of the order of €500/ha the gross margin is €700/ha. A 5% premium for non-GM would add €60/ha revenue, or 8.6% of gross margin. A perceived public antipathy to GM among buyers in the food chain might very easily deter farmers from adopting GM varieties, in spite of the benefits of ease of crop management, insurance against severe pest or weed pressures, and the overall environmental benefit of reduced application of pesticide and herbicide.

The third sensitivity issue is one which applies to any novel crop: how will an untried crop respond to natural variation in climatic conditions? Bt maize, HT oilseed rape and HT sugarbeet have performed satisfactorily in a variety of agro-climatic zones in other parts of the world, but the impact of, for example, climate change on these crops if cultivated in a range of EU environments remains uncertain.

3.3 Case study analysis overview

Detailed analyses of each of the case study farms is presented in appendices. In this section we present an overview of the predicted implications of GM adoption in the form of percentage change in gross margin at three levels of pest or weed pressure, drawing on results from across the case studies.

Evidence from the growing of Bt maize in a range of countries in the EU for over a decade suggests that it is useful to farmers in terms of combating specific pest issues, can increase profitability and, if appropriate measures are taken, does not have major environmental risks. Maize is grown for both grain and forage, being most suited to grain in the more southerly areas of the EU. Evidence suggests that Bt maize may have benefits in both contexts. Table 3.1 illustrates that where a pest problem exists (even at a mild level) then the growth of Bt is likely to have a positive impact on margins in most situations.

Table 3.1 – Percentage change in gross margin/ha after adopting Bt maize

Farm ID		Bt grain maize			Bt silage maize		
	pest pressure:	mild	typical	severe	mild	typical	severe
CZ1					1.20	5.26	9.31
CZ2		1.99	6.17	10.18			

DE1	2.18	6.93	11.61			
DE2	-2.04	2.39	6.74			
SK1	0.28	3.52	6.50	2.80	11.76	21.12
SK2	2.06	6.71	11.22			
SK3	1.90	6.49	10.90			
ES1	2.11	6.48	10.81	1.93	4.46	13.36
ES2	1.68	6.20	10.73	0.94	10.36	17.47
UK1				-0.14	2.77	5.23
UK2	-2.24	1.97	5.43			

Analysis suggest that in all but a few cases when the pest pressure is mild, the reductions in pesticide use and increases in yield for varieties with Bt protection means that financially the increase in margin off-sets the technology fee paid by farmers. On farms where the potential for pest damage is severe this increase in margin can be between 10 and 20%.

Although no HT crops have been grown commercially in the EU, the benefits to farmers of HT crops have been demonstrated in many parts of the world. HT Canola in Canada has proved to be very successful and is planted on the most of the cropped area now. This suggests that is a technology that could be popular with EU farmers and indeed many of the case study farmers would be interested in the technology if it were available. Most of the EU crop is winter sown OSR which is a combinable break crop that fits well into arable rotations. Although no winter-sown HT varieties are currently available our ex –ante analysis makes the assumption that they could be easily available if such a market were available in the EU. Table 3.2 illustrates that many of our case study farms are already growing OSR.

Table 3.2 - Percentage change in gross margin/ha after adopting HT Oilseed Rape

Farm ID		HT rape		
	pest pressure:	mild	typical	severe
CZ2		9.90	17.42	46.54
DE1		5.10	13.13	24.61
SK3		4.11	11.90	48.91
SW1		2.36	10.17	14.76
SW2		0.27	3.08	5.71

SW2 HT+HT*	3.12	8.96	14.74
SW3	0.35	3.12	5.78
SW3 HT+HT*	2.33	8.07	13.69
UK3	-0.77	2.80	5.84
UK4	-0.64	2.66	5.84

*'HT+HT' denotes HT beet and HT rape both adopted in same rotation

an be between 10 and 20%.

Our analysis across the 10 case study farms currently growing OSR suggests that in all but two cases where weeds are not seen as a major issue, that there would be an advantage in growing HT OSR and that the financial benefit would exceed the technology fee. In some cases of severe weed infestation the benefits to growing HT are considerable.

In relation HT sugar beet, evidence from the US and ex-ante studies for the EU have suggested that the introduction of this GM crop in the EU would have a benefit. Sugar beet, although grown widely across the EU, is often confined to specific geographic locations because of soil type, climate and also sugar processing facilities. Hence only a limited number of the case study farms were currently growing SB. Our analysis on the three case study farms that grow SB suggested that at typical levels of weed infestation and above this would indeed be the case, with other spill-over benefits in terms of cleaner seedbeds in following crops, see table 3.3.

Table 3.3 - Percentage change in gross margin/ha after adopting HT sugar beet

Farm ID		HT sugarbeet		
	weed pressure:	mild	typical	severe
SW2		-0.91	2.85	8.99
SW3		-0.35	4.17	8.84
UK3		5.48	12.05	19.05

The model was also used to predict a possible yield improvement in the crop which follows a herbicide-tolerant crop, based on evidence from farm surveys in Canada which suggested that yields of wheat improved on farms that cultivate HT Canola in rotation with wheat, the weed pressure on wheat being reduced without further application of herbicide (Smyth et al, 2010; Gusta et al, 2011), consistent with the findings of Kirkegaard et al (2008) regarding break crop benefits in temperate wheat production. Control cost savings were reported by Gusta et al in the form of reduction in average tillage costs per hectare from 1999 when HT Canola adoption had reached 67% to 2006 when adoption had reached 95%. The respective cost savings were Can$38.48 in 1999 and Can$11.33 in 2006; a saving of about Can$27/ha represents about 5% of the average gross margin per hectare achieved by those farms at that period (Fulton and Keyowski, 1999).

The results which relate to this predicted benefit in a following crop are summarised in Table 3.4. The results are consistent with savings in costs of control of *Alopecurus myosuroides* (blackgrass) in wheat in UK (HGCA, 2009), where blackgrass has become unusually difficult to control. Successive HT crops, and the associated benefit of reduced cost of soil preparation, are predicted to give overall benefit to succeeding crops.

Table 3.4 – Gross margin benefit in crop following HT crop in a rotation (2012 crop values)
*'HT+HT' denotes HT beet and HT rape both adopted in same rotation

	HT crop(s)	following crop	following crop control savings (€/ha):
CZ2	OSR	winter wheat	19
DE1	OSR	winter wheat	27
SK3	OSR	winter wheat	19
SW2:			
HT	OSR	feed wheat	11
HT+HT	sugarbeet, OSR	feed wheat	23
SW3:			
HT	OSR	feed wheat	17
HT+HT	sugarbeet, OSR	feed wheat	30
UK3:			
HT	OSR	winter wheat	39
HT+HT	sugarbeet, OSR	winter wheat	65

4. Overall analysis from the case studies.

The objective of considering a number of case studies was to see if the broad [potential] economic benefits related to the growing of transgenic crops reported in the literature and summarised in deliverable 10.1 applied across a range of farm types in different EU regions. Our analysis suggests that this is the case with consistent benefits where transgenics can help combat a specific agronomic issue. Where such pests and weeds are less of a problem then the benefits of using the currently available transgenic crops is less.

In the case of Bt maize the benefits are mainly from prevention of loss of yield in areas where pest presence is at such a level that it will lead to crop loss, or the considerable expenditure on insecticides to maintain yield. In relation to yield loss, Venus et al (2011) provide evidence that adoption of Bt maize may not always lead to higher gross margin; they calculated a 'break-even' yield loss prevented, defined as the yield improvement required to compensate for technology premium to be paid for Bt maize seed. These break-even points were calculated to be 1.5 % in Spain, 2.8 % in Italy and 3.3 % in Germany. It is worth noting the issues surrounding the ingression of secondary pest species which are modelled in sub-task 10.3. There are increasingly cases internationally, but also in Spain where there is evidence that the use of Bt can remove primary pests, only to allow secondary pest populations to expand and to become economically important. In the EU this can mean that farmers will need to use a combination of both Bt and insecticide if they want to optimize margins. In other parts of the world farmers increasingly have access to stacked trait varieties which can help to overcome issues of secondary pests (see deliverable 10.3 for more detail)

In some areas of the EU the advantages of using Bt maize are much reduced as pest populations are lower, for instance pest pressures that affect maize yield in South-west England are much lower [at the time of writing] than in the worst affected regions of Spain, and thus the predicted benefits from adoption of Bt IR maize are correspondingly reduced on case study farms.

For the HT crops we have considered the potential benefit is largely from the savings in control costs (saving multiple herbicide applications) with associated simplification of crop management. Given that there is no approval or experience of broad acre planting in the EU of HT crops we have developed our analysis from data based on the growth of HT crops in other areas of the world. The evidence for HT rape benefit is mainly from Canola cultivation in Canada, where it is an advantage to drill seed for spring rape as early as possible in the short growing season, and apply glyphosate after drilling.

