

Green Biotechnology and Climate Change

What role is green biotechnology playing in helping to fight climate change? How will that role evolve in future? Whilst not an exhaustive overview of these issues, this document illustrates the benefits that green biotechnology can have in the areas of greenhouse gas reduction, crop adaptation to climate change and dealing with the twin issues of climate change and population growth.

Essential fact: GM crops can, and already do, contribute positively by reducing CO₂ emissions and mitigating the impact of climate change on food security. This contribution will increase as their cultivation is more widely adopted in Europe and around the world.

Climate change – a clear and present danger

Climate change threatens all elements essential for life: water, food, health, land and the environment. The 2006 report¹ by economist, Nicholas Stern, commissioned by the UK government, warned that temperatures could increase by 2 to 3 degrees in the next fifty years, and, if nothing is done, by as much as 5 to 8 degrees by the end of the century – a catastrophic scenario.

Its most obvious manifestation would be the change in weather conditions: more heat waves, storms and floods caused by melting glaciers (which could affect more than 30% of the world's agricultural lands). Unabated, **climate change could cost the world at least 5% of GDP** each year; if more dramatic predictions come to pass, the cost could rise to more than 20% of GDP. The chart below shows some of these effects.

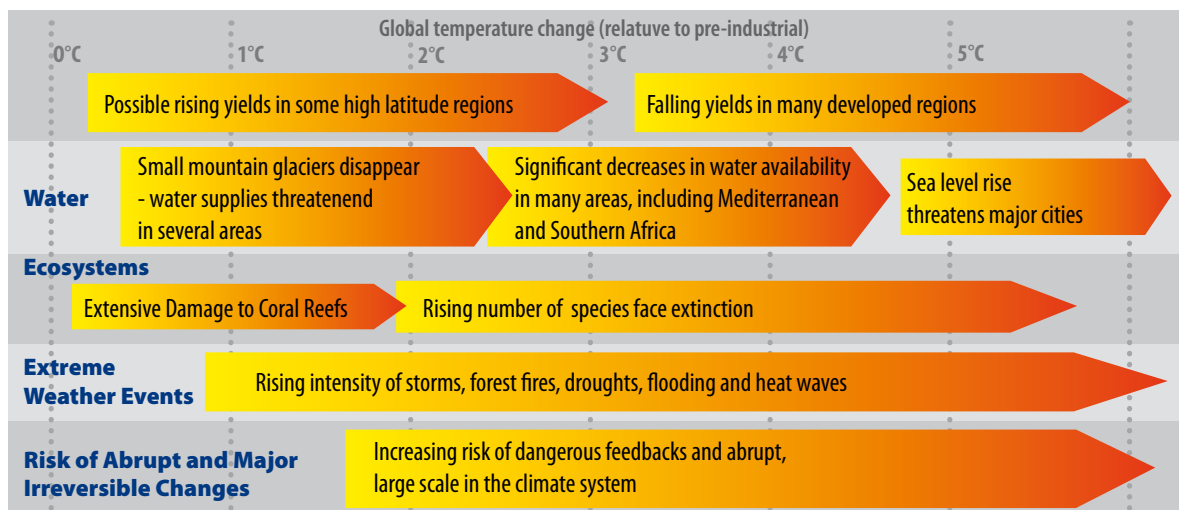
Among the other worrying consequences of climate change predicted by the Stern Report are declining crop yields, ocean acidification, malnutrition and heat stress, population displacement and threatened ecosystems. These effects could be particularly dramatic in the light of **growing population levels**: in order to feed the overall population, the world faces the daunting task of having to double its rate of agricultural production over the next 25 years², having already quadrupled it in the last 50 years.

There is no doubt that the changing meteorological conditions associated with climate change will have an **impact on agricultural yields**. Farmers will have to find new technological solutions to cope with these challenges. Addressing climate change will require substantial efforts; policies will have to be developed now, and then adapted over several decades in light of experience with implementation and evolving scientific and technical understanding.

