The potential economic and environmental impact of using current GM traits in Ukraine arable crop production

Briefing document

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Executive summary

This paper examines the potential economic and environmental impacts of using current commercialised crop biotechnology in Ukraine.

It draws on the wide body of literature that has examined these issues globally and uses this evidence as the primary base for assessing potential impacts in Ukraine relative to current conventional production systems.

The specific biotech traits examined in the paper are:

- Herbicide tolerant (GM HT) and novel hybrid (higher yielding) oilseed rape;
- Herbicide tolerant soybeans;
- Herbicide tolerant sugar beet;
- Herbicide tolerant maize;
- Insect resistant (GM IR) maize (to corn boring and/or corn rootworm pests).

Farm levels economic impacts (see section 3)

Based on the impacts identified in countries that currently use these GM technologies and applying these to local conditions and practices in Ukraine, Table 1 summarises the potential impacts of each trait and crop combination. In almost all cases, the adoption of GM technology is likely to result in a net increase in the levels of profitability for adopting farmers.

The precise level of impact will vary by farm, location, year, and the extent to which farmers suffer from weed and pest problems. In general, more intensive producers, which tend to have above average yields, use the latest seed, crop protection and husbandry practices are likely to gain mainly from reduced costs of production (less expenditure on crop protection), although yield improvements are also likely to occur. For the majority, more extensive producers,[1] the main benefit from using GM technology is likely to be higher yields.

Table 1: Summary of likely farm level economic impacts of using GM technology in Ukraine ($/ha)

	Yield impact % change	Seed premium	Cost of crop protection	Impact on profitability	% change in profitability
GM HT oilseed rape (tolerant to glyphosate)	+3 to +12	+18	-11 to -22	+14 to +108	+2.7 to +21
GM HT oilseed rape (tolerant to glufosinate)	+10 to +12	+18	+18 to +55	+37 to +76	+7.2 to +14.8
GM HT soybeans	+5 to +15	+15 to +20	-23 to -26	+47 to +111	+11.3 to +26.9
GM HT sugar beet	+3 to +15	+50 to +140	-94 to -104	+8 to +322	+1 to +40
GM HT maize	Zero to +5	+20 to +25	-8 to -28	+35 to +60	+6.8 to +11.7
GM IR maize (targeting corn boring pests)	+10	+41	-12 to -25	+67 to +80	+13 to +16.4

[1] And, which tend to have lower yields and spend less on inputs such as seed and crop protection than intensive producers

GM IR maize (targeting corn rootworm)	+9 to +28	+32	Zero	+68 to +126	+13.6 to +25.2

Notes: negative sign denotes decrease in value (of costs) and positive sign denotes increase in profits or costs (seed premium)

As well as these quantifiable direct impacts on farm profitability, there have been other important, indirect impacts that are more difficult to quantify (eg, facilitation of adoption of reduced/no tillage systems, reduced production risk, convenience, reduced exposure of farmers and farm workers to pesticides, improved crop quality). These less tangible benefits have often been cited by GM adopting farmers as having been important influences for adoption of the technology. These benefits are equally likely to be derived by farmers in Ukraine if they use the technology.

National level economic impacts (see section 4)
Based on the farm level benefits summarised above, Table 2 summarises the likely economic impacts at the national level from the use of current commercialised GM technology. The assumptions used for the possible adoption levels in Ukraine are based on, for HT traits, adoption levels in countries that currently use the technology and, for IR traits in maize, limited to the areas typically experiencing economic levels of pest damage in Ukraine. Overall, the total annual potential farm level benefit to Ukraine from using relevant, current GM technology in Ukraine is up to $525 million.

Table 2: Potential annual national level farm economic benefits of using current GM technology ($ million)

	50% adoption	Maximum adoption
GM HT oilseed rape (to glyphosate) OR GM HT oilseed rape (tolerant to glufosinate)	6.4 to 49.1 Or 16.8 to 34.6	11.5 to 88.4 Or 30.3 to 62.2
GM HT soybeans	28.0 to 66.0	50.3 to 118.9
GM HT sugar beet	29.7 to 88.5	53.5 to 159.4
GM HT maize	46.3 to 79.4	64.9 to 111.2
GM IR maize targeting corn boring pests	26.8 to 32.0	33.5 to 40.0
GM IR maize targeting corn rootworm	1.4 to 2.8	3.4 to 7.0
Total	**138.6 to 317.8**	**217.1 to 524.9**

Notes:

1. 50% adoption relates to GM HT crops. For GM IR maize targeting corn boring pests = 0.4 million ha and for GM IR maize targeting corn rootworm = 20,000 ha
2. Maximum adoption based on:

- GM HT soybeans, oilseed rape and sugar beet: 90%
- GM HT maize: 70%
- GM IR maize targeting corn boring pests 0.5 million ha
- GM IR maize targeting corn rootworm: 50,000 ha

As indicated in Table 1, yield gains are likely to arise with the adoption of GM technology. Based on these yield gains and applying them to the two adoption scenarios referred to above, this suggests that production levels of each crop in Ukraine are likely to increase (Table 3).

At the lower levels of area adoption and yield benefit assumptions, there is likely to be a +0.9 million tonnes increase in production of the four crops, equal to +1.5% of the total production of the four crops (range of +1.1% to +2.5% by crop). At the higher levels of area adoption and yield benefit assumptions, a more significant potential annual production benefit of +3.2 million tonnes would arise, equal to 9.5% of total production of the four crops (range of +4% to +15.7% by crop).

Table 3: Potential annual production impacts of using GM technology in Ukraine ('000 tonnes)

	Lowest area adoption and yield impacts	Highest area adoption and yield impacts	% change in total production: lowest impact	% change in total production: highest impact
Soybeans	+48.2	+260.3	+2.5	+13.7
Maize	+188.5	+663.8	+1.1	+4.0
Oilseed rape	+23.2	+167.1	+1.5	+11.1
Sugar beet	+230.7	+2,076.8	+1.7	+15.7

Environmental impact from changes in insecticide and herbicide use (see section 5)
To examine this impact, the study analysed both active ingredient use and utilised the indicator known as the Environmental Impact Quotient (EIQ) to assess the broader impact on the environment, including impact on animal and human health. The EIQ distils the various environmental and health impacts of individual pesticides in different GM and conventional production systems into a single 'field value per hectare' and draws on key toxicity and environmental exposure data related to individual products. It therefore provides a better measure to contrast and compare the impact of various pesticides on the environment and human health than weight of active ingredient alone. Readers should, however, note that the EIQ is an indicator only and does not take into account all environmental issues and impacts. In the analysis of GM HT technology we have assumed that the conventional alternative delivers the same level of weed control as occurs in the GM HT production system.

Table 4 summarises the potential annual changes to herbicide use if current GM HT technology was used in Ukraine. This suggests at the lower level of area adoption, total herbicide active ingredient use across the four crops would fall by between 4.4% and 6.1% (about 0.24 million to 0.33 million kg), with a higher 14.8% to 15.3% decrease in the EIQ value. At the higher levels of adoption that are similar to levels of adoption in current countries using these technologies, the likely fall in total active ingredient use across the four crops is -7.1% (almost -0.39 million kg) to -7.8% (-0.42 million kg). In terms of the associated environmental impact as measured by the EIQ indicator, this would fall by about 24%.

Table 4: Likely annual changes in herbicide use and associated environmental impact of using GM HT technology in Ukraine across the four crops (% change)

	Active ingredient change (kg)	Active ingredient change (% change)	Field EIQ value change
Lower adoption	-237,079 to -333,539	-4.4 to -6.1	-14.8 to -15.3
Higher adoption	-387,049 to -424,107	-7.1 to -7.8	-23.7 to -24.6

Any change in insecticide use associated with the adoption of GM IR technology in maize will be limited because only a relatively small area of conventional maize has traditionally received insecticide treatments targeting corn boring pests (about 100,000 ha annually). On the basis that GM IR (targeting corn boring pests) technology would allow these treatments to stop, the annual saving in insecticide use would be about 23,000 kgs of insecticide active ingredient. As there is no history of using insecticides for the treatment of corn rootworm pests, the adoption of GM IR technology targeting corn rootworm would not result in any insecticide savings relative to current usage patterns.

Environmental impact from changes in greenhouse gas emissions (see section 5)
The scope for biotech crops contributing to lower levels of GHG emissions comes from two principal sources. First, biotech crops contribute to a reduction in fuel use due to less frequent herbicide or insecticide applications and a reduction in the energy use in soil cultivation.

In addition, there has been a shift from conventional tillage to no tillage production systems (NT) facilitated by GM HT technology. In the context of Ukraine, however, NT production systems are not widely practiced. One important factor behind this relates to the lack of suitable machinery and equipment for practicing NT production systems and the lack of capital with which to fund such equipment. As such, whilst GM HT technology has facilitated the adoption of NT production systems in North and South America, it is unlikely to perform a similar role in Ukraine in the next few years (if the technology was allowed for commercial use) because of these problems.

For the purposes of this paper, it is assumed that GM HT technology would not contribute to any change from a plough/tillage to a NT production system in Ukraine arable crop production systems or result in any associated fuel savings from changes in tillage systems used. Hence, the GHG emission savings summarised below are solely attributed to savings in fuel use associated with reduced incidence of herbicide and insecticide spraying.

The potential annual fuel savings from the adoption of GM technology in Ukraine at the lower level of area adoption is about 0.78 million litres of fuel, equal to a saving of 2.73 million kg of carbon dioxide. At the higher level of adoption, the potential annual fuel and carbon dioxide savings would reach 1.56 million litres of fuel and 5.35 million kgs of carbon dioxide (equivalent of taking 2,200 cars off the road for a year).

1 Introduction

1.1 Background

No genetically modified (GM) crops are currently legally permitted for planting in the Ukraine, although it is known[2] that a significant proportion of the soybean crop illegally uses GM herbicide tolerant (GM HT) technology, and there are possibly small areas illegally planted using GM insect resistance (GM IR) technology to control lepidopteran pests (eg, European corn borer (ECB)) in maize. The Ukraine is, however, a country in which the scope for using new technology in crop production systems is enormous, given the large areas devoted to arable crops and the current low levels of productivity achieved relative to production systems in western agricultural economies. The availability and adoption of GM technology therefore offers considerable potential for the arable cropping sector in the Ukraine to make rapid technological and productivity advances, if farmers were permitted access to these products.

1.2 Objectives

This paper explored the potential economic and environmental impacts/benefits that might be deliverable from the commercial adoption of existing GM technology in Ukraine. It examined both the farm level and the national (aggregated) level impacts. The environmental impacts examined were changes in pesticide use and impacts on greenhouse gas (carbon) emissions.

It examined the following crop and trait issues:

- Soybeans, maize, oilseed rape/canola and sugar beet: (HT);
- Maize: insect resistance (IR: targeting ECB and corn rootworm pests)

The research was based on a combination of in-country data collection, desk research and analysis[3].

1.3 Structure

The report is structured as follows:

- Section 1: introduction (this section)
- Section 2: Production base of relevant crops
- Section 3: Farm level economic costs and benefits of using GM technology
- Section 4: Potential national level economic impacts
- Section 5: Environmental impacts (focusing on changes in pesticide use and greenhouse gas emissions)

[2] Sources: industry observers and analysis of glyphosate use on soybeans

[3] The authors also acknowledge assistance in data collection from Dr O Novozhylov, Dr T Novak and Dr S Tribel

2 Production base of relevant arable crops

2.1 Area planted

The agricultural sector is an important part of the Ukraine economy accounting for over 8% of Gross Domestic Product (GDP) in 2010[4]. In 2009, the utilised agricultural area in Ukraine was about 41.1 million hectares (ha)[5], of which 32.47 million ha was arable land.

Within the total arable area, the four crops examined in detail in this paper accounted for nearly 17% of the total area in 2011 (Table 5).

Table 5: Area harvested to key crops: Ukraine 2009 and 2011 ('000 ha)

Crop	2009	2010	2011 (provisional)
Maize	2,089	2,648	2,869
Oilseed rape	1,014	863	910
Soybeans	623	1,037	1,190
Sugar beet	322	492	550
Total: 4 crops	**4,048**	**5,040**	**5,519**

Sources: State Statistics Committee of Ukraine, United States Department of Agriculture (USDA)

The area planted to these crops has, in general, increased in recent years. Whilst the oilseed rape area fell between 2009 and 2011, it is expected to have recovered by the time of the 2012 harvest to an area similar to the 2009 level.

Currently, no GM crops are legally approved for commercial sale or planting in Ukraine. However, GM HT soybeans have been grown illegally for several years since first commercialised in neighbouring Romania in 1999. Currently, 20% to 30% of Ukraine's soybeans are estimated to be illegally planted seed containing GM HT technology. It is likely that a small area of GM IR maize is also planted (illegally) with seed smuggled from the neighbouring Czech and Slovak Republics.

2.2 Profitability

The changes in the area planted to the four crops largely reflect changes in profitability of the crops (Table 6) and their levels of profitability relative to alternative grains and oilseeds. More specifically, maize has consistently been the most profitable cereal[6], with oilseed rape and soybeans being fairly profitable break (rotational) crops. The profitability of sugar beet has also improved in recent years largely due to increases in the price of sugar.

