4

MEASURING THE BENEFITS

The impacts of first-generation genetically modified crops

KEY THEMES

- Higher farm incomes.
- Qualitative advantages for farmers.
- Impact on production volumes.
- Environmental benefits, including reduced CO_2 emissions.

The methods and techniques of modern genetic modification (GM) started to become commercially available in the mid-1990s. So what benefits have farmers derived from them? How has the use of GM-enhanced crops paid off in economic and environmental terms? Studies of three major food crops – soybeans, maize and rapeseed – together with cotton, provide some insights.

Impacts on farm income

In general, GM technology has had a significant positive impact on global farm income as a result of enhanced productivity and efficiency. Table 4.1, which tracks changes from 1996 to 2011, shows incomes increasing by US$ 98.2 billion, with the value of GM crops totalling US$ 19.8 billion in 2011 alone. This means that more than 6 per cent was added to the value of the four crops in question.

Looking more closely at cotton, which has shown the biggest yield gains, the new GM insect-resistant variety raised incomes from cotton by an impressive 14 per cent during the period under study. Substantial gains in farm income are also seen globally in the maize sector, where the adoption of GM crops has resulted in both lower costs and higher yields.

Table 4.1 Income benefits from genetically modified crops, 1996–2011

Worldwide

	Increase in farm income Million US$		Farm income benefit in 2011 as % of total value of:	
	2011	1996–2011	production of crop in GM-adopting countries	global production of crop
GM HT soybeans	3,879.2	32,211.9	3.8	3.2
GM HT maize	1,540.2	4,212.2	1.5	0.7
GM HT cotton	166.9	1,224.1	0.4	0.3
GM HT rapeseed	433.2	3,131.4	1.4	1.2
GM IR maize	7,104.9	25,762.0	6.8	3.3
GM IR cotton	6,559.6	31,263.2	14.7	11.6
Others	83.3	412.0	–	–
Total	19,767.3	98,216.8	6.3	5.9

Source: Brookes and Barfoot, 2013

Notes: HT = herbicide tolerant; IR = insect resistant. Others = virus-resistant papaya and squash and herbicide-tolerant sugar beet. Income calculations are net farm income changes after inclusion of impacts on yield, crop quality and key variable production costs (e.g. payment for seeds and crop protection).

Table 4.2 Income benefits from genetically modified crops, 1996–2011

Selected countries, million US$

	GM HT soybeans	GM HT maize	GM HT cotton	GM HT rapeseed	GM IR maize	GM IR cotton	Total
USA	13,835.9	3,110.5	924.8	241.5	21,497.3	3,769.4	43,379.4
Argentina	12,624.6	510.5	89	–	380.7	362.3	13,967.1
Brazil	4,314.5	431.5	82.6	–	1,796.9	19.9	6,645.4
Paraguay	732.4	–	–	–	–	–	732.4
Canada	231.6	66.7	–	2,862.5	820.5	–	3,981.3
South Africa	7.0	3.8	3.0	–	887.3	31.6	932.7
China	–	–	–	–	–	13,067.8	13,067.8
India	–	–	–	–	–	12,579.5	12,579.5
Australia	–	–	58.4	27.5	–	525.4	611.3
Mexico	4.9	–	51.4	–	–	123.9	180.2
Philippines	–	88.2	–	–	176.2	–	264.4
Romania	44.6	–	–	–	–	–	44.6
Uruguay	83.4	–	–	–	11.7	–	95.1
Spain	–	–	–	–	139.1	–	139.1
Other EU	–	–	–	–	16.2	–	16.2
Colombia	–	0.9	14.9	–	29.2	13.7	58.7
Bolivia	327.0	–	–	–	–	–	327.0
Myanmar	–	–	–	–	–	338.7	338.7
Pakistan	–	–	–	-	–	334.2	334.2

Source: Brookes and Barfoot, 2013

Farmers in the developing world have enjoyed a slightly larger share of global income gains from genetically modified crops than those in the developed world.

Notes: HT = herbicide tolerant; IR = insect resistant. Income calculations are net farm income changes after inclusion of impacts on yield, crop quality and key variable production costs (e.g. payment for seeds and crop protection).

While GM varieties cost more owing to the technology fee charged by agro-biotech companies to cover the costs of development and regulatory compliance, they are still being adopted by farmers because they generate greater profit through improved yields.

How are the general income gains reflected in the individual countries that have adopted new genetic crops? Table 4.2 shows how economically important GM soybeans have been in South America and GM cotton in China and India. A range of GM crops in the USA, South Africa, the Philippines, Mexico and Columbia, too, have proven beneficial.

Farmers in developing countries have enjoyed a slightly larger share of global income gains than those of the developed world – with roughly 55 and 45 per cent of the total respectively – largely through the adoption of GM cotton and soybeans. However, the relative cost of switching to the new crops has been substantially lower for farmers in the developing world, representing 17 per cent of their income gains, with the corresponding figure in the developed world being 37 per cent. This disparity may be due to relative weakness in providing or enforcing intellectual property rights, or may be down to differences in relative gains per hectare planted.