Given the likely impacts of climate change on agricultural productivity and the role played by agricultural practices in contributing to global warming, agricultural biotechnology techniques must play a role as one of the solutions available in the fight against climate change. Green biotechnology offers a "toolbox" which can help farmers produce food sustainably through:

1. Greenhouse gas (GHG) emission reduction
2. Crop adaptation
3. Crop protection and increased yield from less available arable land

Projected Impacts of Climate Change



GREENHOUSE GAS REDUCTION

Context³

Agriculture is a major source of greenhouse gas emissions. Agricultural practices – such as deforestation, cattle feedlots and fertilizer use – currently account for about 25% of all greenhouse gas emissions and 14% of all EU CO₂ emissions. Agriculture is also a major source of methane and nitrous oxide (N₂O), with latest estimates showing that it accounts for 48% of methane emissions and 52% of N₂O emissions in the EU. Implementing sustainable agricultural practices is therefore now more important than ever before.

Solutions

Whilst there is no one solution to these problems, given the likely impacts of climate change on agricultural productivity and the role played by agricultural practices in contributing to global warming, agricultural biotechnology techniques will play a role as one of the solutions available in the fight against climate change. Green biotechnology can help farmers produce food sustainably through:

- i) Less fuel consumption on farms through a reduced need to spray crops**
- ii) Carbon sequestration**
- iii) Reduced fertilizer use and N₂O emissions**

Less fuel consumption on farms

GM herbicide tolerant crops help farmers by reducing the need to plough fields in preparation for planting crops saving fuel. This resultant reduction in tractor use also helps to protect the structure of the soil which reduces erosion. The agricultural practice of ploughing is also known as 'tillage' and the second example below explains how GM crops reduce fuel use by allow for the adoption of 'reduced tillage' or 'no tillage' systems. In addition, GM Insect Resistant Crops have been developed to require fewer insecticide treatments. This in turn means a reduction in fuel use and lower CO₂ emissions since farmers need to spray pesticides less frequently on their fields.

Data and examples

- Barfoot and Brookes' study (2009)⁴ indicated that, in terms of greenhouse gases, each litre of tractor diesel consumed contributes an estimated 2.75 kg of CO₂ into the atmosphere. Therefore, the fuel savings associated with making fewer spray runs (relative to conventional crops) have resulted in permanent cuts in CO₂ emissions. In 2007 this amounted to a reduction of 1,144 million kg of CO₂ (arising from a reduction of 416 million litres of fuel). Over the period 1996 to 2007 the cumulative permanent reduction in fuel use was estimated at 7,090 million kg of CO₂ (arising from a reduction of 2,578 million litres of fuel).
- The adoption of reduced tillage or no-tillage systems in respect of fuel use results in reductions of carbon dioxide emissions of 88.81 kg/ha and 35.66 kg/ha respectively.



How much more fuel could be saved?

Carbon sequestration

Soil carbon sequestration will be an important part of any international strategy to mitigate the increase in atmospheric CO₂ concentrations. By adopting more sustainable management practices, agriculture can play a large part in enhancing global soil carbon sequestration. One way is by reducing the amount of conventional tillage.

As previously mentioned, crops developed with agricultural biotechnology reduce the need for tillage or ploughing, allowing farmers to adopt conservation or “no-till” farming practices. As a result, over time soil quality is enhanced and becomes carbon-enriched since more crop residue can be left on the fields. In addition, since the soil is not inverted by ploughing, less carbon in the soil becomes oxidised through exposure to the air and therefore less CO₂ is released into the atmosphere.

Data and examples

- In 2007, the no-till area nearly doubled in the US and a 5-fold increase was recorded in Argentina, with GM herbicide tolerant (HT) soybeans estimated to account for 95% of the no-till soybean area⁵. Besides soil preservation, no-tillage agriculture saves fossil fuel use in tractors, and decreases the economic costs and environmental impact of productive farming.
- According to Barfoot and Brookes (2009)⁶, the additional amount of soil carbon sequestered since 1996 has been equivalent to 83,179 million tonnes of carbon dioxide which would otherwise have been released into the global atmosphere⁷. Those soil carbon savings have arisen from the rapid adoption of new farming systems in North and South America, for which the availability of GM HT technology has been cited by many farmers as an important facilitator. GM HT technology has been a key contributor to this increase in soil carbon sequestration, though it is not the only influential factor.
- Details of the carbon dioxide savings for 2007, identified by Brookes and Barfoot are shown in the table below