Table 6: Average gross margin profitability 2010/11 ($/hectare)

	Oilseed rape	Soybeans	Maize	Sugar beet
Price ($/tonne)	538	450	215	64
Yield (tonnes/ha)	1.7	1.62	4.51	27.97

[4] Inclusive of the agri-food processing sector and input sectors, this proportion of GDP increases to over 17% (source: World Bank. www.worldbank.org/data)
[5] The share of total land area as utilisable agricultural area (UAA) was 71%
[6] The next best profitable cereal in 2010/11 was wheat with a gross margin of about $350/ha

Revenue	915	729	970	1,790
Variable costs				
Seed	34	64	125	170
Fertiliser	172	124	132	275
Crop protection	68	47	57	177
Labour	19	55	26	27
Machinery	109	26	118	338
Total variable cost	402	316	458	987
Base variable costs	274	235	314	622
Gross margin	**513 (723)**	**413 (654)**	**512 (815)**	**803 (587)**
Base gross margin	**641 (876)**	**494 (777)**	**656 (1,019)**	**1,168 (233)**

Sources: Ukragroconsult, Kleffmann, Gfk Kynetec

Note: Bracketed figures = 2008/09 margins

2.3 Usage

Table 7 summarises the supply balances for each of the four crops. Key points to note are:

- *Oilseed rape*: Ukraine is self-sufficient in supply and use of this crop. Only about 5% of the crop is used domestically with the vast majority of production exported. The main export markets in 2010/11 were the EU and Turkey;
- *Soybeans*: as with oilseed rape, Ukraine is self-sufficient in the supply and domestic use of soybeans. About half of domestic production is exported, with the EU, Egypt, Turkey and Russia being the main markets;
- *Maize*: this is also a crop for which exports are a key market, accounting for just over 60% of total supply in 2010/11. The main export markets are Egypt, the EU, Syria, Libya, Israel and Iran. In relation to domestic use, 88% is used as animal feed, with the balance used as human food and industrial uses;
- *Sugar beet*: domestic sugar beet production supplies about 80% of total sugar used in Ukraine. Exports account for only about 5% of total supply usage. All domestic usage is for human consumption.

Table 7: Supply balance 2010/11 ('000 tonnes)

	Oilseed rape	Soybeans	Maize	Sugar
Opening stocks	70	10	450	80
Domestic production	1,500	1,900	16,700	1,685
Imports	5	0	5	370

Total supply	1,575	1,910	17,155	2,135
Uses				
Exports	1,400	1,000	10,555	109
Crushing	80	800	Not relevant	Not relevant
Domestic use (as whole for oilseeds)	0	80	6,100	1,900
Closing stocks	95	30	500	126

Sources: Oil World, State Statistics Committee of Ukraine, USDA

Notes: Sugar production is raw sugar from 13.25 million tonnes of sugar beet. Sugar imports are comprised of 0.25 million tonnes of raw sugar and 0.12 million tonnes of refined sugar. Sugar exports as refined sugar. Domestic usage is entirely for human consumption

2.4 Conventional pest and weed control

This sub-section briefly considers the nature of conventional pest and weed control in the four crops, focusing only on the pest and weeds that might alternatively be controlled by current commercialised GM technology.

2.4.1 Maize

Ukraine farmers spent nearly $100 million on maize crop protection products in 2010/11. Within this market, herbicide use dominates, accounting for 95% of all of the maize area sprayed with crop protection products. The remaining spray area is accounted for by insecticides.

Corn boring pests

The lepidopteran pest *Ostrinia nubilalis* (European corn borer (ECB)) is a major maize pest in Ukraine. Whilst the incidence and impact of ECB infestation varies significantly by region and year, is influenced by local climatic conditions, use of insecticides and planting times (eg, early planted crops are usually better able to withstand attacks relative to later plantings), typically between 0.4 million ha and 0.5 million ha (15% to 19% of the 2011 crop area) of maize is annually affected by the pest to levels that cause 'economic damage'[7]. The areas worst affected are usually Donetsk, Zaporizhzhya, Ivano-Frankivsk, Kyiv, Lugansk, Poltava, Ternopil, and Chernivtsi regions.

Maize farmers generally have one of three approaches to dealing with ECB pest problems. One is having no active policy of treatment (ie, they take no crop protective action). This approach tends to be a fairly common one (both in Europe and worldwide) because ECB pest pressure varies and hence in some years damage may be limited. Crop protection strategies (see below) have also tended to be limited because many farmers perceive that insecticides have limited effectiveness:

- They may control ECB larvae on the surface of maize plants at the time of spraying but are less effective against larvae that have bored into stalks;
- Egg-laying can occur over a three week period and most insecticides are only effective for 7 to 10 days;

[7] Although data from Golovderzhzakhyst shows that in recent years between 65% and 87% of the total crop has shown presence of ECB populations

- Some farmers probably do not appreciate the level of damage to yields inflicted by the ECB. This is highlighted in surveys of farmers using GM IR technology), where some have indicated that it was only after using this technology that they fully realised the adverse impacts of ECB (see for example, Brookes, 2003 relating to Spain).

The other two conventional approaches involve either the use of insecticides or biological control methods (consisting of the release of the parasitic wasp *Trichogramma).* In Ukraine, data from Golovderzhzakhyst show that in recent years about 18%-19% of the total maize crop has typically been subject to some form of crop protection strategy for pest control and within this, 85%-100% (average 90%) has used *Trichogramma*[8].

The cost of these treatments varies according to which insecticides are used and the method of application (by sprayer or by air). In 2011/12, insecticide treatments were in a range of about $12/ha to $25/ha[9] based on one treatment per crop and about $25/ha for Trichogramma (source: industry).

As indicated above, there is fairly widespread perception and acceptance that these forms of pest control have limited effectiveness (eg, analysis in Poland by Berés and Lisowicz (2005) estimated that insecticides delivered between 62% and 89% levels of efficacy and *Trichogramma* between 57% to 59% efficacy).

Drawing on data from the National Academy of Agrarian Sciences of Ukraine, the loss of maize yield from the damage caused by the ECB is typically in a range of 6% to 25%, and during bad infestations, the yield losses can be as high as 50%. These levels of yield loss are consistent with losses experienced in other countries. For example, in Spain, the ECB related yield losses typically fall within a range of 5% to 15% for crops treated with conventional control measures (insecticides), 10% to 20% for crops for which no active crop protection strategy is used and in years of major infestations, the yield losses can be between 30% and 50% (Brookes (2003)).

Corn rootworm

Western corn rootworm (D*iabrotica virgifera: CRW)* is a fairly recent pest in Europe and was first identified in Ukraine in 2001, in the Zakarpattya region. Since then the area affected has spread each year to additional regions including Ivano-Frankivsk, Lviv and Ternopil. In 2009, the area affected by this pest was estimated to be about 18,000 ha and by 2011, this had increased to between 25,000 ha and 50,000 ha.

Given the relative recent history of this pest, there is limited experience of using control measures, notably soil insecticides and/or seed treatments. Therefore all of the area affected by CRW in Ukraine probably receives no form of chemical pest control.

The impact of CRW on maize yield can be substantial and in extreme cases can result in yield losses of up to 80%. Ultimately the level of yield loss depends on the level of infestation and the degree of control measure efficacy. In the US, where a combination of rotation and widespread use of soil insecticides on 20%-30% of the total crop (prior to the availability of GM IR maize with resistance to this pest) has occurred, yield losses have tended to be in the range of 9% to 28% relative to rootworm affected crops subject to no crop protection measures and about 5% relative to affected crops treated conventionally with soil insecticides (Alsten et al (2003) and Mitchell (2002).

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[8] In 2011, about 100,000 ha of maize were treated with insecticide, mostly targeted at corn boring pests with about 400,000 ha treated with Trichogramma

[9] Inclusive of the cost of spraying – the cost of insecticide being about $5/ha

Weed control

Weeds are a major problem facing all arable crop production in Ukraine. Husbandry practices to deal with weed problems vary by crop across regions of Ukraine and according to the extent of problems. In general, the most common form of weed control practiced is the use of herbicides that may be applied either pre-emergence, post-emergence or a combination of both pre and post emergence.

In relation to conventional weed control methods in the Ukraine maize crop, the key features are as follows:

- There is a mix of important weeds of maize (Table 8);
- About 90 % of the total crop typically receives at least one herbicide treatment per year. In other words 10% uses mechanical/hand weeding or no form of weed control;
- Both pre- and post-emergent herbicides are used, with some farmers using only pre-emergence, some using only post-emergence and some using both pre- and post-emergence. Post-emergent herbicides dominate usage accounting for about 60% of usage by weight of product applied;
- The main active ingredients used are a mix of foramsulam, iodosuluron-methyl sodium and isoxadifen ethyl, acetochlor, rimsulfuron and nicosulfuron. The acetochlor is mostly applied pre-emergence;
- The average number of treatments per crop is between 1.3 and 1.4;
- Average expenditure on herbicide per ha (2010-2011) is between $33/ha and $36/ha, with herbicides typically accounting for 90%-95% of total crop protection expenditure;
- The average amount of herbicide active ingredient used per ha is about 1kg/ha to 1.1 kg/ha.

Table 8: Main weeds of maize in Ukraine

Grass	Annual	Perennial
Setaria spp	Chenopodium	Cirsiun
Echinichloa spp	Amaranthus	Sonchus spp
Agropirum repens	Brassicas	Convolvulus spp
	Volunteer sunflower	
	Ambrosia	

2.4.2 Oilseed rape

Crop protection practices in oilseed rape comprise the use of herbicides for weed control, fungicides for fungal control and insecticides for various forms of pest control. Fungicides and herbicides account for about 35% each of the total area treated with crop protection products, with fungicides accounting for about 20% of total usage.

Weed control

As indicated above, weeds are a significant problem for growers of oilseed rape. More specifically:

- About 80 % of the total crop typically receives at least one herbicide treatment per year, with 20% of the crop either applying mechanical/hand weeding;
- Both pre- and post-emergent herbicides are used in winter oilseed rape though most herbicide is applied post-emergence (75%-80% of total usage by product weight);

- The main active ingredients used on winter oilseed rape are a mix of clopyralid and picloram, metolachlor, fluazifop, quizalofop, haloxfop and clomazone. Clomazone is mostly applied pre-emergence, with the others, post-emergence. For spring oilseed rape, post-emergence herbicides account for the vast majority of usage. The main active ingredients used are a mix of clopyralid and picloram, metolachlor and imaxamox mix, fluazifop and quizalofop;
- The average number of treatments per crop is between 1.0 and 1.1;
- Average expenditure on herbicide per ha (2010-2011) is between $27/ha and $31/ha, with herbicides typically accounting for only 30% of total crop protection expenditure (the largest category being insecticides);
- The average amount of active ingredient used per ha is about 0.63kg/ha for winter oilseed rape and about 0.5 kg/ha for spring oilseed rape.

2.4.3 Soybeans

Weeds cause significant problems for soybean farmers, with herbicides accounting for 90% of total crop protection product use on the crop. The balance is accounted for by insecticides and fungicides.

In relation to herbicide use:

- 80% of the crop usually receives at least one herbicide treatment;
- The main herbicide active ingredients used on soybeans are bentazon, thifensulfuron, quizalofop, glyphosate and metolachlor. Most of these are applied post emergence, accounting for about 90% of applications by product weight;
- The average number of herbicide treatments per crop is between about 1.3 and 1.5;
- Average expenditure on herbicides in 2010/11 was about $38/ha, with herbicides accounting for about 95% of total crop protection expenditure;
- The average amount of herbicide active ingredient used per ha is 1.44 kg/ha.

2.4.4 Sugar beet

Weed control is also the main problem faced by growers of sugar beet, with herbicides typically accounting for 75% to 80% of total use of crop protection products. In relation to herbicide use:

- Almost all of the sugar beet crop (97%-98%) receives at least one herbicide treatment;
- The main active ingredients used are desmedipham, ethofumesate and phenmedipham (mix), clopyralid, thifensulfuron, metamitron and quizalofop;
- Both pre and post emergent herbicides are used, with post emergence use dominating (85% plus of area sprayed);
- The average number of herbicide applications per crop is between 2.8 and 3.0;
- Herbicides account for about 90% of total crop protection expenditure;
- The average expenditure on herbicides in 2010/11 was between $130/ha and $150/ha. There is, however, a broad range around this average, with intensive producers typically spending over $250/ha on herbicides, compared to extensive producers which spend about $100/ha;
- Average active ingredient use in 2011 was about 1.66 kg/ha.

3 Farm level economic costs and benefits of using GM technology

3.1 Global direct economic impacts

Although the first commercial GM crops were planted in 1994 (tomatoes), 1996 was the first year in which a significant area of crops containing GM traits were planted (1.66 million hectares). Since then there has been a dramatic increase in plantings and by 2011, the global planted area reached over 160 million hectares. This is equal to about 4 times the total utilised agricultural area of Ukraine or 5 times the Ukraine area devoted to arable crops.

In terms of the share of the main crops in which GM traits have been commercialised (soybeans, maize, cotton and oilseed rape), GM traits accounted for 42% of the global plantings to these four crops in 2010.

In 2010[10], the direct global farm income benefit from using GM crops was $14 billion (Table 9). This is equivalent to having added 4.3% to the value of global production of the four main crops of soybeans, maize, oilseed rape and cotton. Since 1996, farm incomes have increased by $78.4 billion.

The largest gains in farm income in 2010 have arisen in the cotton sector, largely from yield gains. The $5 billion additional income generated by GM insect resistant (GM IR) cotton in 2010 has been equivalent to adding 14% to the value of the crop in the GM growing countries, or adding the equivalent of 11.9% to the $42 billion value of the global cotton crop in 2010.

Substantial gains have also arisen in the maize sector through a combination of higher yields and lower costs. In 2010, maize farm income levels in the GM adopting countries increased by almost $5 billion and since 1996, the sector has benefited from an additional $21.6 billion. The 2010 income gains are equivalent to adding 6% to the value of the maize crop in these countries, or 3.5% to the $139 billion value of total global maize production. This is a substantial increase in value added terms for two new maize seed technologies.

Significant increases to farm incomes have also resulted in the soybean and oilseed rape sectors. The GM HT technology in soybeans has boosted farm incomes by $3.3 billion in 2010, and since 1996 has delivered over $28 billion of extra farm income (the highest cumulative increase in farm income of the GM traits). In the oilseed rape sector (largely Canada and the US) an additional $2.7 billion has been generated (1996-2010).

In terms of the division of the economic benefits obtained by farmers in developing countries relative to farmers in developed countries, in 2010, 54.8% of the farm income benefits have been earned by developing country farmers. The vast majority of these income gains for developing country farmers have been from GM IR cotton and GM HT soybeans. Over the fifteen years, 1996-2010, the cumulative farm income gain derived by developing country farmers was 50% ($39.24 billion).

Examining the cost farmers pay for accessing GM technology across the four main GM crops, the total cost in 2010 was equal to 28% of the total technology gains (inclusive of farm income gains plus cost of the technology payable to the seed supply chain[11]).