OSR is a popular crop in the EU as it fits well into existing rotations, it provides a break crop, is combinable and provides an opportunity for weed control in otherwise cereal-based rotations. In considering the impacts on case study farms it is clear there are two potential benefits, one associated with reduced herbicides use within the year of OSR growth and also spill over benefits into subsequent parts of the rotation. We have provided quantification of both elements.

Sugar beet is a much more specialised crop, although grown widely across the EU. Its growth requires specialist machinery and processing contracts. Thus fewer farms include it in their rotations. Experience in the US suggests there are significant financial benefits to farmer of growing HT sugar beet and ex ante modelling suggests similar benefits may accrue in the EU. Our case studies mirror these advantages although they appear more conservative when compared to the predictions of Dillen et al (2013).

In relation to the financial modelling we have undertaken there are a number of points to note:

- antipathy to GM crops in Europe may mean that non-GM crops of equivalent quality may command a higher price (but this disadvantage does not seem to apply to the MON810 maize grown in Europe so far, according to farm survey responses on this point). This is difficult to predict and partly dependent on world supply and demand of various commodities and the actual amount of GM grown in the EU.

- even in an infected area the severity of pest pressure is hard to predict in a given year. This is further complicated by the potential spread of insect pests in the medium term as climate changes. Even the costs of the GM technology are difficult to predict as suppliers are known to impose a higher technology premium in the seed price in regions with high risk of pest damage.

- it is very difficult to predict how farmers would behave if they had access to more GM varieties and traits. The literature on farmer behaviour suggests there are clear differences between attitudes to a given technology and how they would actually use it when available.

Overall, based on the previous research undertaken in this work package, the accumulating research evidence from elsewhere in the world and the case studies undertaken in this deliverable it appears clear that where agronomic issues exist that can be tackled by using GM traits then there is likely to be a financial advantage on the majority of farms where they can be used.

It could be argued that a decade of negative attitudes throughout Europe to transgenic crop development has led to a lack of new GM crop varieties for European agriculture. In a *Science and Society* report, Tait and Barker (2011) commented that, in place of government leadership, public apprehensions encouraged the involvement of non-government actors, an increasingly complex set of state–society relationships, and a blurring of the boundaries between the public and private sectors. The role of the state moved from being the main provider of policy to facilitating interaction between interested parties. Tait and Barker called for clearer strategic thinking on how to implement a governance approach to food security.

It appears that GM technologies have, and will continue to have, economic and production benefits in many environments across the globe. The world population has reached 7 billion, and is estimated by the United Nations Department of Economic and Social Affairs (UNDESA) to reach 8 billion by 2023 (UNDESA, 2011). With such estimates in mind, UNDESA commented on the conflicting requirements for food and energy production on the one hand and natural resource conservation on the other. It recommended further investigation by decision-makers into ways to resolve this conflict via all technologies and production systems. Consequently, it is likely that biotechnology and genetically modified crops will continue to have a key role to play across the globe in terms of both food and nutritional security, if not in the EU.

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Appendix 1 – Case studies analysis

CZ1

Dairy farm in west of Czech Republic
Background

Farm size (ha)	487
Number of years farming	40
Level of education	Agric-related univ degree
Crops	Forage maize
Main constraints on production	Pests and weeds
General pest and weed pressure	Moderate
Would grow GM if available	Yes
Potential size of GM parcel	15 ha

This is a 487 ha dairy farm, small by Czech standards, on a plain in west of Czech Republic, close to the Danube (which forms the border with Austria). It operates as a limited company, with 10 employees. The CEO is 58, with degree in agriculture. At the time of the survey, they were growing 106 ha of conventional silage maize in 7 parcels, and 118 ha of Bt silage maize in another 7 parcels, all used on-farm. They grow Bt maize in rotation to alleviate pest pressure, but find compliance with coexistence measures somewhat burdensome. The main incentive is convenience of management, they see little economic advantage.

Current financial situation

Data on costs and prices affecting gross margin in CZ for maize is available from Brookes (2012), and summarised in Table 1. In order to estimate the performance of GMHT forage maize in CZ, data was extrapolated from data for maize in Gómez-Barbera et al (2008). The yield advantage for Bt IR maize reported by Gómez-Barbera et al was strongly associated with pest pressure, and they noted that the technology premium charged for the seed varied with the probability of pest damage; the control costs for the conventional crop, proportional to the number of sprays required, were lower for the Bt IR crop at all levels of pest infestation, and thus the control cost savings were greatest in regions with most severe pressure.

Table 1

Economic data for maize in Czech Republic

	yield t/ha	seed €/ha	fertiliser €/ha	control €/app/ha	harvest €/t
silage maize	35.2	123	66	22	16
Bt IR maize	[-1 to +12%]	[+3 to +23%]	[no change]	20	[no change]
data from Brookes (2012)		Bt maize data based on Gómez-Barbera et al (2008)			

Financial impacts of GM option

The METE model was used to predict the gross margin for Bt IR maize cultivated in place of conventional maize, entirely consumed as on-farm feed at three intensities of pest pressure, where two applications of pesticide are sufficient for mild pressure, but three applications are required for typical pressure, and a fourth application for severe pressure. A proportion of the farm perimeter can only be sown with conventional maize, to comply with coexistence requirements.

The predicted effect of adoption of Bt IR maize on gross margin per hectare at varying levels of pest pressure is shown in Table 2.

Table 2

Model outcomes for this farm: Bt IR forage maize vs conventional forage maize

conv/GM:	pest pressure:	yield- t/ha:	€/ha			
			control costs	crop value	margin	% change
conv	mild	33.3	56	533	477	
	typical	31.6	62	506	444	
	severe	30.1	69	482	413	
Bt IR	mild	34.4	66	550	483	1.2
	typical	33.5	70	537	467	5.3
	severe	32.8	73	524	452	9.3

At this farm, the saving is predicted to exceed the technology premium payable for the BT IR seed at all levels of pest pressure.

Sensitivity to assumptions about pest pressure

It is reasonable to expect economic damage to be severe as the Western Corn Rootworm (Diabrotica virgifera virgifera) continues to spread through Europe (Wesseler and Fall, 2010). The benefit to this farm of adopting a variety of GM maize that is toxic to that pest is significant, by protecting against yield losses of 10 to 30% considered to be likely by Wesseler and Fall.

Concluding comments

Given willingness of the farm to invest in GM technology, and assuming that any problem of coexistence with neighbouring farms can be accommodated, there is a reasonable probability that the farm will obtain an improvement in overall gross margin, and non-pecuniary benefits may also be experienced.

CZ2

All-arable farm in west of Czech Republic

Background

Farm size (ha)	1300
Employees	19
Crops	Wheat/maize/rape/sunflower
Main constraints on production	Pests and weeds
General pest and weed pressure	Moderate
Would grow GM if available	Yes
Potential size of GM parcel	30 ha

This is a 1300 ha all-arable farm, medium size by Czech standards, on a plain in west of Czech Republic, very close to the Danube (which forms the border with Austria). It operates as a limited company, with 19 employees. The CEO is 60, with degree in agriculture. At the time of the survey, they were growing 504 ha of conventional grain maize in 16 parcels, on contract.

They are aware of some potential benefit if they were to adopt Bt maize, but they are doubtful of acceptability to their market. They do think that farmers should be allowed the option to grow GM crops, and that GM will be beneficial in the long term. An assessment of the possible benefit of adopting HT rape, if a suitable variety becomes available, in included in this case study.

The crop rotation in one 30 ha parcel is wheat/maize/spring barley/rape.

Current financial situation

Data on typical crop input costs and gross margin for the crops grown on this farm in rotation is assumed to be as reported in Brookes (2012); the farm grows grain maize in rotation. For this study we assume that conventional and Bt maize would command the same price as conventional maize in the CZ market; the effect of a possible price premium for GM-free is also estimated, below.

Table 1

Economic data for crops that may be cultivated in rotation

	yield kg/ha	seed €/ha	fertiliser €/ha	control €/ha	harvest €/t
millingwheat	5150	61	78	46	143
grain maize	5000	123	66	84	164
Bt IR maize	5000	150	66	45	164
spring barley	4310	65	58	44	129
rape	2990	50	113	65	348
data from (2012)	Brookes	Bt maize data based on Gómez-Barbera et al (2008)			

Financial impacts of GM options

The METE model was used to predict the gross margin for Bt IR grain maize cultivated in place of conventional maize, in rotation with wheat, barley and oilseed rape, at three intensities of pest pressure similar to those reported by Gómez-Barbero et al (2008) in Spain, where two applications of pesticide are sufficient for mild pressure, but three applications are required for typical pressure, and a fourth application for severe pressure.

The predicted effect of adoption of Bt IR maize on gross margin per hectare at varying levels of pest pressure at this farm is shown in Table 2; pest pressures may occur at an intensity similar to the worst affected regions of Spain, and it is assumed that yields can be largely protected by sufficient application of pesticide. There is a predicted improvement at all levels of pest pressure from improved yield and from savings in cost of pesticide, as shown in Table 2a.