Context of carbon sequestration impact 2007: car equivalents

Crop/trait/country	Permanent carbon dioxide savings arising from reduced fuel use (million kg of carbon dioxide)	Average family car equivalents removed from the road for a year from the permanent fuel savings ('000s)	Potential additional soil carbon sequestration savings (million kg of carbon dioxide)	Average family car equivalents removed from the road for a year from the potential additional soil carbon ('000s)
US: GM HT soybeans	247	110	3,999	1,777
Argentina:	609	271	6,136	2,727
GM HT soybeans				
Other countries:	91	40	1,341	596
GM HT soybeans				
Canada: GM HT canola	131	58	1,627	723
Global GM IR cotton	37	16	0	0
Total	1,115	495	13,103	5,823

Notes: Assumption: an average family car produces 150 grams of carbon dioxide of km. A car does an average of 15,000 km/year and therefore produces 2,250 kg of carbon dioxide/year

Reduced fertilizer use

Nitrous oxide or N₂O has a global warming potential (GWP) of 296, or about 300 times greater than carbon dioxide. This means that one kilo of nitrous oxide is equivalent to 296 kilos of CO₂. In addition, nitrous oxide stays in the atmosphere for more than 100 years. N₂O from agricultural fields happens when nitrogen fertilizers applied to crops interact with common soil bacteria. It is estimated that nitrogen fertilizer accounts for one-third of the GHGs produced by agriculture (Stern Review 2006). Reduced fertilizer use will also mean less nitrogen pollution of ground and surface waters.

Data and examples

- GM rice and canola has been developed⁸ that uses nitrogen more efficiently, so the plants need less fertilizer. This so-called “Nitrogen Use Efficiency” (NUE) technology produces plants with yields equivalent to conventional varieties but which require significantly less nitrogen fertilizer because they use it more efficiently. This technology has the potential to reduce the amount of nitrogen fertilizer lost by farmers every year due to leaching into the air, soil and waterways. In addition to environmental impacts, nitrogen costs can represent a significant portion of a farmer’s input costs and can have a major impact farmer profitability in Europe and elsewhere in the world.



Crop Adaptation

Context

Agriculture accounts for 70% of all water use; if current trends continue, predicted water shortages in agriculture have been identified as the single most significant constraint on crop production over the next 50 years. The gravity of the problem becomes apparent when we consider experts' predictions that agricultural output will need to double by 2050 to feed a growing population.

Whereas water shortages used to be rarely associated with northern European climates, today they are emerging as a source of concern. The European Commission's Directorate General for Agriculture working document on "Adaption to Climate Change: the Challenge for European Agriculture and Rural Areas", published in April 2009, outlines that high water-stress areas are expected to increase from 19% today to 35% by 2070 implying "significant changes in the quality and availability of water resources". Given that more than 80% of EU farmland is currently rain-fed, the implications are clear.

In many parts of the world, water is the biggest limiting factor in agriculture production: without adequate supply of water, crop yields are severely compromised. In Europe, this could have a damaging impact on food security; in developing countries, it can contribute to a downward spiral of poverty and poor nutrition.

Solutions

What role can GM crops play?

Agricultural biotechnology can play a significant role in enabling farmers to improve yield by using water more sustainably and helping to cope with water scarcity. This works in two main ways:

- i) By reducing water loss
- ii) By improving drought tolerance

i) Minimising water loss from agriculture

Agricultural biotech practices have been developed to reduce the amount of ploughing required before planting their crops. This means the soil surface is not inverted which helps trap soil moisture. Under drought conditions this can mean the difference between having a crop to harvest and crop failure. Less ploughing also means less fossil-fuel use, less CO₂ emissions and less soil erosion.

ii) Improving drought tolerance

Plants react to stresses such as drought by consuming large quantities of stored energy normally used for growth and seed production. Drought conditions can therefore drain the plant's energy reserves, resulting in irreversible damage to the plant or even death. Agricultural biotechnology practices which improve drought tolerance have an immediate positive impact on the plant's resilience – and the energy available to it for growth to maturity and seed production.

