Global Impact of Biotech Crops: economic and environmental effects 1996-2018

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Background

• 14th annual review of global GM crop impacts
• Authors of more than 30 papers on GM crop impacts in peer review journals
  ➤ Current review in 2 open access papers in journal GM Crops.
• Full report available at www.pgeconomics.co.uk
Coverage

• Cumulative impact: 1996-2018
• Farm income and productivity impacts: focuses on farm income, yield, production
• Environmental impact analysis covering pesticide spray changes and associated environmental impact
• Environmental impact analysis: greenhouse gas emissions
Methodology

- Review and use of considerable impact literature plus own analysis – a lot of this is in peer reviewed journals
- Uses current prices, exchange rates and yields (for each year) and update of key costs each year: gives dynamic element to analysis
- Review of pesticide usage (volumes used) or typical GM versus conventional treatments
- Use of Environmental Impact Quotient (EIQ) indicator
- Review of literature on carbon impacts – fuel changes and soil carbon
Summary of key findings

Pesticide change 1996-2018

- 776 million kg reduction in pesticides (8.6%) & 19% cut in associated environmental impact

Global farm income 1996-2018

- $225 billion increase

Global production 1996-2018

- 824 million tonnes more food/feed/fibre

Carbon emission 2018

- Cut of 23 billion kg CO2 release; equal to taking 15.3 million cars off the road
Farm income gains: highlights

- Total farm income benefit 2018 $19 billion
- Equal to adding 5.8% to value of global production of corn, canola, cotton and soybeans
- Total farm income gain: 1996-2018: $225 billion
- Average gain/hectare (1996-2018): $97
- Income share (1996-2018): 48% developed and 52% developing countries
Average farm income gain 1996-2018 by country ($/ha)
Farm income gains 1996-2018 by country (US $)

- US, 41.1%
- Brazil, 17.8%
- Argentina, 12.5%
- China, 7.9%
- India, 8.0%
- Africa, 1.1%
- Canada, 4.6%
- Australia, 0.4%
- Other countries, 6.6%
### Other farm level benefits

<table>
<thead>
<tr>
<th>GM HT crops</th>
<th>GM IR crops</th>
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</thead>
<tbody>
<tr>
<td>Increased management flexibility/convenience</td>
<td>Production risk management tool</td>
</tr>
<tr>
<td>Facilitation of no till practices</td>
<td>Machinery and energy cost savings</td>
</tr>
<tr>
<td>Cleaner crops = lower harvest cost and quality bonus</td>
<td>Yield gains for non GM crops (reduced general pest levels)</td>
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<td></td>
<td>Convenience benefit</td>
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<td></td>
<td>Improved crop quality</td>
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<td>Improved health and safety for farmers/workers</td>
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In US these benefits valued at $17 billion 1996-2018
Cost of accessing the technology ($billion) 2018

- Distribution of total trait benefit: all (tech cost 27%) – every $1 invested in seed = $3.75 in extra income

- Distribution of benefit: developing countries (tech cost 23%) every $1 invested in seed = $4.42 in extra income

Cost of tech goes to seed supply chain (sellers of seed to farmers, seed multipliers, plant breeders, distributors & tech providers)
Yield gains versus cost savings

- 72% ($162 billion) of total farm income gain due to yield gains 1996-2018
- Remaining gains ($63 billion) from cost savings
- Yield gains mainly from GM IR technology (70%) and cost savings mainly from GM HT technology (90%)
- Yield gains greatest in developing countries and cost savings mainly in developed countries
IR corn: average yield increase 1996-2018

Average across all countries: +16.5%
IR cotton: average yield increase 1996-2018

Average across all countries: +13.7%
IR soybeans: average yield increase 2013-2018

Average across all countries: +9.5%
HT traits: yield and production effects

<table>
<thead>
<tr>
<th>Trait/country</th>
<th>Yield/production effect</th>
</tr>
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<tbody>
<tr>
<td>HT soy: Romania, Mexico and Bolivia</td>
<td>+23%, +5% and +15% respectively on yield</td>
</tr>
<tr>
<td>HT soy: 2\textsuperscript{nd} generation: US and Canada</td>
<td>+9.3% yield</td>
</tr>
<tr>
<td>HT soy Argentina and Paraguay</td>
<td>Facilitation of 2\textsuperscript{nd} crop soy after wheat: equal to +23% and +15% respectively to production level</td>
</tr>
<tr>
<td>HT corn: Argentina, Brazil, Philippines and Vietnam</td>
<td>+10%, +3.7%, 5.3% and +5% respectively on yield</td>
</tr>
<tr>
<td>HT cotton: Mexico, Colombia and Brazil</td>
<td>+13%, +3.6% and +1.6% respectively on yield</td>
</tr>
<tr>
<td>HT canola: US, Canada and Australia</td>
<td>+2.1%, +6.5% and +9.5% respectively on yield</td>
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</table>
Additional crop production arising from positive yield effects of biotech traits 1996-2018 (million tonnes)
Additional conventional area required if biotech not used (m ha)