Table 2a

Model outcomes for this farm: Bt IR vs conventional grain maize in the given rotation

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
conv	mild	4.6	79	639	559	
	typical	4.2	88	588	499	
	severe	3.9	96	544	448	
Bt IR	mild	4.7	91	661	571	2.0
	typical	4.5	97	627	530	6.2
	severe	4.3	102	596	494	10.2

The model was also used to predict the gross margin at this farm for HT oilseed rape, with outcomes as shown in Table 2b.

Table 2b

Model outcomes for this farm: HT OSR vs conventional OSR in the given rotation

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			control costs	crop value	margin	% change
conv	mild	4.3	39	789	751	
	typical	3.8	53	704	651	
	severe	3.7	204	689	485	
HT OSR	mild	4.7	43	868	825	9.9
	typical	4.5	58	823	765	17.4
	severe	4.2	73	784	711	46.5

With severe weed pressure at this farm, adoption of HT OSR, when available, is predicted to be highly benficial.

Benefit carried forward

The farm cultivates maize in a four year crop rotation, wheat/maize/spring barley/rape. At typical weed pressures, the model predicts a yield benefit from ‘cleaner’ soil for wheat following HT oilseed rape, and as shown in Table 3, the net effect on gross margin for the wheat crop from maintaining yield with lower control costs worth €19/ha.

Table 3

Model outcomes for wheat following oilseed rape

			€/ha			
prior crop:		yield-kg/ha	control	sales	margin	change
OSR	winterwheat	4897	92	700	608	
HT OSR	winterwheat	4902	74	701	627	19

Non-pecuniary benefit

The need to spray crops with pesticide and herbicide involves compliance with increasingly strict regulations, and removal of most of the need to spray the grain maize, enabled by the way Bt maize exudes its own toxin, coupled with less onerous soil preparation for wheat following HT oilseed rape, are considered a significant non-pecuniary benefits.

Concluding comments

At the location of this farm, there is an opportunity to take advantage of good prices consistently available for growing grain maize under contract, replacing maize which mostly has to be imported. At the time of writing, the farm is vulnerable to the threat to maize from the Western Corn Rootworm (Diabrotica virgifera virgifera) which affects maize yields in southern Europe. The pest is known to be spreading (Wesseler and Fall, 2010) and Bt IR maize offers significant economic and non-pecuniary benefits if included in crop rotations at this farm.

The farm has experience of growing oilseed rape as a profitable break crop, and if a suitable variety of oilseed rape becomes available, the farm could use the ‘soil cleaning’ attribute of a GM herbicide-tolerant crop to the benefit of the succeeding main crop of winter wheat.

DE1

All-arable farm in Brandenburg

Background

Farm size	900 hectares
Number of years farming	26
Level of education	Science degree
Crops	Grain maize, wheat, barley, rape
Main constraints on production	Water availability
General pest and weed pressure	Quite severe
Would grow GM if available	Will consider
Potential size of GM parcel	40 ha
Would change plans to avoid conflict with neighbour	Neighbours agreeable

This is a 900 ha all-arable farm, with 1.5 km of border shared with nine neighbouring farms, with whom the business is on good terms. The quality of the soil is not ideal, and there are some topographic constraints, but the greatest concerns arise from water availability and weed pressure. There is also a growing concern about ECB damage to the maize crop. In 2012 the farm cultivated 15 ha of grain maize and 65 ha of silage maize, the whole quantity being sold on contract. The business considers that there may be difficulty in obtaining contracts to grow Bt maize.

The crop rotation in one 40 ha parcel is wheat/maize/spring barley.

While noting that maize is a suitable break crop for farms that grow mainly milling wheat, Tricault et al (2011) observed that oilseed rape should also be considered. The possibility of this farm adopting HT rape to precede wheat in the rotation has accordingly been assessed, alongside an assessment of adoption of Bt maize: rape/wheat/maize/barley.

Current financial situation

Data on typical crop yields and input costs for the crops grown on this farm in rotation are shown in Table 1. The farm grows primarily wheat, with some grain maize, barley and oilseed rape in rotation. We assume that the yield of either of the GM crops would be the same as the conventional equivalent, and that the GM crops can be sold at the same price as the conventional equivalent; later, we test the economic outcome using alternative assumptions. The variable costs include seed, fertiliser and treatments. Based on experience with these crops elsewhere, and on reported outcomes from other modelling, we assume initially that the adoption of Bt maize or HT rape enables savings in treatment costs that are more than sufficient to cover the technology premium at typical pest and weed pressures and climate conditions.

Table 1 - Economic data for crops that may be cultivated in rotation

	yield	variable costs	harvest
	kg/ha	€/ha	€/t
millingwheat	7630	443	163
grain maize	8030	751	166
Bt IR maize	8030	700	166
spring barley	5060	382	195
rape	3900	472	380
HT rape	3900	420	380
data from KTBL (2013)	Bt maize data based on Gómez-Barbera et al (2008) HT rape data based on Breustedt et al (2013)		

Financial impacts of GM options

The METE model was used to predict the gross margin for Bt IR grain maize cultivated in place of conventional maize, in rotation with wheat, barley and oilseed rape, at three intensities of pest pressure similar to those reported by Gómez-Barbero et al (2008) in Spain, where two applications of pesticide are sufficient for mild pressure, but three applications are required for typical pressure, and a fourth application for severe pressure.

The predicted effects of adoption of Bt IR maize on gross margin per hectare at varying levels of pest pressure, and of adoption of HT rape at varying levels of weed pressure, at this farm are shown in Table 2; pest pressures may occur at an intensity similar to the worst affected regions of Spain, and it is assumed that yields can be largely protected by sufficient application of pesticide. Weed pressures are comparable to weed pressures simulated by Breustedt et al (2013). There is a predicted improvement in gross margin at all except the mildest pressures, from improved yield and from savings in cost of treatments, as shown in Table 2a.

Table 2a

Model outcomes for this farm for adoption of Bt maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
conv	mild	8.0	224	1,122	898	
	typical	7.4	240	1,032	792	
	severe	6.8	255	955	701	
Bt IR	mild	8.3	243	1,161	918	2.2
	typical	7.9	254	1,101	846	6.9
	severe	7.5	264	1,046	782	11.6

The model was also used to predict the gross margin at this farm for HT oilseed rape, with outcomes as shown in Table 2b.

Table 2b

Model outcomes for this farm: HT OSR vs conventional OSR in the given rotation

conv/GM:	pest pressure:	yield-t/ha:	€/ha			
			control costs	crop value	margin	% change
conv	mild	3.4	111	1,096	985	
	typical	3.1	133	977	844	
	severe	2.9	213	922	708	
HT OSR	mild	3.7	135	1,170	1036	5.1
	typical	3.4	147	1,102	955	13.1
	severe	3.3	158	1,041	883	24.6

Benefit carried forward

When wheat is grown following HT rape, the model predicts a yield benefit from 'cleaner' soil, and as shown in Table 3, the net effect on gross margin for the wheat crop from maintaining yield with lower control costs worth €27/ha.

Table 3

Model outcomes for 4-crop rotation

prior crop:		yield-kg/ha	€/ha			
			control	sales	margin	change
OSR	winterwheat	7350	230	1198	968	
HT OSR	winterwheat	7359	205	1200	995	27

Non-pecuniary benefit

The need to spray crops with pesticides and herbicides involves compliance with increasingly strict regulations, and so removal of most of the need to spray, enabled by the way Bt maize exudes its own toxin and HT rape requires one post-emergence application of relatively benign glyphosate, is considered a significant non-pecuniary benefit.

Concluding comments

At the location of this farm, there is an opportunity to take advantage of good prices consistently available for growing maize under contract, and also to take advantage of herbicide-tolerant rape, if that becomes a permitted option. As there are neighbouring farms, it would be wise to consult with them as to management of coexistence with conventional crops; farm managers in this part of Germany have been asked about their attitudes to GM crops, and in most cases they are receptive to the idea (Areal et al, 2011)

DE2

Mixed farm in Saxony

Background

Farm size	1600 hectares
Level of education	Science degree
Crops	Wheat, maize, spring barley
Main constraints on production	Water availability
General pest and weed pressure	Weed pressure
Would grow GM if available	Has grown BT maize when it was permitted
Potential size of GM parcel	50 ha
Would change plans to avoid conflict with neighbour	There are no problems with neighbours

This is a 1600 ha farm, using contract labour. The farm focus is on cereals. In 2012, 250 ha of silage maize was grown for on farm use. This large farm has 15 farm neighbours, all on good terms. The farm is a member of a co-operative scheme. Use is made of government extension facilities and of commercial advisory services.

A proportion of the 2012 silage maize was Bt maize (50 ha, in one parcel) with yield of 39 t/ha, compared with 36 t/ha for conventional silage maize. Conventional silage maize was confined to 16 smaller parcels. The Bt silage maize was of significantly better quality, with reduced pest damage. The crop rotation in this 50 ha parcel is wheat/maize/spring barley. Segregation of GM seed is considered a mild burden; coexistence costs are acceptable if separation distances are not greater than 150m.