Other economic impacts at farm level

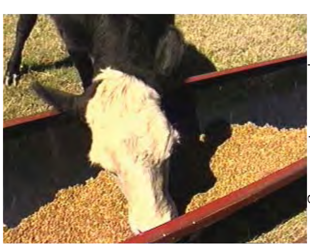
The new GM crops appear to have a number of other, less tangible effects on the profitability of farms, which are difficult to quantify. Even so, these seem to be the most important reasons why farmers embrace the new technologies.

Herbicide tolerance

By growing crops that tolerate modern, broad-spectrum herbicides such as glyphosate, farmers have more time for other activities, including off-farm money-generating enterprises. Also, with conventional crops, herbicides need to be applied after weeds and crops are established, and the herbicide often then impairs the crop's growth, so-called knock-back. Novel GM crops are not affected by this because they are tolerant to herbicides.

Herbicide tolerance facilitates no-till systems by reducing the need for mechanical weed control, so there are cost savings on labour and fuel. And minimising soil disturbance improves moisture retention and reduces soil erosion. Improved weed control means, too, that harvesting costs are reduced because crops are relatively weed-free at harvest time.

Soybeans represent a large share of global agriculture, but few make it to the table as beans. Around 85 per cent of the crop is turned into vegetable oil and high-protein meal, and much of this is fed to livestock.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And because GM herbicide-tolerant crops tolerate broader-spectrum herbicides, herbicide use can actually be reduced, with positive implications for soil quality and less damage to follow-on crops from herbicide residues. In addition, lower herbicide levels create healthier conditions for farmers, local people and the broader environment by reducing poisoning from spray drift or inappropriate application methods.

Insect resistance

Genetic modification takes away much of the worry associated with heavy pest damage – a benefit in itself. But it also reduces insurance premiums for farmers, which in the USA has amounted to savings of around US$ 138 million over just three years. There are also savings in the time and labour spent inspecting crops and applying insecticides, along with a reduced energy use from avoiding aerial spraying.

Crops are of higher quality. Insect-resistant GM maize, for example, seems to show lower levels than conventional plants of mycotoxins – toxic fungal products on maize plants infected by fungi because of damage by corn-boring pests. These plants also have a shorter growing season, allowing farmers in India, for example, to plant a second maize crop in the same season.


USDA/PD

Insect-resistant maize varieties are able to withstand the maize weevil, which attacks crops both pre-and post-harvest. And it doesn't just stick to maize – it also feasts on wheat, rice, sorghum, oats, barley, rye, buckwheat, cassava, peas...

As with herbicides, there are health advantages for farmers and farm workers who handle fewer pesticides and for local people from reduced spray drift. And there are also environmental advantages – particularly for beneficial fauna such as pollinating insects.

Putting a monetary value on the less tangible advantages of the new genetic crops is quite difficult. But a number of studies in the USA based on surveys of maize, soybeans and cotton show improvements in value of between US$ 7 and US$ 25 per hectare. This amounted, in 2010, to an estimated total annual benefit of more than US$ 1 billion.

Impacts on production volumes

The improvements in yield made possible by GM technology feed directly into higher crop production totals. Table 4.3 shows the added tonnage worldwide for 1996–2011.

Environmental impacts – the EIQ

Changes in insecticide and herbicide use brought about by GM crops have had a number of positive effects on the environment in its broadest sense, including impacts on the health of both humans and wildlife. One useful measure of these effects is the Environmental Impact Quotient – EIQ – which combines the various environmental and health impacts into one single per-hectare value.

Table 4.3 Contribution of genetically modified crops to yields, 1996–2011

Worldwide, million tonnes

	Additional (GM) production	
	1996–2011 total for period	2011
Soybeans	110.20	12.74
Maize	195.00	34.54
Cotton	15.85	2.48
Rapeseed	6.55	0.44
Sugar beet	0.45	0.13

Source: Brookes and Barfoot, 2013

Note: Sugar beet is for the USA and Canada only, and from 2008.

Table 4.4 Impact of changes in the use of pesticides owing to genetically modified crops, 1996–2011

Worldwide

	Area of GM crops in 2011 Million hectares	Change in volume of active ingredient used Million kilos	Change in field EIQ Million field EIQ/hectare units	Change in active ingredient used on GM crops %	Change in EIQ associated with pesticide* use on GM crops %
GM HT soybeans	73.2	-12.5	-6,444.2	-0.6	-15.5
GM HT maize	35.1	-193.1	-5,168.0	-10.1	-12.5
GM HT cotton	4.5	-15.5	-420.9	-6.1	-8.9
GM HT rapeseed	7.3	-14.8	-501.5	-17.3	-27.1
GM HT sugar beet	0.46	0.87	-3.3	23.9	-4.1
GM IR maize	37.8	-50.0	-1,884.2	-45.2	-41.7
GM IR cotton	22.2	-188.7	-8,498.0	-24.8	-27.3
Total	180.56	-473.73	-22,920.1	-8.9	-18.3

Source: Brookes and Barfoot, 2013

Like the IQ scale for measuring human intelligence, the EIQ has its limitations, but it does give us a working tool for making comparisons. Worldwide, for example, the use of insecticides and herbicides on the total GM crop area has fallen by 9 per cent since 1996, whereas the environmental impact associated with their use has fallen by practically twice as much (Table 4.4).