Current research projects

- Drought-tolerant maize has now entered the regulatory phase of development in the US, demonstrating that a GM solution to this important issue is well beyond the theoretical stage.
- The Water Efficient Maize for Africa (WEMA) partnership, led by the African Agriculture Technology Foundation (AATF), is a five-year public-private partnership aiming to develop new African drought-tolerant maize varieties incorporating the best technology available internationally. The varieties developed through the project will be distributed to African seed companies through AATF without royalty and made available to smallholder farmers as part of their seed business. The national agricultural research systems, farmers' groups, and seed companies participating in the project will contribute their expertise in field testing, seed multiplication, and distribution. The project will involve local institutions, both public and private, and in the process will expand their capacity and experience in crop breeding, biotechnology, and biosafety. The current timing for the availability of the crop is 2017. Kenya has recently announced its intention to commence field trials with this type of maize.
- Hybrid crops have been developed to tolerate drought and periodic water deficits. Over the next decade, several companies plan to introduce GM crops that will further improve drought tolerance. While no plant can grow without water, hybrids and varieties are being developed that use water sources more efficiently and therefore perform better during water deficits. Maintaining yields during water stress will help preserve grower incomes and yield more grain for the food and energy value chain, as well as reducing the need for irrigation.



Protected and increased yield with less surface

Context

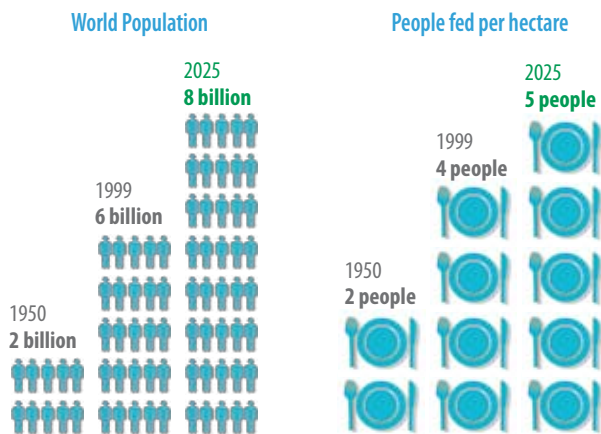
Rising temperatures and desertification are likely to reduce the land area available for farming. Moreover, by 2025, there will be 2.5 billion more people than today – a population boom that will lead to a 35% increase in demand for food supplies. According to a United Nations report, farmers will need to at least double their production over the next 25 years to feed all these people⁹. So combining food production with environmental protection will be a key challenge.

The major aim of agricultural biotechnology is to enhance agricultural productivity and maximise the productive capacity of our diminishing resources. As they have been designed to be more resistant, some species of GM crops are able to develop normally even in harsh conditions. Hence they can be a solution because higher productivity and yields are possible.

As an example, China faces the onerous task of feeding a fifth of the world’s population with less than a tenth of global farmland. Confronted with land degradation, chronic water shortages and a growing population that already numbers 1.3 billion, it is perhaps not surprising that China recently announced its intention to invest \$3.5 billion in research and development of GM plants.¹⁰

Green biotechnology provides options for farmers to help them adopt sustainable agricultural practices that can tackle tomorrow’s challenges. These crops are helping farmers to increase yields whilst using fewer precious natural resources and being more resistant to pests and diseases that are likely to spread in a changing climate.