The business is strongly of the opinion that farmers should be allowed to use GM crops if they so decide, and that this farm would certainly adopt other GM crops if permitted; any risk to the environment can be managed, and there is no risk to human health. The business is of the opinion that lack of access to GM crops is making EU cereals uncompetitive in world markets.

Current financial situation

Data on typical crop input costs and gross margin for the crops grown on this farm in rotation is assumed to be as reported in Venus et al (2011); the farm grows grain maize in rotation. For this study we assume that conventional and Bt maize would command the same price as conventional maize in the CZ market; the effect of a possible price premium for GM-free is also estimated, below.

Table 1

Economic data for crops that may be cultivated in rotation

	yield kg/ha	seed €/ha	control €/ha	harvest €/t
silage maize	40000	105	106	30
Bt IR maize	40000	125	45	30
spring barley	4950	80	62	196

data from Brookes (2012); Venus et al (2011)

Bt maize data based on Gómez-Barbera et al (2008)

Financial impacts of GM options

The METE model was used to predict the gross margin for Bt IR grain maize cultivated in place of conventional maize, in rotation with wheat, barley and oilseed rape, at three intensities of pest pressure similar to those reported by Gómez-Barbero et al (2008) in Spain, where two applications of pesticide are sufficient for mild pressure, but three applications are required for typical pressure, and a fourth application for severe pressure.

The predicted effect of adoption of Bt IR maize on gross margin per hectare at varying levels of pest pressure at this farm is shown in Table 2; pest pressures may occur with intensity similar to the worst affected regions of Spain, and it is assumed that yields can be largely protected by sufficient application of pesticide. There is a predicted improvement at all levels of pest pressure from improved yield and from savings in cost of pesticide, as shown in Table 2.

Table 2

Model outcomes for this farm: Bt IR vs conventional forage maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
conv	mild	36.6	199	1,098	898	
	typical	33.6	218	1,009	792	
	severe	31.1	234	934	701	
Bt IR	mild	37.9	256	1,136	880	-2.0
	typical	35.9	266	1,077	811	2.4
	severe	34.1	275	1,023	748	6.7

Non-pecuniary benefit

The need to spray crops with pesticide involves compliance with increasingly strict pesticide regulations, and removal of most of the need to spray the grain maize, enabled by the way Bt maize exudes its own toxin, is considered a significant non-pecuniary benefit.

Concluding comments

Even at the large technology premium of €60/ha that this farm expects to have to pay for Bt maize seed, they are confident that the investment is worthwhile, given the problem of pest pressure in this part of Germany. They are an efficient co-operative, and they expect to obtain real benefit from the simplified crop management associated with GM IR crops.

SK1

Large arable farm complex close to Nove Zamky in Slovakia
Background

Farm size	5550 hectares
Level of education	Trained agriculturalists
Crops	Wheat, maize, barley
Main constraints on production	Weeds and pests
General pest and weed pressure	Moderate to severe
Would grow GM if available	Y
Potential size of GM parcel	70 ha
Neighbour constraints	200km boundary with 10 neighbouring farms

This is a 5550 ha limited company arable farm complex, located to the east of Nove Zamky in the fertile plain in the southern section of the Danubian Lowland. The main crops are wheat, maize and oilseed rape (OSR), with barley, sugar beet, sunflower and legumes also cultivated within the crop rotations. The farm has some years' experience of cultivating Bt maize.

Current financial situation
Table 1
Economic data for maize in Slovakia

	yield kg/ha	seed €/ha	control €/ha	harvest €/t
grain maize	6400	109	70	151
forage maize	24500	100	60	22.5
Bt grain maize	6400	130	50	151
Bt forage maize	24500	120	50	22.5

data from Brookes (2012)

Bt maize data based on Gómez-Barbera et al (2008)

Financial impacts of GM option
The METE model was used to predict the gross margin for Bt IR grain and forage maize cultivated in place of conventional maize, with forage maize entirely consumed as on-farm feed at three intensities of pest pressure, where two applications of pesticide are sufficient for mild pressure, but three applications are required for typical pressure, and a fourth application for severe pressure. A proportion of the farm perimeter can only be sown with conventional maize, to comply with coexistence requirements.
The predicted effect of adoption of Bt IR maize on gross margin per hectare at varying levels of pest pressure is shown in Tables 2a and 2b.

Table 2a
Model outcomes for this farm: grain maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			
			control costs	sales	margin	% change
conv	mild	5.93	79	895	716	
	typical	5.52	88	833	654	
	severe	5.16	96	779	600	
Bt IR	mild	6.1	91	921	718	0.3
	typical	5.83	97	880	677	3.5
	severe	5.58	102	843	639	6.5

Table 2b
Model outcomes for this farm: forage maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			
			control costs	sales	margin	% change
conv	mild	21.8	79	491	321	
	typical	19.6	88	442	272	
	severe	17.9	96	402	232	
Bt IR	mild	23.2	91	522	330	2.8
	typical	22.1	97	496	304	11.8
	severe	21	102	473	281	21.1

At this farm, the saving is predicted to exceed the technology premium payable for the BT IR seed at all levels of pest pressure.

Sensitivity to assumptions about pest pressure

It is reasonable to expect economic damage to be severe as the Western Corn Rootworm (Diabrotica virgifera virgifera) continues to spread through Europe (Wesseler and Fall, 2010). The benefit to this farm of adopting a variety of GM maize that is toxic to that pest is significant, by protecting against yield losses of 10 to 30% considered to be likely by Wesseler and Fall.

Concluding comments

Given willingness of the farm to invest in GM technology, and assuming that any problem of coexistence with neighbouring farms can be accommodated, there is a reasonable probability that the farm will obtain an improvement in overall gross margin, and non-pecuniary benefits may also be experienced.

SK2

Arable farm at Vrable close to Nitra in Slovakia

Background

Farm size	2430 hectares
Level of education	Owned and run by agronomists
Crops	Wheat, maize, barley, OSR, sunflower, soya
Would grow GM if available	Y
Potential size of GM parcel	60 ha
Would change plans to avoid conflict with neighbour	Yes

This 2430 ha farm is about 100 km east of Bratislava, close to the old city of Nitra at the foothill of the Zobor mountain (587 m), and is located in the warmest and driest part of Slovakia. The annual rainfall is 50-60 cm. The farm grows mainly wheat and maize, with sunflower as the preferred break crop. They have not so far grown Bt maize, but they are interested in the possibility.

Current financial situation

Table 1

Economic data for grain maize in Slovakia

	yield kg/ha	seed €/ha	control €/ha	harvest €/t
grain maize	6400	109	70	151
Bt grain maize	6400	130	50	151

data from Brookes (2012)

Bt maize data based on Gómez-Barbera et al (2008)

Financial impacts of GM option

The METE model was used to predict the gross margin for Bt IR grain maize cultivated in place of conventional maize. A proportion of the farm perimeter can only be sown with conventional maize, to comply with coexistence requirements, and the owners do not expect any difficulty in reaching agreement with neighbours regardsing co-existence.

The predicted effect of adoption of Bt IR maize on gross margin per hectare at varying levels of pest pressure is shown in Table 2.

Table 2
Model outcomes for this farm: grain maize

conv/GM:	pest pressure:	yield- t/ha:	€/ha			
			control costs	sales	margin	% change
conv	mild	5.93	64	895	681	
	typical	5.52	87	833	596	
	severe	5.16	103	779	526	
Bt IR	mild	6.1	76	921	695	2.1
	typical	5.83	94	880	636	6.7
	severe	5.58	108	843	585	11.2

At this farm, the saving is predicted to exceed the technology premium payable for the BT IR seed at all levels of pest pressure.

Sensitivity to assumptions about pest pressure
Bt maize has already been adopted at farms in this region, and found to be beneficial in view of the continuing spread of Western Corn Rootworm. It is likely that the pest pressure affecting the region will continue, and may increase (Wesseler and Fall, 2010).

Concluding comments
Given willingness of the farm to invest in GM technology, and assuming that any problem of coexistence with neighbouring farms can be accommodated, there is a reasonable probability that the farm will obtain an improvement in overall gross margin, and non-pecuniary benefits may also be experienced.

SK3

Cooperative farm complex at Hlohovec in Slovakia

Background

Farm size	3500 hectares
Level of education	Graduate managers
Crops	Various, many small parcels
Main constraints on production	Weeds and pests
General pest and weed pressure	Moderate to severe
Would grow GM if available	Bt maize already mostly in use
Potential size of GM parcel	20 ha
Neighbour relations	Good relations within co-op

Current financial situation

This is a successful, well-established and progressive co-operative, growing primarily wheat, maize and barley, and also sugar beet, legumes and other break crops. The members were early adopters of Bt maize. The farm has responded to a survey questionnaire with comprehensive data for major crops cultivated at the farm. The main economic variables reported are based on prevailing costs and sales values in 2012, and are shown in Table 1.