[10] Latest year for which estimates are available

[11] The cost of the technology accrues to the seed supply chain including sellers of seed to farmers, seed multipliers, plant breeders, distributors and the GM technology providers

For farmers in developing countries the total cost was equal to 17% of total technology gains, whilst for farmers in developed countries the cost was 37% of the total technology gains. Whilst circumstances vary between countries, the higher share of total technology gains accounted for by farm income gains in developing countries relative to the farm income share in developed countries reflects factors such as weaker provision and enforcement of intellectual property rights in developing countries and the higher average level of farm income gain on a per hectare basis derived by developing country farmers relative to developed country farmers.

Table 9: Global farm income benefits from growing GM crops 1996-2010: million US $

Trait	Increase in farm income 2010	Increase in farm income 1996-2010	Farm income benefit in 2010 as % of total value of production of these crops in GM adopting countries	Farm income benefit in 2010 as % of total value of global production of crop
GM herbicide tolerant soybeans	3,299.8	28,389.2	3.5	3.2
GM herbicide tolerant maize	438.5	2,672.8	0.5	0.3
GM herbicide tolerant cotton	148.3	1,062.4	0.4	0.3
GM herbicide tolerant oilseed rape	472.4	2,657.8	5.7	1.4
GM insect resistant maize	4,522.3	18,969.3	5.4	3.2
GM insect resistant cotton	5,030.1	24,371.9	14.0	11.9
Others	90.2	301.5	Not applicable	Not applicable
Totals	**14,001.6**	**78,424.9**	**6.25**	**4.3**

Notes: All values are nominal. Others = Virus resistant papaya and squash and herbicide tolerant sugar beet. Totals for the value shares exclude 'other crops' (ie, relate to the 4 main crops of soybeans, maize, oilseed rape and cotton). Farm income calculations are net farm income changes after inclusion of impacts on yield, crop quality and key variable costs of production (eg, payment of seed premia, impact on crop protection expenditure)

As well as these quantifiable direct impacts on farm profitability, there have been other important, indirect impacts that are more difficult to quantify (eg, facilitation of adoption of reduced/no tillage systems, reduced production risk, convenience, reduced exposure of farmers and farm workers to pesticides[12], improved crop quality: see section 3.3). These less tangible benefits have often been cited by GM adopting farmers as having been important influences for adoption of the technology. This suggests that the farm income benefits quantified above are conservative.

In relation to the nature and size of GM technology adopters, there is clear evidence that farm size has not been a factor affecting use of the technology. Both large and small farmers have adopted GM crops. Size of operation has not been a barrier to adoption. In 2011, 16.7 million farmers were using the technology globally, 90% of which were resource-poor farmers in developing countries.

3.2 Possible direct farm level impact of using existing commercialised GM technology in Ukraine arable crops

This section examines the possible impact of using crop biotechnology in the Ukraine arable cropping sector. The research concentrates on the main arable crops for which GM traits that are currently widely used in global agriculture could be utilised in Ukraine. The relevant traits are:

- Herbicide tolerant and novel hybrid (higher yielding) oilseed rape;
- Herbicide tolerant soybeans;
- Herbicide tolerant sugar beet;
- Herbicide tolerant maize;
- Insect resistant maize (to corn boring and/or corn rootworm pests).

These are examined further in the sub-sections below. Readers should note that all analysis presented relates to commercial farms and that Ukraine farmers are able to make choices as to whether to plant varieties containing GM traits according to technical and agronomic performance criteria and market requirements. Hence, the analysis assumes that any co-existence conditions that might be attached to the planting of GM crops in Ukraine are based on sound scientific principles, are practical and are proportionate.

3.2.1 GM HT and hybrid vigour oilseed rape

a) Commercial experience

Commercial experience of this technology goes back to 1996 in Canada, 1999 in the US and 2008 in Australia, and relates to use in spring oilseed rape ('canola'). Impact on yield varies with local conditions but in general:

- the 'InVigor' hybrid vigour canola (tolerant to the herbicide glufosinate) has delivered higher yields in excess of +10% relative to conventional canola;
- the glyphosate tolerant canola (not containing GM-derived hybrid vigour) has resulted in some yield gains via improved weed control. The yield gains have tended to be in the range

[12] Reduced exposure to pesticides being particularly important in developing countries where most pesticides are applied by hand and workers (often women and children) frequently have access to no protective clothing and little or no training and equipment

of zero to +6% (relative to conventional alternatives, of which the main current alternative is conventional ('Clearfield') herbicide tolerant canola).

Overall, during the period that this technology has been used by farmers, the average yield gain (inclusive of hybrid vigour and better weed control) across all of the GM HT area for the period 1996-2010 has been +7%.

In terms of impact on costs of production, the technology has generally provided for reduced weed control costs. In the last few years, this has been equal to between $60/ha and $65/ha for glyphosate tolerant canola and $18/ha to $21/ha for glufosinate tolerant canola in Canada and the US. In Australia, the average weed control cost saving has also been about $20/ha. The use of the GM HT technology has, however, increased seed costs by about $17/ha to $20/ha in Canada and the US, and by about $30/ha in Australia.

Overall, the impact on net profitability, after taking into consideration impacts on yield, changes to weed control costs and the seed premium (for the technology) has been positive but variable (Table 10). Across the three countries using the technology, the average farm income gain in 2010 was $70/ha and over the period 1996-2010 the average net farm income gain has been $48/ha.

Table 10: Overall farm income gains from using GM HT canola: $/ha)

Country	Average farm income gain (in last 5 years)
US	Glyphosate tolerant $45/ha to $55/ha Glufosinate tolerant 'InVigor' $75/ha to $85/ha
Canada	Glyphosate tolerant $11/ha to $20/ha Glufosinate tolerant 'InVigor' $100/ha to $130/ha
Australia	$60/ha to $90/ha

Source: Brookes and Barfoot (2011)

b) Potential impact in Ukraine

Change in production costs

In 2011, the average expenditure on oilseed rape crop protection in Ukraine was about $68/ha, of which $27/ha to $30/ha is accounted for by herbicides[13]. This typically involved the application of herbicides in one pass/treatment during the growing season (average 1.1 treatments) of a tank mix of active ingredients.

In the US and Canada, farmers using GM HT (to glyphosate) technology have tended to switch to the application of one spray run per crop of 1-2 litres of glyphosate/ha (0.48 kg ai/ha to 0.96 kg ai/ha). The adoption of similar practices in Ukraine if GM HT technology was used would result in the average cost of herbicides (at current prices) falling to between $11/ha and $22/ha. This would effectively reduce average crop protection costs to between $49/ha and $63/ha.

Farmers using GM HT (to glufosinate) technology in Canada and the US typically use between 2 and 3 litres of glufosinate (0.24 kg ai/ha to 0.36 kg ai/ha) plus 2 litres of quixalofop (0.1 kg ai/ha). Based on current prices of these products in Ukraine, this would result in herbicide costs of $43/ha to $63/ha, and average crop protection costs increasing by between $13/ha and $36/ha (Table 11).

[13] The balance being fungicides, insecticides and cost of spraying

The overall impact of the use of this technology on variable costs of production will depend on the likely seed premium that might be charged to Ukrainian farmers. In North America, the average seed premium has been about $18/ha. If the current North American seed premium was applied in Ukraine, this would result in total variable costs being marginally lower (by $1/ha) or up to $13/ha more expensive, depending on whether one or two litres of glyphosate were used by GM HT producers. If InVigor technology was used total variable costs would increase by between $31/ha and $54/ha.

Impact on yield

In Canada and the US, GM HT (to glyphosate) has given many farmers improved weed control and, as a result, higher yields. These yield gains were initially about 6% to 7% although in more recent years, with improvements in conventional varieties, this has fallen to zero to +2%[14] Based on the yield impacts from Canada and the US, yield increases of between 3% and 4% might reasonably be achieved in Ukraine. However, it should be noted that the impacts of the technology in North America apply to spring canola/oilseed rape, which only accounts for about 10% of the oilseed rape crop in Ukraine. It is therefore possible that higher average levels of yield improvement might be realised if trial results from winter oilseed rape in adjacent/nearly countries in the EU (eg, Poland and Germany) are used as the benchmark for assessing potential impact in Ukraine. In Poland, trials of GM HT oilseed rape suggested yield improvements of between +15% and +20%, whilst trials in other EU countries (eg, Germany and the UK) delivered yield improvements of between +10% and +15%.

In Table 11, the yield gain assumptions used for GM HT (to glyphosate) oilseed rape are +3% and +12%. Inclusive of the cost changes referred to above, this results in profitability gains of between $14/ha and $108/ha (+2.7% to +21%).

For InVigor technology, higher average yield increases of +10% to +12% have been common in Canada and the US. Applying this range of yield increases to Ukraine would result in profitability gains of between $37/ha and $76/ha (+7.2% and +14.8%)

Table 11: Potential farm level economic impact of using GM HT oilseed rape in Ukraine ($/hectare)

	Average 2010/11	GM HT to glyphosate	GM HT tolerant to glufosinate and hybrid vigour
Price ($/tonne)	538	538	538
Yield (tonnes/ha)	1.7	1.751-1.9	1.87-1.9
Revenue	915	942-1,022	1,006-1,022
Variable costs			
Seed	34	52	52
Fertiliser	172	172	172

[14] The main 'conventional' alternative is herbicide tolerant by non GM methods to the Imidazoline group of herbicides – what is know as 'Clearfield' canola/oilseed rape

Crop protection	68	49-63	81-104
Labour	19	19	19
Machinery	109	109	109
Total variable cost	402	401-415	433-456
Base variable costs	274	273-287	305-328
Gross margin	**513**	**527-621**	**550-589**
Base gross margin	**641**	**655-749**	**678-717**

Notes:

1. GM HT to glyphosate: yield gain of +3% to +12%, seed premium of $18/ha and herbicide cost falling to between $11/ha and $22/ha
2. GM HT to glufosinate: yield gain of 10% to 12%, seed premium of $18/ha and herbicide cost falling to between $43/ha and $63/ha

Looking at the potential impact from the perspective of intensive and extensive producers, this is likely to vary:

GM HT (to glyphosate: Table 12):

- *Intensive producers*: these producers use higher levels of inputs than extensive producers and obtain significantly higher yields. As weed control levels in the conventional crop are likely to be fairly good, the impact of using GM HT technology is likely to result in small increases in yield, probably at the lower end of the 3% to 12% range from improved weed control. The main benefit from using GM HT technology for intensive producers is likely to be reduced costs for crop protection of between 20% and a third ($20/ha to $31/ha). The overall profitability gains are likely to be between $45/ha and $196/ha (+4.5% to +19.8%), although as indicated above the lower end of this range is more probable;
- *Extensive producers*: due to the lower yields obtained by extensive growers and lower levels of input use, it is likely that this category of grower may potentially derive significant yield gains from improved weed control if GM HT technology is used. Yield improvements nearer the higher end of the 3% to 12% range are possible, and as a result, these are likely to be the main benefit derived from the technology. In terms of costs of production, the herbicide cost savings are likely to be cancelled out by the seed premium, especially if Canadian and US seed premia levels are used in Ukraine. The impact on gross margin profitability is likely to see increases of between $8/ha (if only low levels of yield increase are realised) and $89/ha (if higher yield impacts are derived). These increases are equal to +2% to +22.8%.

Table 12: Potential farm level economic impact of using GM HT (tolerant to glyphosate) oilseed rape in Ukraine: intensive versus extensive producers ($/hectare)

	Baseline 2010/11; intensive	Baseline 2010/11: extensive	GM HT to glyphosate: intensive	GM HT to glyphosate: extensive
Price ($/tonne)	538	538	538	538
Yield (tonnes/ha)	2.82	1.42	2.9-3.16	1.46-1.59
Revenue	1,517	764	1,560-1,700	785-855
Variable costs				
Seed	45	31	63	49
Fertiliser	218	160	218	160
Crop protection	99	63	68-79	47-58
Labour	21	19	21	19
Machinery	145	100	145	100
Total variable cost	528	373	515-526	375-386
Base variable costs	362	254	349-360	256-267
Gross margin	**989**	**391**	**1,034-1,185**	**399-480**
Base gross margin	**1,155**	**510**	**1,200-1,351**	**518-599**

Notes:

1. Yield gain assumptions of +3% and +12%
2. Seed premium $18/ha for both forms of technology

GM InVigor (HT to glufosinate: Table 13*):*

- *Intensive producers*: the impact of using this technology is likely to result in important increases in yield, reduced costs of herbicides and a small rise in total variable costs. The overall profitability gains are likely to be between $106/ha and $161/ha (+10.7% to +16.3%);
- *Extensive producers*: these producers are also likely to achieve significant yield increases but increases in both herbicide costs and total variable costs of production. The impact on gross margin profitability is likely to be increases of between $22/ha (+5.6%) and $55/ha (+14.1%).

Table 13: Potential farm level economic impact of using GM InVigor (HT) oilseed rape in Ukraine: intensive versus extensive producers ($/hectare)

	Baseline 2010/11; intensive	Baseline 2010/11: extensive	GM InVigor	GM InVigor
Price ($/tonne)	538	538	538	538
Yield (tonnes/ha)	2.82	1.42	3.1-3.16	1.56-1.59

Revenue	1,517	764	1,668-1,700	839-855
Variable costs				
Seed	45	31	63	49
Fertiliser	218	160	218	160
Crop protection	99	63	103-126	81-98
Labour	21	19	21	19
Machinery	145	100	145	100
Total variable cost	528	373	550-573	409-426
Base variable costs	362	254	384-407	290-307
Gross margin	**989**	**391**	**1,095-1,150**	**413-446**
Base gross margin	**1,155**	**510**	**1,261-1,316**	**532-565**

Notes:

1. Yield gain assumption of +10% to +12%
2. Seed premium $18/ha

3.2.2 GM HT soybeans

a) Commercial experience

GM HT technology has been widely used in the leading soybean producing countries of the world since 1996. In 2010, 70% of the world's soybean area of 102.7 million hectares used this technology (legally) in nine countries.