The Environmental Impact Quotient (EIQ) measures the impact of herbicides and pesticides on human and wildlife health. A minus figure indicates improvement.

Notes: HT: herbicide tolerant; IR: insect resistant; *herbicides and insecticides.

In terms of the volumes of pesticides used and the number of hectares treated, the largest environmental benefit revealed by the EIQ is from GM insect-resistant cotton, while in percentage terms it is GM insect-resistant maize that shows the greatest fall in both pesticide use and adverse environmental impact. But particularly impressive is the positive effect of GM soybeans. Here, herbicide use has dropped by less than 1 per cent, but the EIQ indicates a fall in adverse environmental impacts of more than 15 per cent.

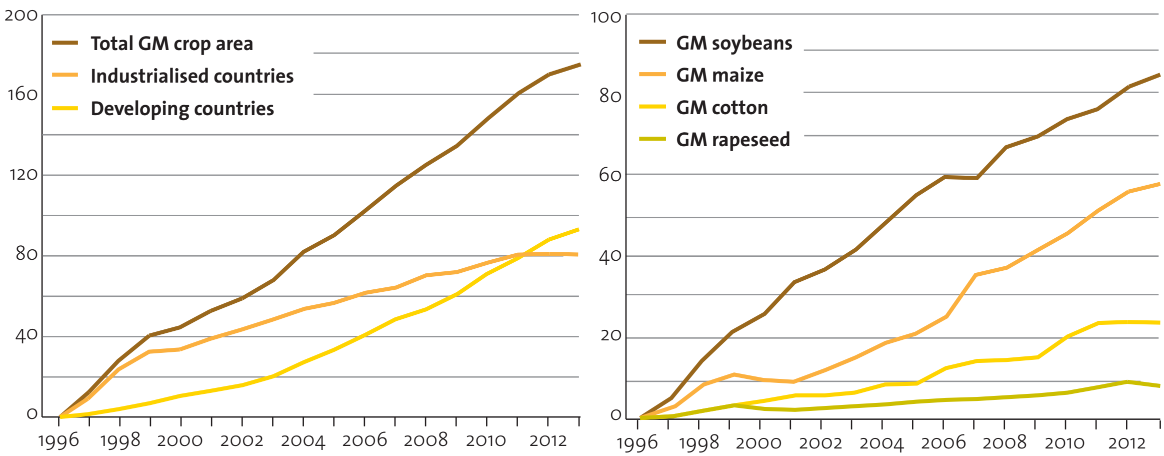
The environmental benefits associated with lower use of herbicides and insecticides as measured by the EIQ vary a little between developed and developing countries, with the developed countries enjoying a 55:45 advantage. Most of the developing countries' gains come from insect-resistant GM cotton.

Greenhouse gas emissions

New GM crops have already made a considerable contribution towards lowering levels of greenhouse gases, principally carbon dioxide (CO_2). There are two main mechanisms.

Figure 4.1 Growth in genetically modified crops by area and crop type, 1996–2013

Million hectares



Source: ISAAA

- Less frequent herbicide or insecticide applications means lower fuel use, which in turn drives down CO2 emissions. In 2010 alone, farmers worldwide reduced their fuel consumption by just over 642 million litres, with the result that 1,715 million kilos less CO2 found its way into the atmosphere. That is the equivalent to taking 763,000 cars off the road.
- More no-till or low-till farming has a direct impact on the amount of tractor fuel farmers use. In addition, because soil quality is enhanced and erosion reduced, more carbon tends to remain within the soil. This sequestering effect is estimated to have cut atmospheric emissions by 17,634 million tonnes in 2010. Nearly 8 million cars would need to come off the world's roads to reach that figure.

A record 18 million farmers in 27 countries planted 175.2 million hectares of genetically modified crops in 2013, an increase of 3 per cent – or 5 million hectares – on 2012.

Two kinds of contribution

In the 17 years or more since the new GM technologies came on stream, they have improved productivity and profitability for more than 18 million farmers around the world. By 2013, these advantages were seen across more than 175 million hectares of agricultural land (Figure 4.1). Developing countries, with 54 per cent of the global hectarage in 2013, grew more GM crops than industrial countries, with 46 per cent.

These important socio-economic and environmental benefits have come about through a combination of inherent technical advances and by facilitating more cost-effective and environmentally friendly farming practices. Summarising specifically:

Reducing herbicide and pesticide use creates healthier conditions for farmers, their workers and neighbours, as well as the broader environment.

- Direct technological advances in GM insect resistance have improved yields, reduced production risks and decreased pesticide use. This has enabled farmers to enjoy higher returns while, at the same time, being able to practise farming methods that may be less damaging to the environment.
- The herbicide-tolerance traits developed through GM have benefited farmers both by lowering costs and by facilitating changes in farming systems, such as enabling them to use low-cost broad-spectrum herbicides. This in turn has enabled a move away from conventional plough-based production systems to low- or no-till systems.