Table 1

Economic data for crops grown at Hlohovec

	yield t/ha	seed €/ha	control €/ha	sales €/t
Winter wheat	3.56	54	70	200
Winter OSR	2.07	42	183	475
Winter barley	3.37	55	35	207
Spring barley	2.8	55	29	220
Sugar beet	49.7	150	323	38.8
Sunflower	2.22	85	133	440
grain maize	6.0	100	72	190
Bt grain maize	6.0	140	20	190
silage maize	28.5	100	72	40
Bt silage maize	28.5	140	20	40

Conventional crop data based on VUEPP (2014) and Brookes (2012)

Bt maize data based on Venus et al (2011)

Financial impacts of GM option

The METE model was used to compare the gross margin for Bt IR grain maize cultivated in place of conventional maize with results claimed at this farm, at three intensities of pest pressure.

There was close correspondence between the sets of data; the main results are shown in Table 2.

Table 2
Model outcomes for this co-operative: Bt IR maize vs conventional grain maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
conv	mild	5.72	79	1086	684	
	typical	5.4	88	1026	601	
	severe	5.03	96	956	532	
Bt IR	mild	5.96	91	1133	697	1.9
	typical	5.69	97	1081	640	6.5
	severe	5.43	102	1032	590	10.9

After validating the model for grain maize cultivation at this farm, the model was used to predict the outcome if a suitable variety of winter HT oilseed rape becomes available for cultivation, in rotation with wheat. The results are summarised in Table 3.

Table 3
Model outcomes: HT OSR vs conventional OSR

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
conv OSR	mild	1.8	143	855	462	
	typical	1.6	183	762	395	
	severe	1.51	223	719	274	
HT OSR	mild	1.92	94	913	481	4.1
	typical	1.81	107	860	442	11.9
	severe	1.71	121	812	408	48.9

The farm community at this co-operative are firmly convinced of the advantage of Bt IR maize at the prevailing levels of pest pressure, and in most seasons the GM maize provides a substantial increase in gross margin for this crop.

Oilseed rape is cultivated on about 10% of the co-operative area in most years, and the model predicts that HT GM rape, if available, would be more profitable than conventional rape at any levels of weed pressure (although there has been no indication as yet of the technology premium that that would be payable for this hypothetical product).

Benefit carried forward

When wheat is grown following HT rape, the model predicts a yield benefit from ‘cleaner’ soil, and as shown in Table 3, the net effect on gross margin for the wheat crop from maintaining yield with lower control costs worth €14/ha.

Table 3

Model outcomes for winter wheat following HT crop

prior crop:		yield-kg/ha	€/ha control	sales	margin	change
OSR	winterwheat	3423	70	685	229	
HT OSR	winterwheat	3488	70	698	242	19

Concluding comments

This progressive farm enterprise is already gaining substantial benefit from Bt maize, and the management team are receptive to any new crop varieties that be cultivated profitably, and also preserve soil quality and simplify management.

ES1

Arable farm in Los Monegros, Spain

Background

Farm size	330 ha
Main cropping system	Grain maize, rotated, irrigated
Main constraint on production	Water availability
General pest and weed pressure	Maize pests
Adoption of Bt maize	Bt maize grown since 2005
Typical maize area	110 ha
Would change plans to avoid conflict with neighbour	Bt maize well accepted in locality

This is an all-arable farm in the central part of the autonomous community of Aragon in north-east Spain, where Bt maize has been cultivated with economic success for more than a decade. This is an arid locality, and the farm has installed a sprinkler irrigation system, of the automated type described by Playan et al (2013), which maintains crop yield with efficient use of water during seasons affected by severe drought. The sprinkler system is used to apply fertiliser prior to seeding.

The cropping system is maize-based, and a three crop rotation grain maize/ silage maize/ spring barley is spread over two years, with legumes or oilseeds grown as break crops in other years .

Current financial situation

Data on typical crop input costs and gross production value for the crops grown on this farm in rotation is assumed to be as summarised in table 1.

Table 1

Economic data for crops that may be cultivated in rotation

	yield kg/ha	seed €/ha	control €/ha	harvest €/t
grain maize	13500	331	170	200
Bt IR maize	13500	350	70	200
silage maize	32000	123	120	30
Bt silage maize	32000	143	50	30

data from Brookes (2012)

Bt maize data based on Gómez-Barbera et al (2008)

The seed cost of conventional and Bt maize indicated in table 1 is consistent with the findings of Gomez-Barbero et al (2008) for this part of Spain; suppliers in Spain vary the technology component of the seed cost according to the pest prevalence in the region.

Financial impacts of GM options

Data available since first adoption of Bt maize in this part of Spain was used to validate the METE model, and the model outcomes were then obtained for three intensities of pest pressure. The results for grain maize and for silage maize are shown in Tables 2a and 2b.

Table 2a

Model outcomes for this farm: conventional vs Bt grain maize

conv/GM:	pest pressure:	yield- t/ha:	€/ha			% change
			control costs	sales	margin	
conv	mild	12.5	140	2500	1609	
	typical	11.64	170	2327	1436	
	severe	10.89	200	2177	1286	
Bt IR	mild	12.87	91	2574	1643	2.1
	typical	12.3	108	2459	1529	6.5
	severe	11.77	125	2355	1425	10.8

Table 2b

Model outcomes for this farm: conventional vs Bt silage maize

conv/GM:	pest pressure:	yield- t/ha:	€/ha			% change
			control costs	sales	margin	
conv	mild	28.2	100	846	421	
	typical	26.5	130	795	333	
	severe	25.5	160	765	251	
Bt IR	mild	29.6	60	889	429	1.9
	typical	27.6	75	828	348	4.5
	severe	25.8	90	775	285	13.4

The modern sprinkler irrigation system installed at this farm enables the farm to obtain exceptionally strong yields of grain maize. This is only attainable during one year of the three year rotation. Bt maize ensures that the high yield is largely preserved even when pest pressure is severe.

During the silage maize year, the irrigation is at a lower rate, and Bt maize enables the farm to sustain the gross margin (at a much lower level) under severe pest pressure.

Non-pecuniary benefit

The need to spray crops with pesticide has management and logistical requirements that are not reflected in direct costings, but add to the stresses associated with the busy schedule for staff on a modern farm with complex irrigation and other equipment. The reassurance that maize crop yields are intrinsically protected at any level of pest pressure eases anxiety about crop performance.

Validation of yield benefit

Data for Spain reported in the meta-analysis of Finger et al (2011) showed 5.6% average increase in yield of Bt compared with conventional maize, and 9.8% increase in gross margin.

Concluding comments

This farm is modern and efficiently managed, with nine years experience of growing Bt maize. There are no coexistence problems with neighbours; maize grows strongly and is a popular crop in this region of Spain, and GM maize has long been an accepted component of pest management strategy. The farm managers are convinced of the advantages of Bt maize, with pest pressure a recurring problem for them. Even in the years when pest pressure is relatively light, the assurance of consistent yield is welcome, given the other management problem of efficient water use in this arid locality.

ES2

Mixed farm in la Hoya de Huesca, Spain

Background

Farm size	40 ha
Cropping system	Grain/silage maize, rotated, partly irrigated
Main constraints on production	Water availability
General pest and weed pressure	Maize pests
Adoption of Bt maize	Established since 2008
Maize parcel	8 ha
Would change plans to avoid conflict with neighbour	Bt maize well accepted in locality

This is a mixed farm in the northern part of the autonomous community of Aragon in north-east Spain, where Bt maize has been cultivated with economic success for more than a decade. The farm still uses a traditional surface irrigation system, pending investment in a sprinkler system; the investment required to switch from surface to sprinkler irrigation is about €9000/ha (Lecina et al, 2010). Surface irrigation is installed for approximately 40% of the farm area. In this district water delivery is available based on previous water consumption.

An eight hectare parcel is used for grain maize followed by silage maize and barley or legumes, with oilseed as an occasional break crop which is not irrigated.

Current financial situation

Data on typical crop input costs and gross production value for the crops grown on this farm in rotation is assumed to be as summarised in Table 1.

Table 1

Economic data for crops that may be cultivated in rotation

	yield kg/ha	seed €/ha	control €/ha	harvest €/t
grain maize	13500	331	170	200
Bt IR maize	13500	350	70	200
silage maize	32000	123	120	30
Bt silage maize	32000	143	50	30

data from Brookes (2012)

Bt maize data based on Gómez-Barbera et al (2008)

The economic advantage of Bt maize relative to conventional maize indicated in table 1 is consistent with the findings of Gomez-Barbero et al (2008) for this part of Spain, and with the findings in ther meta-analysis of Finger et al (2011) for arable farms in other countries which are under similar intensity of pest pressure.

Financial impacts of GM options

Data available since first adoption of Bt maize in this part of Spain was used to validate the METE model, and the model outcomes were then obtained for three intensities of pest pressure. The results for grain maize and for silage maize are shown in Tables 2a and 2b.