The technology has increased soybean farmer incomes by a total of $3.3 billion in 2010 (equal to 3.2% of the total value of global soybean production in 2010) and, for the period 1996-2010, the increase in farm income has been $28.4 billion. A breakdown of the distribution of this benefit in 2010 is shown in Figure 1. US farmers have derived the largest aggregate benefit, closely followed by Argentina, Brazil and Paraguay. Overall, 57% of the total income gain (1996-2010) has been earned by farmers in developing countries, mostly located in South America[15].

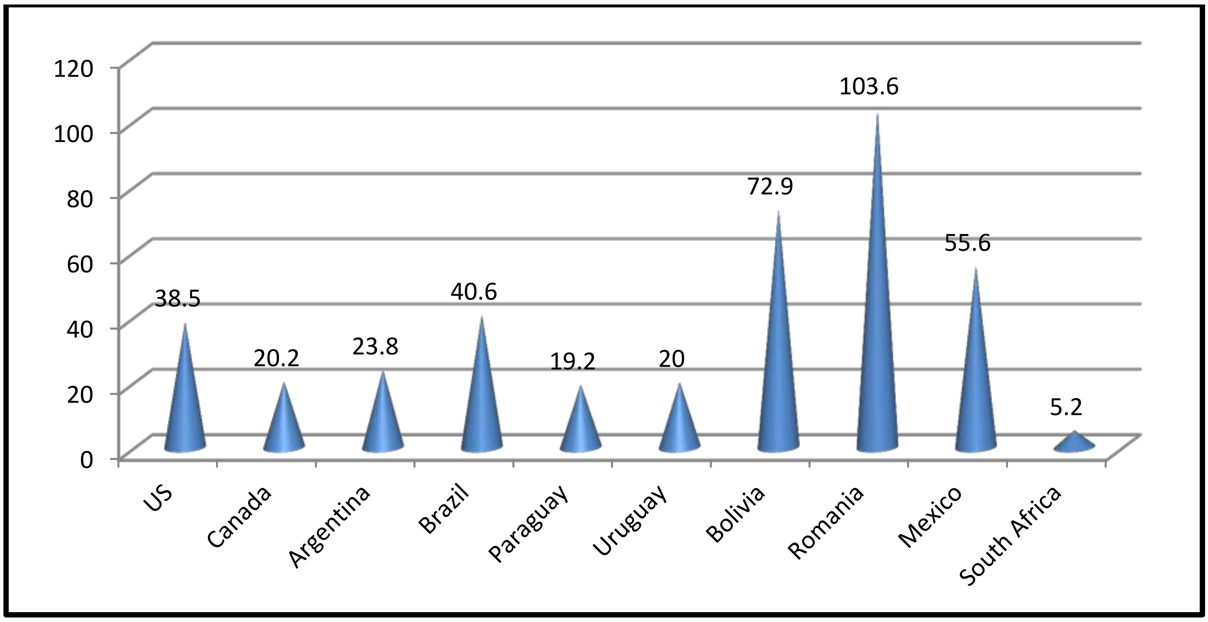
In terms of average benefits, these have been highest in Romania, Mexico and Bolivia, reflecting the yield gains derived by farmers using GM HT soybeans in these countries as well as cost savings

[15] Developing countries for the purposes of this analysis are Mexico, Argentina, Bolivia, Brazil, Paraguay, Uruguay and South Africa

(Figure 1). Not surprisingly, if second crop benefits are included[16], the total farm income gain is highest for farmers in Argentina and Paraguay.

Examining the cost farmers pay for accessing the technology, the total cost (1996-2010) was equal to 25% of the total technology gains (inclusive of farm income gains plus cost of the technology payable to the seed supply chain[17]). For farmers in developing countries the total cost was equal to 12% of total technology gains, whilst for farmers in developed countries the cost was 38% of the total technology gains. The higher share of total technology gains accounted for by farm income gains in developing countries relative to the farm income share in developed countries reflects factors such as weaker provision and enforcement of intellectual property rights in developing countries and the higher average level of farm income gain on a per hectare basis derived by developing country farmers relative to developed country farmers.

Figure 1: Average farm income benefit (1996-2009) from using biotech HT soybeans: by country ($/ha)



Note: average values relate to period during 1996-2010 when the technology was used in each country (eg, all years in the US, 1999-2006 in Romania). Excludes second crop benefits in Argentina and Paraguay which were $266/ha and $254/ha respectively and second generation biotech HT soybeans grown in the US and Canada from 2009 (average farm income benefit of $66/ha in the US and $57/ha in Canada).

72% of the cumulative farm income benefit has derived from production cost savings, with the balance (28%) due to yield increases and second crop benefits. Whilst cost saving benefits, have been derived by farmers in all of the countries using GM HT soybeans, the second crop, quality and yield gains have mostly been derived by farmers in developing countries, although the highest yield gains from use of this technology occurred in Romania.

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[16] Second crop benefits refer to the shortening of the crop production cycle for GM HT soybeans (via use of no tillage and improved weed control) that has allowed many farmers to plant a crop of soybeans following wheat in the same season

[17] In other words, the total benefit 1996-2010 of $37.85 billion comprising farm income benefit of $28.4 billion and a cost of technology of $9.45 billion. The cost of the technology accrues to the seed supply chain including sellers of seed to farmers, seed multipliers, plant breeders, distributors and the technology providers

b) Potential impact in Ukraine

Although a proportion of soybeans in Ukraine are likely to already use (illegally) GM HT technology, there are, not surprisingly, no publicly available analyses of the impact the technology. Based on the impacts identified in the countries that have used the technology, and assuming that the GM HT trait was made available in leading varieties suitable for growing in Ukraine, the potential impacts are as follows.

Change in production costs

The average level of herbicide expenditure in 2011 on soybeans in Ukraine was about $38/ha, out of a total expenditure on crop protection of $47/ha[18]. As with all other crops, the amount farmers spend on weed control varies according to weed types, weed pressure and timing of application.

If GM HT (tolerant to glyphosate) soybeans were used and herbicide usage patterns commonplace in the countries using the technology are adopted in Ukraine, it is likely that the crop would be treated with glyphosate between one and two times (average of about 1.25 spray runs and an average dose of about 1.5 litres of glyphosate: about 0.72 kg ai/ha) plus possibly one other herbicide such as 2 4 D (0.6 kg ai/ha) or metribuzin (0.2 kg ai/ha). Based on 2011 herbicide costs[19], this would result in average herbicide costs of about $12/ha to $15/ha. This is a net saving relative to 2011 average costs of herbicide use on conventional soybeans of between $23/ha and $26/ha. Taking into account the cost of the technology ($15/ha to $20/ha if based on typical costs in countries that currently use the technology[20]), this would result in the total variable costs of production falling by between $3/ha and $11/ha (equivalent to about a 1% to 3% decrease in total variable costs: Table 14).

Change in yields

In countries such as the US, Canada, Argentina and Brazil, where levels of weed control before the adoption of GM HT technology were widely considered to be good, little or no positive yield impact arose from the adoption of GM HT technology. However, in other adopting countries, important yield increases associated with improved weed control have occurred. Of particular note is the impact on yield from using GM HT soybeans in Romania, where the average yield increase in the first few years of adoption was over 30%. Whilst this very high level of yield improvement was mostly attributed to adoption after a period of several years in which little or no effective weed control had been used in arable crops in Romania (following the major economic and political changes that occurred during the 1990s), yield improvements of about 15% were still being delivered in the last year of use (2006) before entry into the EU[21].

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[18] The remaining expenditure accounted for by insecticides, fungicides and the cost of spraying

[19] Sources: Kleffmann and Gfk Kynetec

[20] This is based on the seed premium between GM HT first generation soybeans and conventional soybean seed. If farm saved seed is used the net seed premium would be much lower and probably add no more than $2/ha-$3/ha (as occurs in many parts of South America)

[21] On entry into the EU, Romania was no longer permitted to allow the use of GM HT soybeans because this trait had not been approved for planting in the EU

Based on the average levels of expenditure on herbicides and yields in conventional soybeans in Ukraine, this suggests that yield improvements from the adoption of GM HT technology are probable, provided the technology is made available in the leading varieties suitable for growing in Ukraine. The analysis presented in Table 14 assumes two alternatives for yield improvements within a range of +5% and +15% based on the range of yield improvements identified in other GM HT user countries, including neighbouring Romania. After taking into consideration the cost of production changes discussed above, gross margin profitability would increase by between $47/ha and $111/ha, equivalent to increases of between 11.3% and 26.9%.

Table 14: Potential farm level economic impact of using GM HT soybeans in Ukraine ($/hectare)

	Average 2010/11	**GM HT: impact 1**	**GM HT impact 2**
Price ($/tonne)	450	450	450
Yield (tonnes/ha)	1.62	1.7	1.86
Revenue	729	765	837
Variable costs			
Seed	64	79	84
Fertiliser	124	124	124
Crop protection	47	21	24
Labour	55	55	55
Machinery	26	26	26
Total variable cost	316	305	313
Base variable costs	235	224	232
Gross margin	**413**	**460**	**524**
Base gross margin	**494**	**541**	**605**

Note: Yield assumptions GM HT impact 1 +5% and GM HT impact 2 +15%

This analysis, based on average profitability levels does, however, not show the extent of impacts based on different intensities of production. Intensive producers tend to spend more on inputs, use leading/new varieties of seed and the latest/most effective crop protection products, whilst the extensive producers may use farm-saved seed and use older and cheaper 'generic' crop protection products. The potential impact of using GM HT technology for these two groups of soybean producer is likely to offer both some similarities and differences. More specifically (Table 15):

- *Intensive producers*: these producers tend to use and spend significantly more on inputs than extensive producers and obtain yields that are about double that of extensive producers. For this category of producer, weed control levels in the conventional crop are likely to be fairly good and as a result, the impact of using GM HT technology is likely to result in limited yield gains from improved weed control. The main benefit from using GM HT technology for intensive producers is likely to come from reduced costs for crop protection, equal to between $46/ha and $54/ha. The overall profitability gains are likely to be between $46/ha and $110/ha (+7.5% to +18%);

- *Extensive producers*: given the significantly lower yields obtained by extensive growers and lower levels of input use, it is likely that this category of grower will derive most from yield gains if GM HT technology is used. There is likely to be little change to total variable costs of production (the reduced expenditure on herbicides being largely cancelled out by the seed premium). Overall, the impact on gross margin profitability is likely to be increases of between $23/ha and $85/ha (+ 8.8% to +32.7%).

Table 15: Potential farm level economic impact of using GM HT soybeans in Ukraine: intensive versus extensive producers ($/hectare)

	Baseline 2010/11; intensive	Baseline 2010/11: extensive	GM HT: intensive	GM HT: extensive
Price ($/tonne)	450	450	450	450
Yield (tonnes/ha)	2.5	1.2	2.5-2.625	1.26-1.38
Revenue	1,125	540	1,125-1,181	567-621
Variable costs				
Seed	100	55	115-120	70-75
Fertiliser	220	110	220	110
Crop protection	90	40	21-24	21-24
Labour	75	50	75	50
Machinery	31	25	31	25
Total variable cost	516	280	462-470	276-284
Base variable costs	410	205	356-364	201-209
Gross margin	**609**	**260**	**655-719**	**283-345**
Base gross margin	**715**	**335**	**761-817**	**358-420**

Notes:

1. Intensive producers: yield gain assumption of between zero and +5%
2. Extensive producers: yield gain assumptions of between +5% and +15%

3.2.3 GM HT sugar beet

a) *Commercial experience*

GM HT (tolerance to glyphosate) sugar beet has been grown commercially in the US and Canada since 2008. In 2010, almost all (96%) of the total crop in both countries used the technology. In terms of impact at the farm level:

- Yields have improved by an average of between 3% and 4%;
- Cost savings from reduced cost of weed control have broadly been equal to the additional cost of the technology (about $140/ha-$150/ha respectively);
- The net impact on profitability (inclusive of yield gains and cost changes) was about +$145/ha in 2010, and an average of +$115/ha over the three year period since 2008.

c) *Potential impact in Ukraine*

Change in production costs

In 2011, the average expenditure on sugar beet crop protection in Ukraine was about $177/ha, of which $130/ha to $140/ha is accounted for by herbicides[22]. This typically involved the application of herbicides in three passes/treatments during the growing season.

In the US and Canada, farmers using GM HT technology have typically switched to the application of two spray runs per crop with each application applying about 2 litres of glyphosate/ha (1.08 kg ai/ha, a few use a third spray run equal to 1.62 kg ai/ha). The adoption of similar practices in Ukraine if GM HT technology was used would result in the average cost of herbicides used falling to about $36/ha ($54/ha if a third spray application is used: Table 16).

The overall impact of the use of this technology on profitability will depend on the likely seed premium that might be charged to Ukrainian farmers. In Canada and the US, the average seed premium has been about $140/ha although when the technology was being considered for commercial release in the EU about 10 years ago, a premium of about $50/has was planned. If the current Canadian and US seed premium of $140/ha was applied in Ukraine, this would effectively cancel out the savings from reduced herbicide costs (Table 16), resulting in a small net increase to average variable costs of production. At the lower level of $50/ha seed premium, the average sugar beet producer would see significant reductions in total variable costs of between $44/ha and $54/ha (-4.4% to -5.5%).

Impact on yield

Based on the yield impacts from Canada and the US, yield increases of between 3% and 4% might be achieved in Ukraine. However, it is also possible that higher average levels of yield improvement might be realised if the trials results from adjacent countries in the EU (notably Poland) are used as the benchmark for assessing potential impact in Ukraine. In Poland, trials of GM HT sugar beet suggested yield improvements of between +15% and +30%, whilst trials in other EU countries (eg, Germany and the UK) delivered yield improvements of between +5% and +15%.

In Table 16, the yield gain assumptions used are +3% and +15%. Inclusive of the cost changes referred to above, this results in profitability gains of between $8/ha and $108/ha at the 3% yield gain level (+1% to +13.4%) and between $222/ha and $322/ha at the 15% yield gain level (+27.6% to +40%).