Ever more mouths to feed



Source: FAO, World Bank



Data and examples

- One of the early successes of biotechnology was the ability to insert genes from a naturally occurring soil bacterium, *Bacillus thuringiensis* (Bt), into maize, cotton, and other crops to impart intrinsic protection from insect feeding. For many farmers, Bt crops are proving to be a valuable tool for integrated pest management programs by giving growers new pest control choices. This is also the case for fungal diseases, a real problem for farmers in maize and cereal cultivation. As well as causing yield losses, some fungi can also produce toxic substances known as “mycotoxins”. There are over 300 known toxins, each with specific effects. For example, high levels of fumonisin, one of those 300, is associated with oesophageal cancer and neural tube defects. Since fungal infections arise at the point of insect damage, Bt maize is a powerful tool to reduce the level of fumonisin which could have significant benefits in developing countries, especially where unprocessed maize is a key part of the diet.
- A recent survey conducted in the three leading Bt maize regions in Spain (Aragon, Catalonia and Castilla-La Mancha) showed that farmers adopting Bt maize experienced higher average yields than conventional growers for the three growing seasons studies (from 2002 to 2004). Over the three years, these higher yields were statistically most significant for the province of Zaragoza, with a yield increase of 11.8%¹¹. In France, a 2005 study of 13 plots of Bt maize¹² demonstrated an average gain was about 9.2 quintal per hectare compared to conventional maize.
- Across all of the maize growing regions affected by corn boring pests, the primary impact of the adoption of GM IR maize has been higher yields compared to conventional maize. Average yield benefits have often been +10% and sometimes higher, although impacts vary by region and year according to pest pressure (Brookes (2008))¹³
- The latest Brookes & Barfoot (2009) global impact study shows that since 1996, biotech traits have added 67.8 million tonnes and 62.4 million tonnes respectively to global production of soybeans and corn. The technology has also contributed an extra 6.85 million tonnes of cotton lint and 4.44 million tonnes of canola. The production of soybeans, corn, cotton and canola on the areas planted to biotech crops, in 2007, were respectively +29.8%, +7.6%, +19.8% and +8.5% higher than levels would have otherwise been if GM technology had not been used by farmers.
- This study also shows that if GM technology had not been available to the (12 million) farmers using the technology in 2007, maintaining global production levels at the 2007 levels would have required additional plantings of 5.9 million ha of soybeans, 3 million ha of corn, 2.5 million ha of cotton and 0.3 million ha of canola. This total area requirement is equivalent to about 6% of the arable land in the US, or 23% of the arable land in Brazil.

Footnotes

- ¹ Stern Review on the economics of climate change, HM Treasury, 2006
- ² Speech by Jack Wilkinson, President IFAP February 2008 <http://www.ifap.org/en/publications/documents/Finland-Speech.pdf>
- ³ "Environment and agriculture", Food and Agriculture Organization of the United Nations (2007)
- ⁴ Global impact of biotech crops: economic and environmental effects 1996-2007 Barfoot, P. and Brookes, G. (2009) www.pgeconomics.co.uk
- ⁵ Conservation Tillage and Plant Biotechnology: How New Technologies Can Improve the Environment By Reducing the Need to Plow" Richard Fawcett, Dan Towery, Conservation Technology Information Center
- ⁶ GM Crops: global socio-economic and environmental impacts 1996-2007, Barfoot P. and Brookes, G (2009)
- ⁷ These estimates are based on fairly conservative assumptions and therefore the true values could be higher. Also, some of the additional soil carbon sequestration gains from Reduced till/No Till systems may be lost if subsequent ploughing of the land occurs. As only an estimated 15-25% of the crop area is in continuous no-till

systems it is likely that the total cumulative soil sequestration gains have been lower than the 83,179 million tonnes referred to above. Estimating the possible losses that may arise from subsequent ploughing would be complex and difficult to undertake.

- ⁸ <http://www.arcadiabio.com/>
- ⁹ "State of World Population 2001," Chapter 2, Environment Trends, Moving Towards Food Security subhead", United Nations Population Fund, Nov. 7, 2001
- ¹⁰ www.sciencemag.org vol 321 5 September 2008, Richard Stone
- ¹¹ Bt maize in Spain—the performance of the EU's first GM crop, Nature, April 2008
- ¹² "Gm Maize in the field : conclusive results", Orama, 2007
- ¹³ Brookes G (2007) the benefits of adopting GM insect resistant (Bt) maize in the EU: first results from 1998-2006 www.pgeconomics.co.uk. Also in the International Journal of Biotechnology (2008) vol 10, 2/3 pages 148-166

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