Table 2a

Model outcomes for this farm: conventional vs Bt grain maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			% change
			control costs	sales	margin	
conv	mild	11.25	65	2250	1609	
	typical	10.24	80	2048	1436	
	severe	9.36	96	1872	1286	
Bt IR	mild	12.23	62	2445	1636	1.7
	typical	11.44	76	2287	1525	6.2
	severe	10.71	90	2143	1424	10.7

Table 2b

Model outcomes for this farm: conventional vs Bt silage maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			% change
			variable costs	sales	margin	
conv	mild	24.5	65	735	288	
	typical	21.6	80	647	183	
	severe	20.4	96	612	99	
Bt IR	mild	26.1	62	782	290	0.9
	typical	24.8	76	743	201	10.4
	severe	23.6	90	708	116	17.5

The traditional gravity irrigation system installed at this farm enables the farm to obtain strong yields of grain maize, only slightly below the yields achievable with a sprinkler system. This is only attainable during one year of the three year rotation. Bt maize ensures that the high yield is largely preserved even when pest pressure is severe.

During the silage maize year, the irrigation is at a lower rate, and Bt maize enables the farm to sustain the gross margin (at a much lower level) under severe pest pressure.

Non-pecuniary benefit

The need to spray crops with pesticide has management and logistical requirements that are not reflected in direct costings, but add to the stresses associated with the busy schedule for staff on a modern farm with complex irrigation and other equipment. The reassurance that maize crop yields are intrinsically protected at any level of pest pressure eases anxiety about crop performance.

Validation of yield benefit

Data for Spain reported in the meta-analysis of Finger et al (2011) showed 5.6% average increase in yield of Bt compared with conventional maize, and 9.8% increase in gross margin.

Concluding comments

This relatively small and remote farm is not as advanced as some of the larger farms in Aragon, but after observing the larger yields achieved by early adopters of Bt maize, the farm decided that Bt maize would enhance their profitability, as has turned out to be the case. The farm is now in a position to invest in modernisation of their irrigation system, confident that Bt maize will continue to provide sufficiently enhanced income to pay off the substantial cost. The investment decision is welcome in the locality, because a modern sprinkler irrigation system makes best use of the limited water supply available to the community.

SW1

Small all-arable farm in province of Scania

Background

Farm size	103 hectares
Crops	Wheat, barley, some OSR
Main constraints on production	Weeds and pests
General pest and weed pressure	Moderate to severe
Potential size of GM parcel	10 ha

Current financial situation

This is a family owned and operated farm, with 81 ha of own land and a further 22 ha of rented UAA. The margins are typical of margins achieved generally in this region, summarised in Table 1.

Table 1

Economic data for crops grown

	yield kg/ha	seed €/ha	control €/ha	harvest €/t
oilseed rape	2580	67	29	396
HT oilseed rape	2580	90	20	396
sugarbeet	52900	207	99	27
HT sugarbeet	52900	230	50	27

data from Brookes (2012)

HT OSR data based on Smyth et al (2010)

HT sugarbeet data based on Dillen et al (2011)

Financial impacts of GM option

The METE model was used to predict the gross margin for herbicide-tolerant (HT) oilseed rape (OSR) cultivated in place of conventional oilseed rape at three intensities of pest pressure.

The typical effect of adoption of HT OSR on gross margin per hectare at varying levels of weed pressure is shown in Table 2.

Table 2

Model outcomes for HT OSR

conv/GM:	weed pressure:	yield- t/ha:	€/ha			
			variable costs	sales	margin	% change
OSR	mild	2.2	202	879	677	
	typical	2	220	800	580	
	severe	1.9	239	754	515	
HT OSR	mild	2.3	214	907	693	2.4
	typical	2.2	236	875	639	10.2
	severe	2.1	245	836	591	14.8

The model prediction indicates that the yield is protected for the HT crop sufficiently to ensure an improvement in gross margin at all levels of weed pressure.

Concluding comments

The variable costs shown in Table 2 include an estimate for the technology premium charged by the seed supplier. AS GM crops become more widely adopted, it may be that the premium will be reduced.

The farm cultivates oilseed rape primarily as a break crop, but it is a high value crop, and if the adoption of HT rape proves successful in overcoming the persistent problem with weeds, the farm will probably adopt it for a larger proportion of their activity.

SW2

Large arable farm in Scania

Background

Farm size	673 hectares
Crops	Wheat, barley, sugarbeet, OSR
Main constraints on production	Weeds and pests
General pest and weed pressure	Moderate to severe
Potential size of GM parcel	60 ha

Current financial situation

This 673 ha owner-occupied arable farm employs one additional full-time worker. They grow about 100 ha of sugarbeet and about 60 ha of rape alongside about 400 ha of cereals. They use advanced farming methods, and achieve winter wheat yields of almost 8 t/ha. It may be well-worthwhile adopting HT sugarbeet when available, and perhaps HT rape as well.

Table 1
Economic data for crops grown

	yield kg/ha	seed €/ha	control €/ha	harvest €/t
oilseed rape	2580	67	29	396
HT oilseed rape	2580	85	20	396
sugarbeet	52900	207	100	27
HT sugarbeet	24500	230	50	27

data from Brookes (2012)

HT rape data based on Smyth et al (2010)

HT sugarbeet data based on Dillen (2013)

Financial impacts of GM option

The METE model was used to predict the gross margin for herbicide-tolerant (HT) oilseed rape (OSR) cultivated in place of conventional oilseed rape, and of HT sugarbeet in place of conventional sugarbeet, at three intensities of pest pressure.

The typical effect of adoption of HT OSR on gross margin per hectare at varying levels of weed pressure is shown in Table 2a, and the corresponding output for sugarbeet is shown in Table 2b.

Table 2a
Model outcomes for HT OSR

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
OSR	mild	2.1	110	847	738	
	typical	2	119	800	681	
	severe	1.9	124	754	631	
HT OSR	mild	2.2	143	883	740	0.3
	typical	2.2	153	855	702	3.1
	severe	2.1	164	832	667	5.7

At this farm (larger than SW1), strongly confident in technology and very efficient, they are able to limit the cost of weed management per hectare, and enjoy correspondingly improved margins with conventional as well as HT rape.

Table 2b
Model outcomes for HT sugarbeet

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	crop value	margin	% change
conv beet	mild	50	131	901	770	
	typical	47.2	148	850	702	
	severe	45.1	178	812	634	
HT beet	mild	51	154	917	763	-0.9
	typical	49.9	176	898	722	2.8
	severe	48.2	177	868	691	9.0

The model prediction indicates that the yield is protected for the HT crop sufficiently to ensure an improvement in gross margin at all except the mildest level of weed pressure.

If in due course the farm is able to use HT OSR and HT sugarbeet in rotation with wheat and spring barley, then the second HT crop (HT rape in this example) is likely to be even more profitable, as yields are further enhanced in the cleaner soil, as shown in Table 3.

Table 3
Model outcomes for HT OSR following HT sugarbeet

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
OSR	mild	2.1	110	847	738	
	typical	2	119	800	681	
	severe	1.9	124	754	631	
HT OSR	mild	2.4	181	942	761	3.1
	typical	2.4	193	935	742	9.0
	severe	2.3	203	927	724	14.7

Benefit carried forward

A similar advantage may be obtainable from the cleaner soil for the succeeding season of winter wheat as well, as illustrated in Table 4.
Table 4
Model outcomes for winter wheat following HT crops

feed wheat	yield-t/ha:	extra yield (t/ha)	€/ha value at €175/t
normal rotation	5.032		
following HT OSR	5.097	0.065	11.45
following HT beet + HT OSR	5.163	0.131	23.00

There is evidence from Canada (Smyth et al, 2011), on farms which also experience extreme low temperatures in winter, that HT Canola leaves soil with smaller weed populations, to the benefit of a succeeding wheat crop.

Concluding comments
This is a progressive and well-managed farm that will be well-placed to take advantage of whatever GM crops eventually become available for cultivation in northern regions of EU.

SW3

Medium size arable farm in Scania

Background

Farm size	358 hectares
Crops	Wheat, barley, sugarbeet, OSR
Main constraints on production	Weeds and pests
General pest and weed pressure	Moderate to severe
Potential size of GM parcel	40 ha

Current financial situation

The 358 ha family farm with two additional employees also uses modern soil management techniques to achieve impressive yields – 7.4 t/ha of winter wheat and 6.5 t/ha of barley. They grow about 65 ha of sugarbeet in rotation with wheat and rape, and are very likely to welcome an opportunity to adopt HT sugarbeet, and perhaps HT rape as well.

Table 1

Economic data for crops grown

	yield kg/ha	seed €/ha	control €/ha	harvest €/t
oilseed rape	2580	67	29	396
HT oilseed rape	2580	90	20	396
sugarbeet	52900	207	100	27
HT sugarbeet	52900	230	50	27

data from Brookes (2012)

HT rape data based on Smyth et al (2010)

HT sugarbeet data based on Dillen (2013)

Financial impacts of GM option

The METE model was used to predict the gross margin for herbicide-tolerant (HT) oilseed rape (OSR) cultivated in place of conventional oilseed rape, and for HT sugarbeet cultivated in place of conventional sugarbeet, each at three intensities of pest pressure.