[22] The balance being fungicides, insecticides and cost of spraying

Table 16: Potential farm level economic impact of using GM HT sugar beet in Ukraine ($/hectare)

	Average 2010/11	GM HT: impact 1	GM HT impact 2
Price ($/tonne)	64	64	64
Yield (tonnes/ha)	27.97	28.81	32.16
Revenue	1,790	1,844	2,058
Variable costs			
Seed	170	220-310	220-310
Fertiliser	275	275	275
Crop protection	177	73-83	73-83
Labour	27	27	27
Machinery	338	338	338
Total variable cost	987	933-1,033	933-1,033
Base variable costs	622	568-668	568-668
Gross margin	**803**	**811-911**	**1,025-1,125**
Base gross margin	**1,168**	**1,176-1,276**	**1,390-1,490**

Notes:

3. GM HT impact 1: yield gain of 3%, seed premium range of $50/ha to $140/ha and herbicide cost falling from between $130/ha and $140/ha to $36/ha
4. GM HT impact 2: yield gain of 15%, seed premium range of $50/ha to $140/ha and herbicide cost falling from between $130/ha and $140/ha to $36/ha

Looking at the potential impact from the perspective of intensive and extensive producers, this is likely to vary (Table 17):

- *Intensive producers*: these producers use higher levels of inputs than extensive producers and obtain significantly higher yields. As weed control levels in the conventional crop are likely to be fairly good, the impact of using GM HT technology is likely to result in small increases in yield, probably at the lower end of the 3% to 15% range from improved weed control. The main benefit from using GM HT technology for intensive producers is likely to be reduced costs for crop protection. This is likely to be between $3/ha and $107/ha. The overall profitability gains are likely to be between $81/ha and $185/ha (+5.3% to +12.1%);
- *Extensive producers*: due to the lower yields obtained by extensive growers and lower levels of input use, it is likely that this category of grower will derive significant yield gains from improved weed control if GM HT technology is used. Yield improvements nearer the higher end of the 3% to 15% range are probable, and as a result, these are likely to be the main benefit derived from the technology. In terms of costs of production, the herbicide cost savings are likely to be cancelled out by the seed premium, especially if Canadian and US seed premia levels are used in Ukraine. The impact on gross margin profitability is likely to

be a decrease of $29/ha if only low levels of yield increase are realised but an increase of $236/ha if higher yield impacts are derived. These changes are equal to -5.5% to +45.5%.

Table 17: Potential farm level economic impact of using GM HT sugar beet in Ukraine: intensive versus extensive producers ($/hectare)

	Baseline 2010/11; intensive	Baseline 2010/11: extensive	GM HT: intensive	GM HT: extensive
Price ($/tonne)	64	64	64	64
Yield (tonnes/ha)	40.9	21.6	42.13	22.25-24.84
Revenue	2,618	1,382	2,696	1,424-1,590
Variable costs				
Seed	190	90	240-330	140-230
Fertiliser	296	265	296	265
Crop protection	245	144	88-102	66-75
Labour	27	27	27	27
Machinery	338	338	338	338
Total variable cost	1,096	864	989-1,093	836-935
Base variable costs	731	499	624-728	471-570
Gross margin	**1,522**	**518**	**1,603-1,707**	**489-754**
Base gross margin	**1,887**	**883**	**1,968-2,072**	**854-1,119**

Notes:

3. Intensive producers: yield gain assumption of 3%
4. Extensive producers: yield gain assumptions of +3% and +15%

3.2.4 GM HT maize

a) *Commercial experience*

GM HT maize has been grown commercially since 1997, and 2010, about 27 million ha in seven countries (the US, Canada, Argentina, Brazil, Colombia, South Africa and the Philippines) used the technology. As with GM HT soybeans, the main impact has been to reduce farmers weed control costs, through reduced expenditure on herbicides (and/or reduction in hand weeding requirements), although farmers in some countries (notably Philippines, Argentina and Brazil) have obtained higher yields (of up to 10%) associated with improved weed control levels.

The average net farm income gain in 2010 from using GM HT maize technology across the seven user countries was $16.2/ha and cumulatively since 1997, the average farm income gain has been $18.8/ha. The cost of the technology varies between countries but was within a range of $15/ha to $30/ha in 2010.

b) Potential impact in Ukraine

Whilst there are two GM HT maize traits currently available commercially (tolerance to glyphosate and tolerance to glufosinate), the analysis presented below for possible impact in Ukraine is limited to GM HT (to glyphosate) because this is the trait that accounts for the vast majority of global usage. The potential impacts of this trait in Ukraine are discussed below[23].

Change in production costs

Crop protection expenditure in 2011 by average performing commercial maize producers was about $57/ha, of which about $51/ha was accounted for by herbicides. This level of expenditure on herbicides could fall with the use of GM technology, with its precise impact dependant on weed types, weed pressure and timing of application in either post-emergent application in the autumn and/or the spring.

If glyphosate tolerant GM HT maize technology was used in Ukraine and herbicide usage patterns commonplace in countries such as the US and Argentina are adopted, it is likely that a pre-emergent treatment of 'traditional' soil based herbicides (at half dose rates compared to usage levels in conventional maize) might be used, coupled with one post-emergent treatment of glyphosate (1.5 to 2.5 litres: see appendix 1 for details of the amount of ai used). Given the pattern of herbicide use in the conventional crop, this is a more likely scenario for intensive growers only rather than the 'majority' extensive growers (see below). Based on 2011 herbicide costs, this would result in total herbicide costs being between $23/ha to $43/ha. This represents a net reduction relative to 2011 average herbicide costs of between $8/ha and $28/ha. Taking into account the cost of the technology ($15/ha to $20/ha if based on typical costs in countries that currently use the technology), this would result in the total variable costs of production changing within a range of -$13/ha to +$12/ha. Thus depending on the farm, weed pressure and herbicide usage levels, some maize producers in Ukraine would potentially see a modest decrease in total production costs, whilst others would potentially experience a small net increase in production costs (Table 18).

Change in yields

The scope for yield increases associated with the adoption of GM HT technology largely depends on the current baseline levels of efficacy in conventional maize crop weed control. In countries such as the US and Canada, where levels of weed control before the adoption of GM HT maize technology were widely considered to be excellent, little or no positive yield impact arose from the adoption of GM HT technology. However, in significant parts of Argentina, in Brazil and in the Philippines, annual average yield increases of up to 5% have been delivered from improved weed control. Whilst there have not been any trials of GM HT maize in Ukraine to assess the potential impact on yields, the average levels of expenditure on maize herbicides and average yields in the Ukraine suggest that impacts more typically seen in South America, rather than North America (where average yields and expenditure on herbicides are significantly higher than in Ukraine) might reasonably be expected. In Table 18, a range of zero yield change to +5% have been used to illustrate potential impact. After taking into consideration the cost changes discussed above, the net impact on profitability would be

[23] Assuming the trait is available for use in leading varieties adapted to agronomic conditions in Ukraine

between +$35/ha and +$60/ha (+6.8% to +11.7%). If little or no yield gains from improved weed control occur, the direct farm income benefit from using the technology would be marginal (unless the assumed technology fee was lower).

Table 18: Potential farm level economic impact of using GM HT maize in Ukraine ($/hectare)

	Average 2010/11	**GM HT: impact 1**	**GM HT impact 2**
Price ($/tonne)	215	215	215
Yield (tonnes/ha)	4.51	4.51	4.73
Revenue	970	970	1,017
Variable costs			
Seed	125	140-145	140-145
Fertiliser	132	132	132
Crop protection	57	29-49	29-49
Labour	26	26	26
Machinery	118	118	118
Total variable cost	458	445-470	445-470
Base variable costs	314	301-326	301-326
Gross margin	**512**	**500-525**	**547-572**
Base gross margin	**656**	**644-669**	**691-716**

Note: Yield impact assumptions: GM HT impact 1 zero, GM HT impact 2 +5%

In terms of different types of producer, Table 19 summarises the potential impact for intensive and extensive producers:

- *Intensive*: these above average users of inputs would derive positive farm income gains within a range of $11/ha and $110/ha depending on whether yield improvements from better weed control occurred. Even if no yield gains occurred, there would be a net increase in farm income as the savings in herbicide costs would be greater than the seed premium;
- *Extensive*: for this type of producer, with lower levels of expenditure on inputs and lower yields, the farm income impacts would potentially be within a range of -$23/ha (-4.5%) to +$42/ha (+8.2%). In this category of producer, it is probable that improved weed control and higher yields would occur and therefore the likely farm income impact would be positive and at the higher end of the range referred to above. If little or no yield gains were derived, farmers in this category of producer would probably not use the technology as the seed premium could be greater than any savings that might arise from changes to herbicides used (unless the seed premium was set at a lower than assumed).

Table 19: Potential farm level economic impact of using GM HT maize in Ukraine: intensive versus extensive producers ($/hectare)

	Baseline 2010/11; intensive	Baseline 2010/11: extensive	GM HT: intensive	GM HT: extensive
Price ($/tonne)	215	215	215	215
Yield (tonnes/ha)	6.91	3.91	6.91-7.26	3.91-4.1
Revenue	1,486	841	1,486-1,561	841-881
Variable costs				
Seed	145	43	160-165	58-63
Fertiliser	220	110	220	110
Crop protection	82	44	31-51	27-47
Labour	28	25	28	25
Machinery	164	107	164	107
Total variable cost	639	329	603-628	327-352
Base variable costs	447	197	411-436	195-220
Gross margin	**847**	**512**	**858-958**	**489-554**
Base gross margin	**1,039**	**644**	**1,050-1,150**	**621-686**

Notes:

1. Yield gain assumptions zero and +5%

3.2.5 GM IR maize

a) *Commercial impact*

Two GM IR traits have been commercially used targeting the common corn boring pests including European corn borer (*Ostrinia nubilalis)* and Mediterranean stalk borer (*Sesamia nonagrioides* – MSB) and corn rootworm pests – *Diabrotica spp).* These are major pests of maize crops in many parts of the world and significantly reduce yield and crop quality, unless crop protection practices are employed. The GM IR maize targeting corn boring pests has been commercially used since 1996 and in 2010/11 was utilised in 15 countries. The GM IR maize targeting corn rootworm was commercially used first in 2003 and is currently used in two countries, the US and Canada. The respective areas using these technologies in 2010/11 were 34.1 million ha for GM IR maize targeting corn boring pests and 17.7 million ha targeting corn rootworm.

The two GM IR maize traits have delivered positive yield impacts in all user countries when compared to average yields derived from crops using conventional technology (mostly the application of insecticides and seed treatments) for control of corn boring and rootworm pests.

The positive yield impact varies from an average of about +5% in the US and Canada for corn rootworm resistant technology and a range of +7% (in the US and Canada) to +24% (Philippines) for corn boring resistant technology. Cumulatively since 1996 (1996-2010), the average yield gain from using GM IR maize resistant to corn boring pests across all user countries has been +9.6%.

GM IR technology resistant to corn boring pests has also been used in the European Union since 1998, and in 2011 was used on about 110,000 ha in Spain, Portugal, the Czech Republic, Slovakia, Poland and Romania. In the EU countries, average yield gains have been between +5% and +12.5% (Table 20).

Table 20: Yield impacts from using GM IR maize in the EU

Country	Average yield of GM IR maize relative to conventional % difference	Range of yield impacts (where identified)	Comments
Spain	+6.3% 1998-2003 +10% 2004 onwards	+1% to +30%	Bottom of range is low infestation locality in a year of low pest pressure and top of range is high infestation locality in year of high pest pressure
France	+10%	+5% to +24%	Bottom of range is low pest pressure year and top of range is high pest pressure year
Germany	+4%	+4% to +5%	No additional data available for low and high pest pressure years
Czech Republic	+10%	+5% to +20%	Range of impacts recorded in different regions with differing levels of pest pressure; low end of range = low pest pressure, high end of range = high pest pressure
Portugal	+12.5%	+8% to +17%	Range of impacts recorded in different regions with differing levels of pest pressure; low end of range = low pest pressure, high end of range = high pest

			pressure
Poland	+12.3%	+2% to +26%	Range of trial results in 2005 with top of range based on 2006 trials in year/region of high infestation
Slovakia	+12.5%	+10% to +14%	Range of commercial plot monitoring in 2006
Romania	+7.2%	+4.8% to +9.6%	Range of commercial plot monitoring 2007-2009

Source: Brookes (2008) and updated

In relation to impact on costs of production, this varies mainly due to whether or not farmers previously used insecticides to control corn boring and rootworm pests before GM IR technology became available:

- *GM IR resistant to corn boring pests*: the cost of the technology (seed premium) relative to conventional corn costs varies across user countries, within a range of $15/ha and $57/ha (2010) and the insecticide cost savings varied between zero and $66/ha (2010). In the EU, the average cost of the technology, charged as a seed premium has been about $41/ha, with insecticide cost savings being between zero and $66/ha;
- *GM IR resistant to corn rootworm*: the cost of the technology in the US and Canada was about $32/ha in 2010, with an average insecticide/seed treatment cost saving of $37/ha.

After taking into consideration the yield gains from using GM IR technology, the seed premium and any change in pest control costs, the average farm income gain:

- across all countries using GM IR technology (*targeting corn boring pests*) was $89/ha in 2010 and for the period 1996-2010 was $66/ha. In the EU, the average farm income gain from using the technology in 2010 was $250/ha and for the period 1998-2010 has been $179/ha;
- in the US and Canada, using GM IR technology targeting corn rootworm, in 2010, was $83/ha and for the period 2003-2010 has been $75/ha.

b) Potential impact in Ukraine

The two currently available GM IR traits of resistance to corn boring pests and to corn rootworm could both be of relevance to Ukraine because corn boring pests are an established pest problem and corn rootworm is a recently established pest, currently limited to a small area.

The main potential impacts of these traits in Ukraine are discussed below[24].

[24] Assuming these traits are available for use in leading varieties adapted to agronomic conditions in Ukraine

Change in production costs

As indicated above, expenditure in 2011 by average-performing commercial maize producers on crop protection was about $57/ha. Insecticide use is, however, used only on a limited area (about 0.1 million ha) targeting corn boring pests and a further 0.3 million ha use the parasitic wasp *Trichogramma* to control this pest. Costs of applying insecticides and *Trichogramma* are between about $12/ha and $25/ha. This level of expenditure on crop protection measures targeted at corn boring pests could be eliminated for the farmers that currently incur such costs. In respect of corn rootworm, the small scale of current problems with this pest means that few, if any farmers undertake any active crop protection measures to control this pest and therefore any adoption of GM IR maize containing corn rootworm resistance technology would not (relative to current practices) result in savings in insecticide use[25].

The net impact of using these technologies on variable costs of production will depend on the cost of the technology. Based on costs incurred in existing countries where the technology is used, this could fall within a range of about $15/ha to $57/ha for GM IR technology targeting corn boring pests. The 'benchmark' cost from the nearest countries using the technology to Ukraine is the EU, where the average cost of the technology is about $41/ha. At these potential costs, the use of GM IR technology targeting corn boring pests would likely result in a net increase in variable costs for any users. For corn rootworm, it is more difficult to assess likely costs that might be incurred if the technology was made available in Ukraine. In the US and Canada, farmers currently pay about $32/ha for the technology, largely based on the fact that the pest is well established, is a significant problem and a third of the US crop used to routinely apply insecticides and seed treatments to control this pest before GM IR rootworm resistant technology became available. It is possible that the cost of this technology, if made available in Ukraine could be lower than the US level, to reflect the relative lower levels of benefits that might accrue to Ukraine maize growers than their counterparts in the US. Analysis of the impact of the use of these technologies are summarised in Table 21.

Change in yields

The potential for yield increases associated with the adoption of GM IR technology will depend on the level of infestations and efficacy in conventional maize crop control methods. As indicated above (see section 2.4), existing conventional technology is not considered to be very effective against corn boring pests and therefore for maize crops suffering infestations of this pest and using conventional forms of control (*Trichogramma* or insecticides), the impact of using GM IR technology has typically delivered yield gains of over 10% in EU countries. It is reasonable to assume that this level of impact might be delivered in the Ukraine. For corn rootworm, the yield gain relative to crops currently treated with insecticides in the US is typically 5%, and relative to untreated but infested crops the yield gains have been within a range of 9% to 28%. For the purposes of the analysis presented in Table 21, conservative yield gain assumptions at the lower half of the range for potential impact in Ukraine have been used for CRW-protected maize (+9% to +15%) and typical EU impacts (+10%) have been used as the basis for the yield gain assumptions for GM IR technology targeting corn boring pests.

[25] It would, however, offer potential savings relative to what might alternatively have to be used – using the US as a benchmark the average saving on insecticide treatments used for corn rootworm has been about $37/ha

After taking into consideration the cost changes discussed above, the net impact on profitability would be:

- *GM IR technology targeting corn boring pests*: a positive farm income gain of between +$67/ha and +$80/ha (+13% to +16.4%);
- *GM IR technology targeting corn rootworm:* a farm income gain of between $68/ha (+13.6%) and $126/ha (+25.2%).

The primary benefit of these technologies derives from enhanced pest control which delivers higher yields. For the many farmers that suffer yield losses from these pests but may not use conventional forms of control, the determining factor for potential use will be the level of yield (and revenue) gain relative to the cost of the seed premia. This will vary seasonally and at the farm level.

Table 21: Potential farm level economic impact of using GM IR maize targeting corn boring pests in Ukraine ($/hectare)

	Average 2010/11	GM IR targeting corn boring	GM IR targeting corn rootworm
Price ($/tonne)	215	215	215
Yield (tonnes/ha)	4.51	4.96	4.92-5.19
Revenue	970	1,066	1,058-1,116
Variable costs			
Seed	125	166	157
Fertiliser	132	132	132
Crop protection	69-82	57	57
Labour	26	26	26
Machinery	118	118	118
Total variable cost	470-483	499	490
Base variable costs	326-339	355	346
Gross margin	**487-500**	**567**	**568-626**
Base gross margin	**631-644**	**711**	**712-770**

Notes:

1. Crop protection expenditure based on average plus a range of $12/ha to $25/ha specific to maize that uses conventional treatments of insecticides or *Trichogramma* to control corn boring pests
2. Yield benefit assumption for GM IR technology targeting corn boring pests is +10%
3. Yield benefit assumption for GM IR technology targeting corn rootworm is +9% to +15% (based on US research on impact of the pest on untreated crops)
4. Seed premium GM IR maize targeting corn boring pests $41/ha and for GM IR maize targeting corn rootworm $32/ha

3.3 Indirect (non pecuniary) farm level economic impacts

As well as the tangible and quantifiable impacts on farm profitability presented above, there are other important, more intangible (difficult to quantify) impacts of an economic nature that have arisen in adopting countries. These include the following:

Herbicide tolerant crops

- Increased management flexibility and convenience that comes from a combination of the ease of use associated with broad-spectrum, post emergent herbicides like glyphosate and the increased/longer time window for spraying. This not only frees up management time for other farming activities but also allows additional scope for undertaking off-farm, income earning activities;
- In a conventional crop, post-emergent weed control relies on herbicide applications after the weeds and crop are established. As a result, the crop may suffer 'knock-back' to its growth from the effects of the herbicide. In the GM HT crop, this problem is avoided because the crop is tolerant to the herbicide;
- Facilitates the adoption of conservation or no tillage systems. This provides for additional cost savings such as reduced labour and fuel costs associated with ploughing, additional moisture retention and reductions in levels of soil erosion;
- Improved weed control has contributed to reduced harvesting costs – cleaner crops have resulted in reduced times for harvesting. It has also improved harvest quality and led to higher levels of quality price bonuses in some regions and years (eg, HT soybeans and HT canola in the early years of adoption respectively in Romania and Canada);
- Elimination of potential damage caused by soil-incorporated residual herbicides in follow-on crops and less need to apply herbicides in a follow-on crop because of the improved levels of weed control;
- A contribution to the general improvement in human safety (as manifest in greater peace of mind about own and worker safety) from a switch to more environmentally benign products.

Insect resistant crops

- Production risk management/insurance purposes – the technology takes away much of the worry of significant pest damage occurring and is, therefore, highly valued. Piloted in 2008 and more widely operational from 2009, US farmers using stacked corn traits (containing insect resistant and herbicide tolerant traits) are being offered discounts on crop insurance premiums (for crop losses) equal to $12.97/ha in 2010. Over the three years, this has applied to 12.7 million ha, resulting in insurance premia savings of $137.8 million;
- A 'convenience' benefit derived from having to devote less time to crop walking and/or applying insecticides;
- Savings in energy use – mainly associated with less use of aerial spraying;
- Savings in machinery use (for spraying and possibly reduced harvesting times);
- Higher quality of crop. There is a growing body of research evidence relating to the superior quality of GM IR corn relative to conventional and organic corn from the perspective of having lower levels of mycotoxins. Evidence from Europe (as summarised in Brookes (2008)) has shown a consistent pattern in which GM IR corn exhibits significantly reduced levels of mycotoxins compared to conventional and organic alternatives. In terms of revenue from sales of maize, however, no premia for delivering product with lower levels of mycotoxins have, to date, been reported. Nevertheless, where adoption of the technology has resulted in reduced frequency of crops failing to meet maximum permissible fumonisin levels in maize

grain (eg, in Spain), this delivers an important economic gain to farmers selling their grain to the food using sector;

- Improved health and safety for farmers and farm workers (from reduced handling and use of pesticides, especially in developing countries where many apply pesticides with little or no use of protective clothing and equipment);
- Shorter growing season (eg, for some cotton growers in India) which allows some farmers to plant a second crop in the same season[26]. Also some Indian cotton growers have reported knock on benefits for bee keepers as fewer bees are now lost to insecticide spraying.

These benefits are largely intangible and difficult to measure. Nevertheless, they have been considered by many farmers as a primary reason for adoption of GM technology. In some cases farmers have been willing to adopt for these reasons alone, even when the measurable impacts on yield and direct costs of production suggest marginal or no direct economic gain. Some limited attempts have been made to put values on some of these benefits, most notably in the US[27], where a number of farmer-survey based studies (employing contingent valuation techniques[28]) have been used to obtain farmers valuations of these non pecuniary benefits). For example, a 2002 survey of maize growers identified a value for the intangible benefits of insect resistant maize of about $7.4/ha and a 2002 survey of soybean farmers found a value for these intangible benefits of $12.35/ha.

Clearly if GM technology was to be adopted in Ukraine, farmers would also potentially derive some of these non pecuniary/intangible benefits. Estimating the level of such benefits is, however, not possible and would require repeating the type of US farmer-surveys referred to above in Ukraine after farmers had gained experience of using the technology.

[26] Notably maize in India

[27] See Marra and Piggott (2006) and (2007)

[28] Survey based method of obtaining valuations of non market goods that aims to identify willingness to pay for specific goods (eg, environmental goods, peace of mind, etc) or willingness to pay to avoid something being lost

4 Potential national level economic impacts

Building on the analysis presented in section 3, this section briefly examines the possible aggregated impact of using current commercial GM traits in Ukraine.

The assumptions used for the possible adoption levels in Ukraine are based on, for HT traits, adoption levels in countries that currently use the technology and, for IR traits in maize, limited to the areas typically experiencing economic levels in pest damage in Ukraine. These are summarised in Table 22.

Table 22: Area adoption assumptions for GM traits

Crop	Baseline area 2011 (ha)	GM HT adoption assumptions examined	GM IR
Soybeans	1,190,000	50% to 90%	Not applicable
Maize	2,869,000	50% to 70%	IR to corn boring pests: 400,000-500,000 ha IR to corn rootworm: 20,000-50,000 ha
Oilseed rape	910,000	50% to 90%	Not applicable
Sugar beet	550,000	50% to 90%	Not applicable

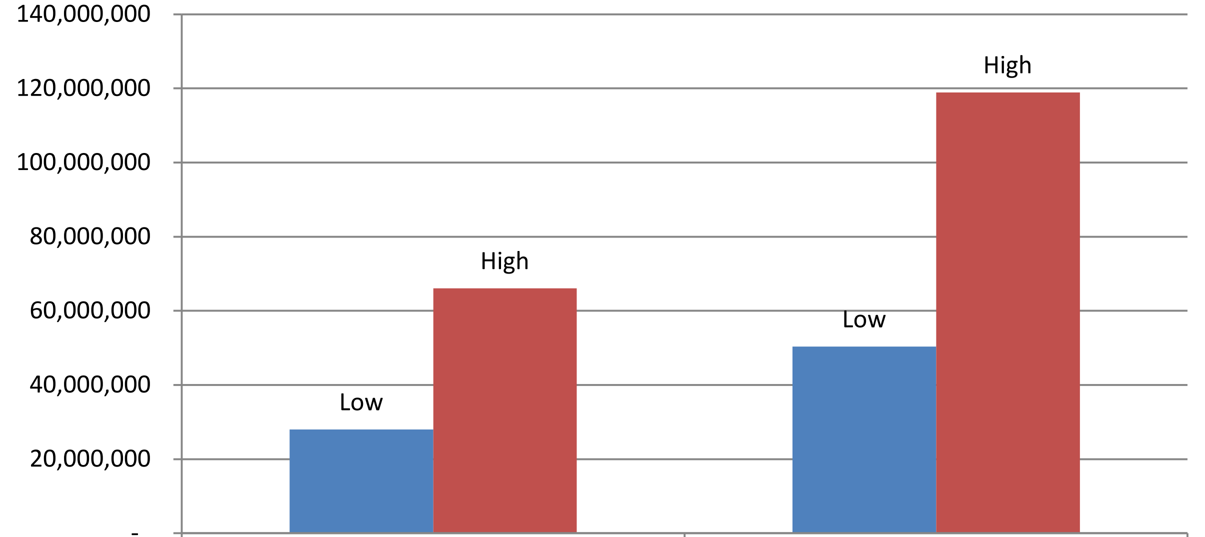
4.1 Farm level income

Based on the range of farm income benefits identified in section 3 and the area adoption assumptions above, Figures 2 to 7 summarise the potential farm income benefit impacts by trait. More specifically:

- *GM HT soybeans (Figure 2*): at a 50% adoption level, the likely annual farm income gain would potentially be between $28 million and $66 million. At the 90% adoption level, which is common in most current adopting countries, the potential annual benefits are between $50 million and $119 million;
- *GM HT maize (*Figure 3*):* depending on the adoption level (50% or a typical adoption level in user countries: 70%), the range of annual farm income benefits is $46 million to $111 million;
- *GM HT oilseed rape (Figure 4 and Figure 5):* the level of potential impact is likely to vary according to which technology is used. Based on glyphosate tolerant technology, the annual farm income benefit is potentially between $6.4 million and $89 million, whilst if InVigor (tolerant to glufosinate) technology is used, the annual benefit might be between $17 million and $62 million;
- *GM HT sugar beet (Figure 6):* at a 50% adoption level the annual farm income gains would potentially be between $30 million and $88 million. At the 90% level of adoption, these benefits would increase to between $53 million and $150 million;
- *GM IR maize:* based on the current areas typically suffering economic levels of damage from this pest (0.4-0.5 million ha), the potential annual farm income benefits are between $26.8 million and $40 million (Figure 7). In respect of GM IR technology targeting corn rootworm, the current area experiencing problems with this pest is fairly small (10,000-20,000 ha) and therefore at an aggregated level the potential impact of using this technology would be limited (little change to overall profitability to +$1.4 million to +$2.8 million (assuming 20,000 ha using the technology) or +$3.4 million to +$7 million if 50,000 ha use the technology).