The typical effect of adoption of HT OSR on gross margin per hectare at varying levels of weed pressure is shown in Table 2a, and the corresponding data for HT sugarbeet in Table 2b.

Table 2a

Model outcomes for HT OSR

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
conv OSR	mild	2.4	143	958	738	
	typical	2.3	183	901	681	
	severe	2.1	223	851	631	

HT OSR	mild	2.5	94	980	740	0.3
	typical	2.4	107	942	702	3.1
	severe	2.3	121	907	667	5.8

Adoption of HT OSR at this farm is expected to improve gross margin relative to conventional OSR at all levels of weed pressure.

Table 2b

Model outcomes for HT sugarbeet

conv/GM:	weed pressure:	yield- t/ha:	€/ha			
			variable costs	crop value	margin	% change
conv beet	mild	50.0	131	901	757	
	typical	47.2	148	850	690	
	severe	45.1	178	812	629	
HT beet	mild	51.0	154	917	755	-0.4
	typical	49.9	176	898	719	4.2
	severe	48.2	177	868	685	8.8

Adoption of HT sugarbeet at this farm is expected to improve gross margin at all except the lowest level of weed pressure.

Table 3

Model outcomes for HT OSR following HT sugarbeet

conv/GM:	weed pressure:	yield- t/ha:	€/ha			
			variable costs	sales	margin	% change
OSR	mild	2	79	808	729	
	typical	1.9	95	764	669	
	severe	1.9	113	741	628	
HT OSR	mild	2.5	240	986	746	2.3
	typical	2.4	243	966	723	8.1
	severe	2.5	264	978	714	13.7

The gross margin for HT OSR is predicted to increase at all levels of original weed pressure if the crop follows HT sugarbeet.

Benefit carried forward

A similar advantage may be obtainable from the cleaner soil for the succeeding season of winter wheat as well, as illustrated in Table 4.

Table 4

feed wheat	yield-t/ha:	extra yield (t/ha)	€/ha value at €175/t
normal rotation	4.897		
following HT OSR	4.996	0.099	17.33
following HT beet + HT OSR	5.071	0.174	30.45

Concluding comments

In common with other farms in southern Sweden, this farm is run at a high level of efficiency, and the small number working at the farm are very receptive to new technology, particularly innovation such as herbicide-tolerance, with the labour saving associated with fewer treatments to apply.

UK1

Mixed farm in South-west of England growing continuous maize for on-farm use

Background

Farm size	90 hectares
Number of years farming	31
Level of education	Agric-related further edu
Crops	Continuous maize
Main constraints on production	Topographic, then pests
General weed pressure	High
Would grow GM if available	Yes
Potential size of GM parcel	90 ha
Concerned mainly about attitude of bee keepers	Yes

This is a mixed farm in Wiltshire. The farm cultivates continuous maize, all for on-farm use. Field size is constrained by topographic features.

The farm has 6 immediate neighbours, and the farmer expects that there would be additional costs in complying with coexistence regulations, but is confident of amicable relations with neighbours; he has some concern about attitudes of bee keepers.

Current financial situation

Some data on costs for production in UK of forage maize is available from the Farm Management Pocketbook (Nix, 2015); Nix comments that there is no fundamental difference between forage and grain maize – for the latter, the crop is left 3-6 weeks longer before harvest to allow the cobs to mature. The subsequent drying treatment required for grain maize is not relevant to margins applicable for forage maize.

Table 1

Economic data for forage maize

	yield-kg/ha	seed-€/ha	sprays,€/ha	harvest-€/t
forage maize	12000	161.29	80.01	48.2
Bt forage maize	12000	193.04	55.88	48.2

data from Nix (2015) with £1 = €1.27

Bt maize data based on Gómez-Barbera et al (2008)

The yield advantage for Bt IR maize reported by Gómez-Barbera et al (2008) was strongly associated with pest pressure, and they noted that the technology premium charged for the seed varied with the probability of pest damage; the control costs for the conventional crop, proportional to the number of sprays required, were lower for the Bt IR crop at all levels of pest infestation, and thus the control cost savings were greatest in regions with most severe pressure.

Financial impacts of GM options

The METE model was used to predict the gross margin for Bt IR maize cultivated in place of conventional maize, entirely consumed as on-farm feed at three intensities of pest pressure, where two applications of pesticide are sufficient for mild pressure, but three applications are required for typical pressure, and a fourth application for severe pressure. A proportion of the farm perimeter can only be sown with conventional maize, to comply with coexistence requirements.

The predicted effect of adoption of Bt IR maize on gross margin per hectare at varying levels of pest pressure is shown in Table 2:

Table 2

Model outcomes for this farm: Bt IR maize vs conventional forage maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
OSR	mild	10.9	72	509	437	
	typical	10.5	101	493	392	
	severe	10.2	123	478	354	
HT OSR	mild	10.9	72	508	436	-0.1
	typical	10.6	80	493	403	2.8
	severe	10.4	94	486	373	5.2

At this farm, the performance of Bt maize is likely to exceed conventional forage maize only marginally at likely levels of pest pressure, but there are some savings in management costs.

Sensitivity to assumptions about pest pressure

It is reasonable to expect economic damage to be severe if the Western Corn Rootworm (Diabrotica virgifera virgifera) continues to spread northwards through Europe (Wesseler and Fall, 2010). There may be steps that can be taken to limit the spread, but if, for example, the pest becomes a major problem in southern England as a result of climate change, the benefit to this farm of adopting a variety of GM maize that is toxic to that pest would become very much greater, by protecting against yield losses of 10 to 30% considered to be likely by Wesseler and Fall.

Concluding comments

At the location of this farm in the South-west of England, pest pressure [at the time of writing] can be contained at reasonable cost. If circumstances change, the availability of Bt IR maize already shown to be effective in preserving yield in regions of Spain infested with pests susceptible to Bt toxin will provide a useful option for farms such as this one that rely on forage maize.

UK2

All-arable farm in the South-west of England

Background

Farm size	236 hectares
Number of years farming	56
Level of education	Agric-related further edu
Crops	Wheat, barley, maize
Main constraints on production	Soil quality, climate
General pest pressure	Moderate, severe
Would grow GM if available	Yes
Potential size of GM parcel	50 ha
Respectful of attitudes of neighbours, and bee keepers	Yes

This is an all-arable farm in Somerset, the owner is 74 years old, and works the farm himself with 4 full-time staff. The farm is partially south facing, and in those parts of the farm the soil is sufficiently warm in the spring for cultivation of grain maize. The maize is ripe by mid-October, when it is cut at 30-35% moisture, and sent for off-farm drying.

The farm grows wheat, barley and maize in rotation, and suffers moderate to severe pest pressure. 50 ha of maize are grown annually, all under contract.

Current financial situation

Data on typical crop input costs and gross margin for the crops grown on this farm in rotation is assumed to be as reported in Nix (2015); on harvesting of grain maize in southern England, Nix comments that it is dried to 15% for storage as a crimped product, with added preservative, and the drying and crimping costs amount to €40 - 56/t.

Herbicides are used to control weeds in wheat and barley, and additional pesticide sprays are required for the grain maize.

Table 1

Economic data for grain maize

	yield-kg/ha	seed-€/ha	sprays,€/ha	harvest-€/t
grain maize	7500	248.92	113.03	248.9
Bt grain maize	7500	281.94	55.88	248.9

data from Nix (2015) with £1 = €1.27

Bt maize data based on Gómez-Barbera et al (2008)

Financial impacts of GM options

The METE model was used to predict the gross margin for Bt IR grain maize cultivated in place of conventional maize, in rotation with wheat and barley, at three intensities of pest pressure, where two applications of pesticide are sufficient for mild pressure, but three applications are required for typical pressure, and a fourth application for severe pressure.

The predicted effect of adoption of Bt IR maize on gross margin per hectare at varying levels of pest pressure at this farm is shown in Table 2. The loss of yield under pest pressure is partially alleviated, and there are savings in cost of pesticide to offset the technology premium payable for the seed.

Table 2

Model outcomes for this farm: Bt IR vs conventional grain maize

conv/GM:	pest pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
OSR	mild	6.8	128	1,342	1214	
	typical	6.3	157	1,234	1077	
	severe	5.8	183	1,142	960	
HT OSR	mild	7.0	191	1,378	1187	-2.2
	typical	6.7	218	1,316	1098	2.0
	severe	6.4	239	1,251	1012	5.4

Non-pecuniary benefit

The need to spray crops with pesticide involves compliance with increasingly strict pesticide regulations, and removal of most of the need to spray the grain maize, enabled by the way Bt maize exudes its own toxin, is considered a significant non-pecuniary benefit.

This farmer expresses concern about the attitude of bee keepers. Bee keepers should be pleased if pesticide spraying becomes unnecessary, but some bee keepers are concerned for the reputation of their honey if traces of Bt toxin are detected.