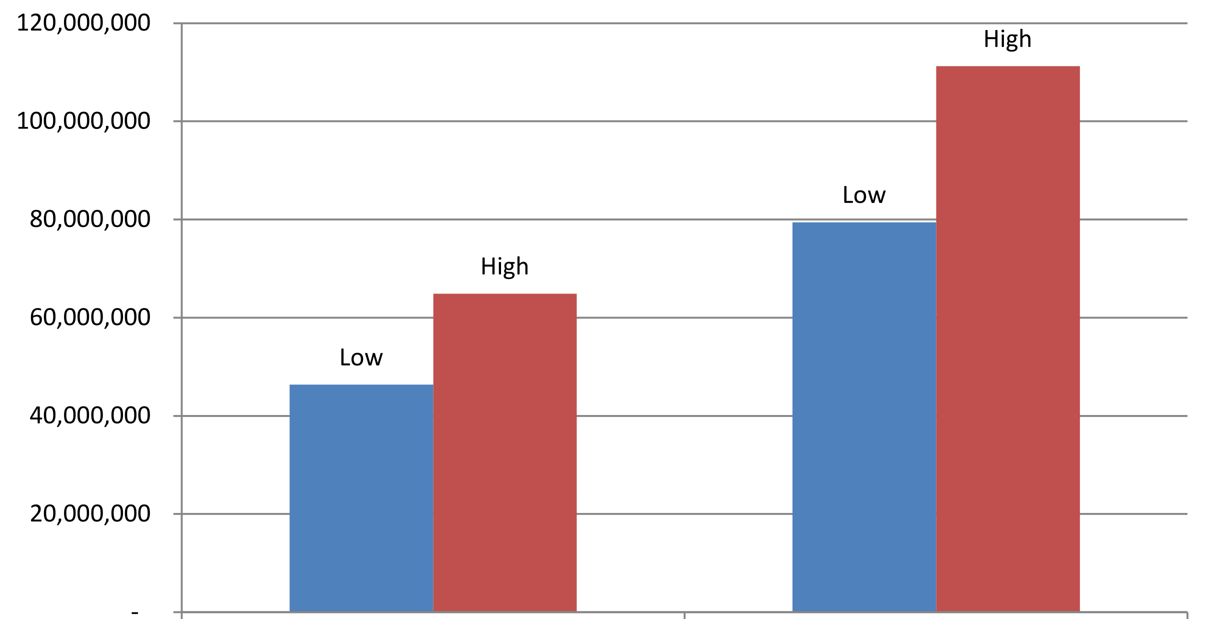
Overall, the total annual potential farm level benefit to Ukraine from using the current GM technology used globally and of relevance to Ukraine is up to $525 million.

Figure 2: Potential aggregated farm level benefits of GM HT soybeans for Ukraine ($)



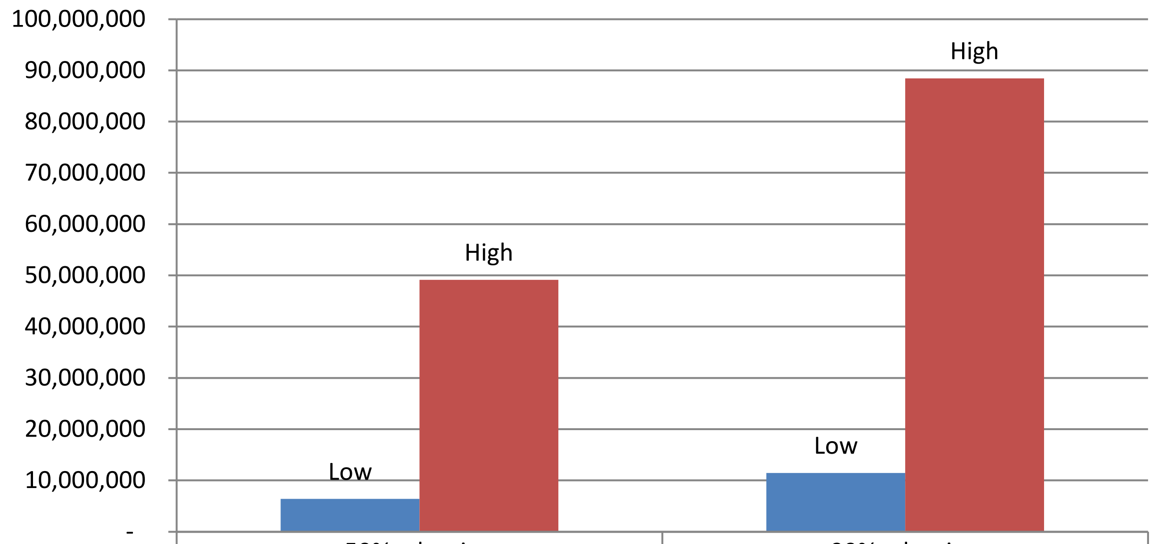
	50% adoption	90% adoption
Low	27,965,000	50,337,000
High	66,045,000	118,881,000

Figure 3: Potential aggregated farm level benefits of GM HT maize for Ukraine ($)



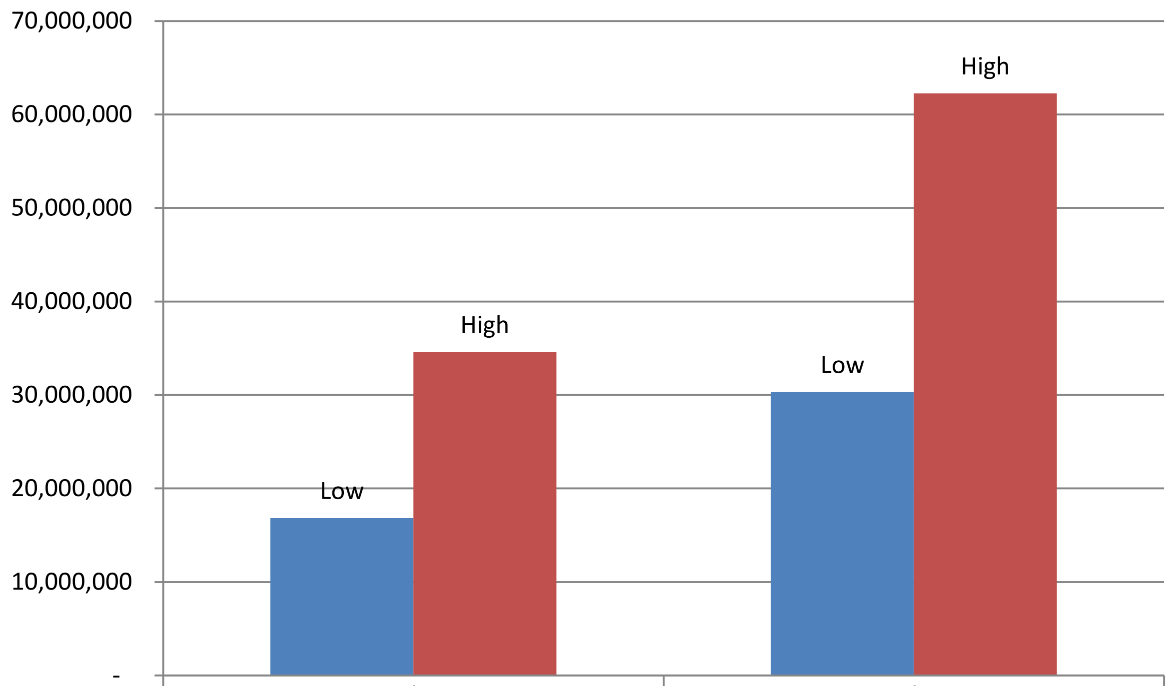
	50% adoption	70% adoption
Low	46,340,000	79,440,000
High	64,876,000	111,216,000

Figure 4: Potential aggregated farm level benefits of GM HT oilseed rape (tolerant to glyphosate) for Ukraine ($)



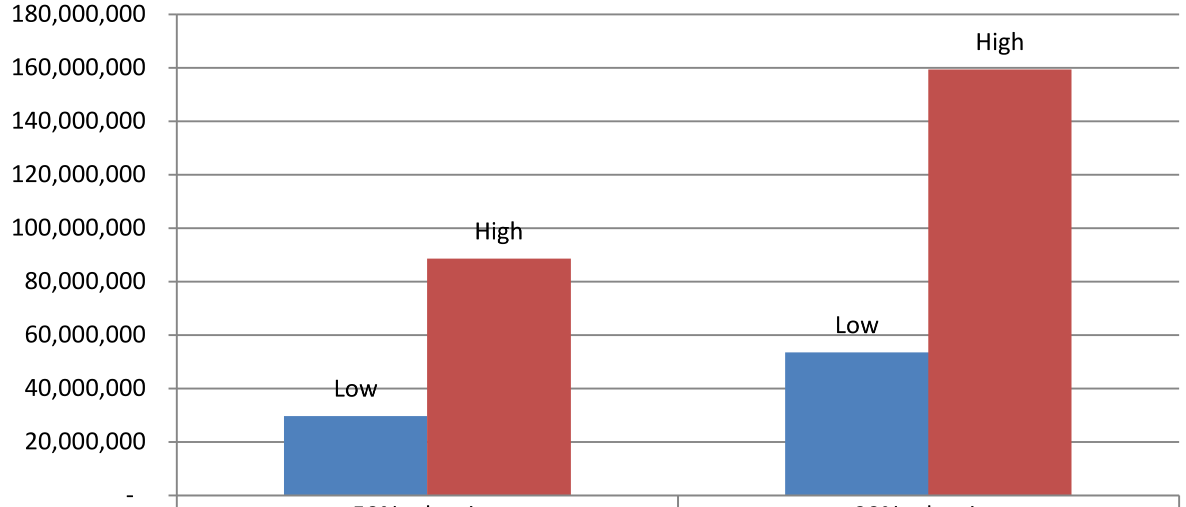
	50% adoption	90% adoption
Low	6,370,000	11,466,000
High	49,140,000	88,452,000

Figure 5: Potential aggregated farm level benefits of GM HT oilseed rape (InVigor) for Ukraine ($)



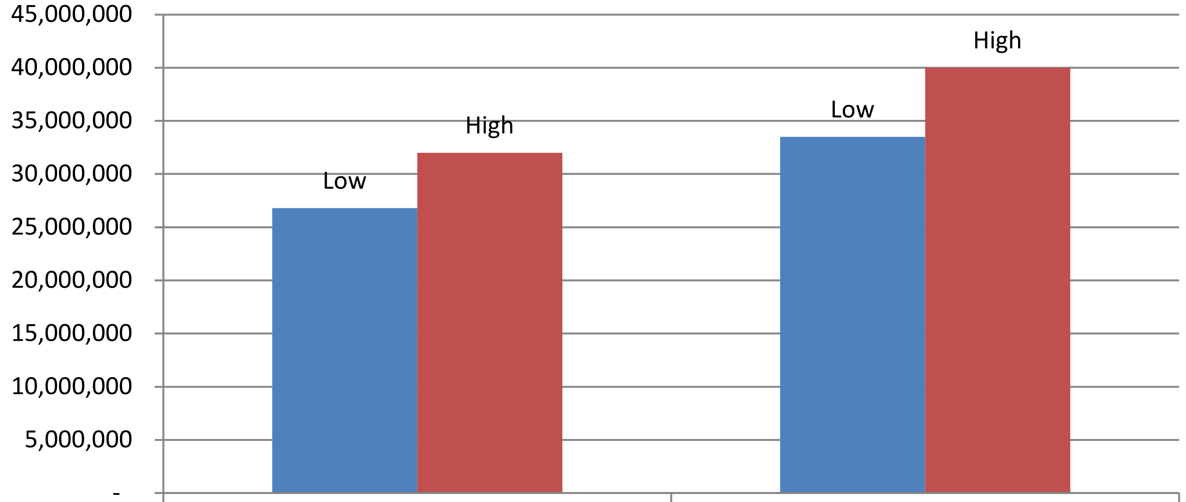
	50% adoption	90% adoption
Low	16,835,000	30,303,000
High	34,580,000	62,244,000

Figure 6: Potential aggregated farm level benefits of GM HT sugar beet for Ukraine ($)



	50% adoption	90% adoption
Low	29,700,000	53,460,000
High	88,550,000	159,390,000

Figure 7: Potential aggregated farm level benefits of GM IR maize (targeting corn boring pests) for Ukraine ($)



	Min area affected	Max area affected
Low	26,800,000	33,500,000
High	32,000,000	40,000,000

4.2 Production and supply availability

Table 23 summarises the potential annual impact on the production levels of the four main crops if existing commercialised GM traits were adopted in Ukraine. At the lower levels of area adoption and yield benefit assumptions, the impact at the crop level is about +0.9 million tonnes equal to +1.5% of the total production of the four crops (range of +1.1% to +2.5% by crop). At the higher levels of area adoption and yield benefit assumptions, a more significant potential annual production benefit of +3.2

million tonnes would arise, equal to 9.5% of total production of the four crops (range +4% to +15.7% by crop).

Table 23: Potential annual production impacts of using GM technology in Ukraine ('000 tonnes)

	Lowest area adoption and yield impacts	Highest area adoption and yield impacts	% change in total production: lowest impact	% change in total production: highest impact
Soybeans	+48.2	+260.3	+2.5	+13.7
Maize	+188.5	+663.8	+1.1	+4.0
Oilseed rape	+23.2	+167.1	+1.5	+11.1
Sugar beet	+230.7	+2,076.8	+1.7	+15.7

5 Environmental impacts

5.1 Changes in herbicide use

5.1.1 Background

Assessment of the impact of biotech crops on herbicide use requires comparisons of the respective weed control measures used on biotech versus the 'conventional alternative' form of production. This presents a number of challenges relating to availability and representativeness. Comparison data ideally derives from farm level surveys which collect usage data on the different forms of production. A search of literature on global biotech crop impact on herbicide use at the trait, local, regional or national level shows that the number of studies exploring these issues is limited (eg, Qaim and Traxler (2002)), with even fewer, providing data to the pesticide (active ingredient) level (eg, Brookes (2005)). Secondly, national level pesticide usage survey data is also extremely limited. In the case of Ukraine, there are no published annual pesticide usage surveys conducted by national authorities. Some data are collected, largely on an ad hoc basis by private market research companies, and these data, where available have been used in the analysis below.

The most common way in which changes in pesticide use with biotech crops has been presented in the literature has been in terms of the volume (quantity) of pesticide applied. Whilst comparisons of total pesticide volume used in biotech and conventional crop production systems are a useful indicator of associated environmental impacts, amount of active ingredient used is an imperfect measure because it does not account for differences in the specific pest control programmes used in biotech and conventional cropping systems. For example, different specific products used in biotech versus conventional crop systems, differences in the rate of pesticides used for efficacy and differences in the environmental characteristics (mobility, persistence, etc) are masked in general comparisons of total pesticide volumes used.

In this paper, the pesticide related environmental impact changes associated with biotech crop adoption are examined in terms of changes in the volume (amount) of active ingredient applied but supplemented by the use of an alternative indicator, developed at Cornell University in the 1990s, the environmental impact quotient (EIQ). The EIQ indicator, developed by Kovach et al (1992) and updated annually, effectively integrates the various environmental impacts of individual pesticides into a single 'field value per hectare'. The EIQ value is multiplied by the amount of pesticide active ingredient (ai) used per hectare to produce a field EIQ value. For example, the EIQ rating for glyphosate is 15.33. By using this rating multiplied by the amount of glyphosate used per hectare (eg, a hypothetical example of 1.1 kg applied per ha), the field EIQ value for glyphosate would be equivalent to 16.86/ha.

The EIQ indicator used is therefore a comparison of the field EIQ/ha for conventional versus biotech crop production systems, with the total environmental impact or load of each system, a direct function of respective field EIQ/ha values and the area planted to each type of production (biotech versus conventional). The EIQ indicator provides an improved assessment of the impact of biotech crops on the environment when compared to only examining changes in volume of active ingredient applied, because it draws on some of the key toxicity and environmental exposure data related to individual products, as applicable to impacts on farm workers, consumers and ecology. The EIQ does not take into account all environmental issues and impacts and is therefore not a comprehensive indicator.

5.1.2 Profile of the environmental impact of herbicide use on current crops in Ukraine

The analysis presented below relating to the use of herbicides and their associated environmental impact (as measured by the EIQ indicator), is derived from the private market research sources Kleffmann/AMIS Global and Gfk Kynetec. These are farm survey-based sources of information on herbicide use.

On the basis of these survey data, Table 24 shows the breakdown of average active ingredient use and the associated EIQ profile of herbicides used on the four crops examined in this study for 2010/11.

Table 24: Conventional crops of relevance: Ukraine 2010/11 average herbicide use

Crop	Average amount of active ingredient used/ha (kg/ha)	Average field EIQ/ha
Oilseed rape:		
- Winter	0.63	9.77
- Spring	0.53	10.72
Soybeans	1.44	27.30
Maize	1.03	22.00
Sugar beet	1.66	43.08

Source: derived from Kleffmann/AMIS Global and Gfk Kynetec

5.1.3 Potential impact on herbicide use and the associated environmental impact from use of GM HT technology

Table 25 shows the potential profile for herbicide use on GM HT crops in Ukraine[29]. This shows that:

- *Oilseed rape*: the likely herbicide regimes that might be adopted with the adoption of GM HT (to glyphosate or glufosinate) technology in winter oilseed rape[30] show that there would be an average 9% reduction in the amount of herbicide active ingredient and a 10% improvement in the environmental profile per ha from the use of glyphosate tolerant oilseed rape. For glufosinate tolerant oilseed rape, the amount of active ingredient used per ha would fall by 43% and the associated environmental profile would improve by 23%;
- *Soybeans*: the potential GM HT herbicide regimes would result in a 9% reduction in the average amount of active ingredient applied per ha and a 15% reduction in the associated EIQ value;
- *Maize*: the likely profile for herbicide regimes used with GM HT maize suggests that the adoption of this technology would result in a 7% reduction in the average amount of herbicide active ingredient applied per ha and a 29% improvement in the associated environmental profile;

[29] Additional information is presented in Appendix 1

[30] Which accounts for 90% of the total crop

- *Sugar beet*: the herbicide regimes used with GM HT sugar beet would potentially lead to a 9% reduction in the average amount of herbicide active ingredient applied per ha and a 46% improvement in the associated environmental profile.

Table 25: GM HT crops in Ukraine: potential average herbicide use

Crop	**Average amount of active ingredient used/ha (kg/ha)**	**Average field EIQ/ha**
Oilseed rape: - Winter - Spring	 0.364-0.576 As above	 7.55-8.83 As above
Soybeans	1.312	23.21
Maize	0.954	15.6
Sugar beet	1.51	23.18

Notes:

1. Suggested profiles of active ingredients likely to be used and amounts: see section 3
2. GM HT oilseed rape range for glyphosate and glufosinate tolerant crops (lower end of range is glufosinate tolerant, higher end of range is glyphosate tolerant)

The potential total environmental impacts associated with changes in herbicide use from the adoption of GM HT technology in Ukraine will depend on the level of adoption of each trait. Using the same adoption scenarios examined in section 4 (50% and 90%[31]), Table 26 and Table 27 summarise the potential changes in active ingredient use and the associated environmental impact as measured by the EIQ indicator. At the 50% adoption level, total herbicide active ingredient use across the four crops would fall by between 4.4% and 6.1% (about 0.24 million to 0.33 million kg), with a higher 14.8% to 15.3% decrease in the EIQ value. At the higher levels of adoption that are similar to levels of adoption in current countries using these technologies, the likely fall in total active ingredient use across the four crops is -7.1% (almost -0.39 million kg) to -7.8% (-0.42 million kg). In terms of the associated environmental impact as measured by the EIQ indicator, this would fall by about 24%.

Table 26: 50% adoption: changes to amount of herbicide active ingredient use and associated environmental impact (as measured by the EIQ indicator)

	Change in active ingredient use (kgs)	**% change in ai use**	**% change in EIQ rating**
GM HT oilseed rape Glyphosate tolerant Glufosinate tolerant	 -21,644 -118,104	 -4.6 -25.2	 -6.3 -14.2
GM HT maize	-99,233	-6.5	-11.4
GM HT soybeans	-75,872	-6.5	-11.4
GM HT sugar beet	-40,829	-4.9	-25.8
Total	**-237,079 to -333,539**	**-4.4 to -6.1**	**-14.8 to -15.3**

[31] The higher adoption for GM HT maize being 70%

Table 27: 90% adoption (70% GM HT maize): : changes to amount of herbicide active ingredient use and associated environmental impact (as measured by the EIQ indicator)

	Change in active ingredient use (kgs)	% change in ai use	% change in EIQ rating
GM HT oilseed rape			
Glyphosate tolerant	-38,960	-8.3	-11.4
Glufosinate tolerant	-212,588	-45.3	-25.5
GM HT maize	-138,927	-4.6	-18.7
GM HT soybeans	-136,570	-11.7	-20.5
GM HT sugar beet	-72,593	-8.9	-46.5
Total	**-387,049 to -424,107**	**-7.1 to -7.8**	**-23.7 to -24.6**

5.2 Changes in insecticide use

Any change in insecticide use associated with the adoption of GM IR technology in maize will be limited because only a limited area of conventional maize has traditionally received insecticide treatments targeting corn boring pests (about 100,000 ha annually). On the basis that GM IR (targeting corn boring pests) technology would allow these treatments to stop, the annual saving in insecticide use would be about 23,000 kgs of insecticide active ingredient. As there is no history of using insecticides for the treatment of corn rootworm pests, the adoption of GM IR technology targeting corn rootworm would not result in any insecticide savings relative to current usage patterns.

5.3 Possible sources of greenhouse gas emission savings and assumptions used

Reductions in the level of greenhouse gas emissions (GHG) associated with the adoption of biotech crops are acknowledged in a wide body of literature including CTIC (2002), Fabrizzi et al (2003), Jasa (2002), Lazarus and Selley (2005), Reicosky (1995), Robertson et al (2000), Johnson et al (2005), Liebig (2005) and West and Post (2002).

First, biotech crops contribute to a reduction in fuel use due to less frequent herbicide or insecticide applications and a reduction in the energy use in soil cultivation. Lazarus (2011) estimated that one pesticide spray application uses 1.31 litres of fuel which is equivalent to 3.5 kg/ha of carbon dioxide emissions.

In addition, there has been a shift from conventional tillage to reduced/no till. This has had a marked impact on tractor fuel consumption due to energy intensive cultivation methods being replaced with no/reduced tillage and herbicide-based weed control systems. The GM HT crop where this is most evident is GM HT soybeans. Here adoption of the technology has made an important contribution to facilitating the adoption of reduced or no tillage farming[32]. Before the introduction of GM HT soybean cultivars, no tillage (NT) systems were practiced by some farmers using a number of herbicides and with varying degrees of success. The opportunity for growers to control weeds with a

[32] See for example, CTIC 2002 and American Soybean Association (2001)

non-residual foliar herbicide as a "burndown" pre-seeding treatment followed by a post-emergent treatment when the soybean crop became established has made the NT systems more reliable, technically viable and commercially attractive. These technical advantages combined with the cost advantages have contributed to the rapid adoption of GM HT cultivars and the near doubling of the NT soybean area in the US (also more than a fivefold increase in Argentina). In both countries, GM HT soybeans have accounted for over 95% of the NT soybean crop area since 2008.

In the context of Ukraine, however, NT production systems are not widely practiced. One important factor behind this relates to the lack of suitable machinery and equipment for practicing NT production systems and the lack of capital with which to fund such equipment. As such, whilst GM HT technology has facilitated the adoption of NT production systems in North and South America, it is unlikely to perform a similar role in Ukraine in the next few years (if the technology was allowed for commercial use) because of these problems.

For the purposes of this paper, it is therefore assumed that GM HT technology would not contribute to any change from a plough to a NT production system in Ukraine arable crop production systems or any associated fuel savings resulting from changes in tillage systems used. Hence, any GHG emission savings identified in this paper are solely attributed to savings in fuel use associated with reduced incidence of herbicide and insecticide spraying.

Examining the average frequency of herbicide and insecticide applications in the four Ukraine crops, Table 28 summarises the differences between conventional and GM HT production systems. This suggests the use of GM HT technology would result in small reductions in the number of herbicide applications.

Table 28: Average number of herbicide applications for the four crops: Ukraine

Crop	Conventional	GM HT (likely average)
Oilseed rape	1	1
Maize	1.4	1.2
Soybeans	1.5	1.2
Sugar beet	3	2
Total	*6.9*	*5.4*
Saving		*1.5*

Drawing on the analysis above relating to fuel and carbon dioxide emissions associated with a typical spray application (1.31 litres of fuel which is equivalent to 3.5 kg/ha of carbon dioxide emissions), this suggests that each hectare of GM HT will potential result in a 1.96 litre fuel saving (and 5.25 kg/ha carbon dioxide saving) relative to conventional crops.

The potential annual fuel savings from the adoption of GM technology will depend on the level of adoption. Using the two adoption scenarios analysed above, Table 29 suggests that the potential annual fuel and carbon dioxide savings associated with adoption of GM technology could reach 1.56 million litres and 5.35 million kgs of carbon dioxide (Table 29).

Table 29: Potential fuel and carbon dioxide savings from GM crop adoption

	Fuel saved: 50% adoption (million litres)	Fuel saved: 90% adoption (70% GM HT corn: million litres)	Carbon dioxide savings: 50% adoption (million kg)	Carbon dioxide saved: 90% adoption (70% GM HT corn: million kg)
Oilseed rape	Nil	Nil	Nil	Nil
Maize	0.265	0.371	0.927	1.298
Maize: insect resistance	0.131	0.131	0.350	0.350
Soybeans	0.156	0.281	0.546	0.982
Sugar beet	0.360	0.648	1.261	2.270
Total	**0.781**	**1.300**	**2.733**	**4.549**

Examining further the context of these carbon dioxide savings, in terms of car use equivalents, this shows that the annual permanent carbon dioxide savings from reduced fuel use would be the equivalent of taking 2,200 cars off the road for a year.

Appendix 1: Potential herbicide regimes for GM HT crops in Ukraine

GM HT winter oilseed rape

Active ingredient	Amount (kg/ha of crop)	Field EIQ/ha
Glyphosate tolerant		
Option one: glyphosate	0.48	7.35
Option 2: glyphosate	0.96	14.7
Weighted average (based on 80% of option 1 and 20% of option 2)	*0.576*	*8.83*
Conventional	0.63	9.77
Difference to conventional	**-0.054**	**-0.94**
Glufosinate tolerant		
Option 1 Glufosinate Quizalofop *Total*	 0.24 0.10 *0.34*	 4.85 2.21 *7.06*
Option 2 Glufosinate Quizalofop *Total*	 0.36 0.10 *0.46*	 7.27 2.21 *9.48*
Weighted average (based on 80% of option 1 and 20% of option 2)	*0.364*	*7.55*
Difference to conventional	**-0.27**	**-2.22**

Note: Herbicide adoption weightings based on consideration of current conventional usage patterns for average, intensive and extensive producers

GM HT maize

Active ingredient	Amount (kg/ha of crop)	Field EIQ/ha
Option one: Glyphosate	 0.81	 12.39

Atrazine *Total*	0.72 *1.53*	15.84 *28.23*
Option 2: glyphosate	*0.81*	*12.39*
Weighted average (based on 20% of option 1 and 80% of option 2)	*0.954*	*15.56*
Conventional	1.03	22.0
Difference to conventional	**-0.07**	**-6.44**

Note: Herbicide adoption weightings based on consideration of current conventional usage patterns for average, intensive and extensive producers

GM HT soybeans

Active ingredient	**Amount (kg/ha of crop)**	**Field EIQ/ha**
Option one: Glyphosate 2 4 D *Total*	 0.72 0.6 *1.32*	 11.04 12.42 *23.46*
Option 2: Glyphosate Metribuzin *Total*	 1.08 0.2 *1.28*	 16.56 5.67 *23.23*
Weighted average (based on 80% of option 1 and 20% of option 2)	*1.312*	*23.21*
Conventional	1.44	27.5
Difference to conventional	**-0.13**	**-4.3**

Note: Herbicide adoption weightings based on consideration of current conventional usage patterns for average, intensive and extensive producers

GM HT sugar beet

Active ingredient	**Amount (kg/ha of crop)**	**Field EIQ/ha**
Option one: glyphosate	1.08	16.56

Option 2: glyphosate	1.62	24.83
Weighted average (based on 20% of option 1 and 80% of option 2)	*1.51*	*23.2*
Conventional	1.66	43.1
Difference to conventional	**-0.15**	**-19.9**

Note: Herbicide adoption weightings based on consideration of current conventional usage patterns for average, intensive and extensive producers

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