Sensitivity to price and yield

Bt grain maize is of equivalent quality to conventional grain maize, and the removal of risk of pest damage provides insurance against insect spoilage of the stored product. In some markets, this would allow Bt maize to command a premium price. In the UK however, a residual unease about any form of GM tends to result in an opposite premium , obtainable for non-GM product. As shown in Table 3, a 5% price advantage for non-GM grain maize would remove almost all the advantage of pesticide savings at most levels of pest pressure.

Concluding comments

At the location of this farm, there is an opportunity to take advantage of good prices consistently available for growing grain maize under contract, replacing maize which mostly has to be imported. At the time of writing, the UK is free of threat to maize from the Western Corn Rootworm (Diabrotica virgifera virgifera) which affects maize yields in southern Europe. The pest is known to be spreading northwards (Wesseler and Fall, 2010) and global warming could accelerate the arrival of the pest in UK. Meanwhile, in current conditions, Bt IR maize offers only limited advantages if included in crop rotations at this farm.

UK3

Arable farm in the East of England growing all arable crops including sugar beet and oilseed rape (OSR)

Background

Farm size	240 hectares
Number of years farming	30
Level of education	University level education
Crops	Wheat, barley, OSR, sugar beet
Main constraints on production	Weeds and climate
General weed pressure	High
Would grow GM if available	Yes
Potential size of GM parcel	30 hectares for SB
Concerned about effects of GM on neighbours and bee-keepers	No

This is a reasonably large farm in Cambridgeshire on high quality grade 1 and 2 land. The farmer is around 50 years of age and has been farming at this location for about 30 years. The farm operates a five year rotation which is normally wheat, wheat, sugar beet, winter barley and oilseed rape. The overall arable area of the farm is 240 hectares of which about 10% each year is grown to sugar beet.

The farm is not ring fenced and thus the different parcels of land mean the farm has 11 immediate neighbours. This makes co-existence measures a challenge, although the owner does not have serious concerns about cross contamination with neighbours.

The main management issues the farm faces are in relation to high weed burdens and occasional summer drought. The latter requires irrigation of the sugarbeet in some years. The farmer would grow GM crops if allowed to help combat continued weed pressure. The main GM options that could be available in the near future are HT sugar beet and oilseed rape. The advent of drought tolerant GM varieties in the future could offer an additional benefit. The farmer is very positive about the adoption of GM if available and would adopt if available providing there was a clear market for the products.

Current financial situation

Data on typical farm seed and input costs per hectare at low, average and high production levels are published annually in the Farm Management Pocketbook (Nix, 2015). Prices achieved for crops in this region of England, together with associated fertiliser and crop protection costs are reported in the Farm Business Survey reports (FBS, 2014). The seed premium likely to be payable if the farm decides to adopt GM sugarbeet to fulfil their beet quota, together with associated fertiliser and reduction in cost of crop protection, have been inferred from reports of experience with GM beet cultivation in North America (Dillen et al, 2013).

The data from these sources is summarised in Table 1.

Table 1

Economic data for crops that may be cultivated in rotation

	yield-kg/ha	seed-€/ha	sprays,€/ha	harvest-€/t
winterwheat	8400	92.71	374.65	243.84
rape	3400	82.55	314.96	425.45
sugarbeet	70000	306.07	369.57	46.99
spring barley	5450	101.6	222.25	243.84
HT rape	3400	104.14	128.27	425.45
GM sugarbeet	70000	353.06	128.27	46.99

data from Nix (2015) with £1 = €1.27

HT rape data based on Smyth et al (2010)

HT sugarbeet data based on Dillen (2013)

Financial impacts of GM options

The METE model was used to predict the change in gross margin for an initial year in which the farm grows HT OSR in place of conventional OSR, or HT sugarbeet in place of conventional beet. The results are summarised in Table 2.

Table 2a

Model outcomes for HT OSR

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	crop value	margin	% change
conv beet	mild	2.8	155	931	776	
	typical	2.7	184	898	714	
	severe	2.5	220	854	634	
HT beet	mild	3.0	232	1,002	770	-0.8
	typical	2.9	240	974	734	2.8
	severe	2.8	257	928	671	5.8

Table 2b

Model outcomes for HT sugarbeet

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	sales	margin	% change
OSR	mild	62.9	92	2,326	2234	
	typical	57.0	184	2,110	1926	
	severe	52.2	249	1,931	1682	

HT OSR	mild	65.4	63	2,420	2356	5.5
	typical	61.4	112	2,270	2158	12.0
	severe	57.8	136	2,139	2002	19.1

Benefit carried forward

The model enables estimation of the further benefit that arises for the crop which follows GMHT sugarbeet, such as has been reported in places where herbicide-tolerant GM crops are in widespread cultivation, for example GM Canola in Canada (Brimner et al, 2005).

The model was used to predict the overall economic outcome for a rotation sequence:

sugarbeet/oilseed rape/winter wheat/spring barley

for two scenarios with HT OSR, with conventional sugarbeet replaced by HT sugarbeet in the second scenario. The economic outcome is shown in Table 3.

Table 3

Model outcomes winter wheat following HT OSR and HT beet+HT OSR

winter wheat	yield-t/ha:	extra yield (t/ha)	€/ha value at €175/t
normal rotation	7.47		
following HT OSR	7.68	0.206	36.05
following HT beet + HT OSR	7.81	0.338	59.15

Concluding comments

Given willingness of the farm to invest in GM technology, and assuming that any problem of coexistence with neighbouring farms can be accommodated, there is a reasonable probability that the farm will obtain a minor improvement in overall gross margin from adoption of HT OSR if available, and a larger advantage if permitted to adopt HT sugarbeet. If both HT crops are included in one rotation with winterwheat, then the resulting soil, largely weed free, will enable small increases in yield of winter wheat.

Non-pecuniary benefits may also be experienced. Farmers elsewhere have readily adopted GM technology because it makes farm management easier, and also reduces overall environmental impacts (May et al, 2005); furthermore, it provides a form of insurance against severe losses in years when there is exceptional weed pressure.

UK4

Arable farm in the East of England growing all arable crops including oilseed rape (OSR)

Background

Farm size	400 hectares
Number of years farming	15
Level of education	Agric-related univ degree
Crops	Wheat, barley, OSR
Main constraints on production	Pests, then weeds
General weed pressure	High
Would grow GM if available	Yes
Potential size of GM parcel	100 ha
Would change plans to avoid conflict with neighbour	Yes

This is a 400 ha all-arable farm in Norfolk, with 3 full-time staff. The farm operates a four year rotation which is normally wheat, second wheat, OSR, barley, with 100ha of OSR grown each year under contract.

The farm has 3km of border with 7 immediate neighbours.

The main GM option that could be available in the near future is HT oilseed rape. The farmer is very positive about the adoption of GM if available and would adopt if available providing there was an amicable arrangement with neighbouring farms.

Current financial situation

Data on costs and prices affecting gross margin in UK for wheat, barley and OSR is available from the Farm Management Pocketbook (Nix, 2015), are summarised in Table 1. In order to estimate the performance of GMHT oilseed rape in UK, data was extrapolated from data for spring canola in Brookes and Barfoot (2014); winter OSR grown in UK is not directly equivalent to spring canola as grown in Canada, but Brookes and Barfoot, in commenting on the Canadian crop, noted that processors were prepared to pay a small premium for the convenience of having fewer weeds in the harvested consignments. For this study we assume initially that conventional and GM OSR would command the same price in the UK market.

Table 1

Economic data for crops that may be cultivated in rotation

	yield-kg/ha	seed-€/ha	sprays,€/ha	harvest-€/t
winterwheat	8400	92.71	374.65	243.84
rape	3400	82.55	314.96	425.45
sugarbeet	70000	306.07	369.57	46.99
spring barley	5450	101.6	222.25	243.84
HT rape	3400	104.14	128.27	425.45
GM sugarbeet	70000	353.06	128.27	46.99

data from Nix (2015) with £1 = €1.27

HT rape data based on Smyth et al (2010)

HT sugarbeet data based on Dillen (2013)

Financial impacts of GM option

The METE model was used to predict the gross margin for an initial crop of GMHT OSR cultivated in place of conventional OSR, at three intensities of weed pressure. The results are summarised in Table 2.

Table 2

Model outcomes for HT OSR

conv/GM:	weed pressure:	yield-t/ha:	€/ha			
			variable costs	crop value	margin	% change
conv beet	mild	2.8	155	931	776	
	typical	2.7	184	898	714	
	severe	2.5	220	854	634	
HT beet	mild	3.0	241	1,012	771	-0.6
	typical	2.9	252	985	733	2.7
	severe	2.8	257	928	671	5.8

Concluding comments

Given willingness of the farm to invest in GM technology, and assuming that any problem of coexistence with neighbouring farms can be accommodated, there is a reasonable probability that the farm will obtain an improvement in overall gross margin, and non-pecuniary benefits may also be experienced.