<table>
<thead>
<tr>
<th>Crop</th>
<th>2018</th>
</tr>
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<tbody>
<tr>
<td>Soybeans</td>
<td>12.3</td>
</tr>
<tr>
<td>Maize</td>
<td>8.1</td>
</tr>
<tr>
<td>Cotton</td>
<td>3.1</td>
</tr>
<tr>
<td>Canola</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24.2</strong></td>
</tr>
</tbody>
</table>

equal to 38% of cropping area of Brazil
## Focus on India: IR cotton

<table>
<thead>
<tr>
<th>Issue</th>
<th>Impact</th>
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</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>2002</td>
</tr>
<tr>
<td>% of crop using technology (2018)</td>
<td>95%</td>
</tr>
<tr>
<td>Yield impact</td>
<td>+29%</td>
</tr>
<tr>
<td>Average farm income gain ($/ha)</td>
<td>193.56</td>
</tr>
<tr>
<td>Average return on investment - $/ha extra income per extra $1 spent on seed</td>
<td>12.95</td>
</tr>
<tr>
<td>Total farm income gain $ billion (2002-2018)</td>
<td>24.31</td>
</tr>
<tr>
<td>Production impact 2002-2018 (million tonnes lint)</td>
<td>14.73</td>
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Source: Brookes and Barfoot 2020

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Focus on Vietnam: stacked corn

<table>
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<tbody>
<tr>
<td>Introduction</td>
<td>2015</td>
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<tr>
<td>% of crop using technology (2019)</td>
<td>10.2%</td>
</tr>
<tr>
<td>Yield impact</td>
<td>+15.2% to +30.4%</td>
</tr>
<tr>
<td>Average farm income gain ($/ha)</td>
<td>195.67 to 329.75</td>
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<tr>
<td>Average return on investment - $/ha extra income per extra $1 spent on seed</td>
<td>6.84 to 12.55</td>
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<tr>
<td>Total farm income gain $ million (2015-2019)</td>
<td>+43.8 to +74.1</td>
</tr>
<tr>
<td>Production impact 2015-2019 (million tonnes)</td>
<td>+0.16 to +0.32</td>
</tr>
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Source: Brookes and Dinh 2020, Brookes and Barfoot 2020
Note: analysis to 2019 included based on Brookes and Dinh 2020

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Impact on pesticide use

- Since 1996, use of pesticides down by 776 million kg (-8.6%, equivalent to 1.6 times annual pesticide active ingredient use on crops in China). Associated environmental impact (EIQ indicator) - 19%

- Largest environmental gains from GM IR cotton: savings of 331 million kg insecticide use (-32%) and 35% reduction in associated environmental impact (EIQ measure) of insecticides

- Of which environmental gains from GM IR cotton in India: savings of 137 million kg insecticide use (34%) and 43% reduction in associated environmental impact (EIQ measure) of insecticides
Impact on greenhouse gas emissions

Lower GHG emissions:

2 main sources:

- Reduced fuel use (less spraying and soil cultivation)
- GM HT crops facilitate no till systems = less soil preparation = additional soil carbon storage

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Reduced GHG emissions: 2018

- Reduced fuel use (less spraying and tillage) = 2.4 billion kg less carbon dioxide
- Facilitation of no/low till systems = 20.6 billion kg of carbon dioxide not released into atmosphere
- Total 23 billion kg

Equivalent to removing 15.3 million cars — 48% of cars registered in the United Kingdom — from the road for one year
Any negatives?

- Over reliance on glyphosate by some farmers in North/South America (with HT crops) contributed to weed resistance problems – farmers had to adapt and change weed control systems resulting in increased herbicide use and higher cost compared to 15 years ago.

BUT:

- Weed resistance problems and increased herbicide use also a trend in conventional crops.
- Environmental profile of herbicides used with HT crops remains better than equivalent on conventional crops.
- HT crops remain more profitable than conventional alternative.
Summary of key global findings

- **Pesticide change 1996-2018**: 776 million kg reduction in pesticides (8.6%) & 19% cut in associated environmental impact.

- **Global farm income 1996-2018**: $225 billion increase.

- **Global production 1996-2018**: 824 million tonnes more food/feed/fibre.

- **Carbon emission 2018**: Cut of 23 billion kg CO2 release; equal to taking 15.3 million cars off the road.
Concluding comments

- **GM IR technology**: higher yields, less production risk, decreased insecticide use, higher incomes, more reliable food supply, more environmentally-friendly farming methods

- **GM HT technology**: higher incomes, extra production, facilitation of adoption of more sustainable farming systems (eg, no till), carbon emission savings

- **Both technologies**: important contributions to increasing world production of soybeans, corn, canola and cotton – results in less pressure to bring new land into agriculture

- **Newer traits**: drought tolerant (corn), fungal resistant potatoes and insect resistant (brinjal) now beginning to contribute positively
Concluding comments

- After 23 years of widespread use – there is a considerable amount of consistent evidence in peer reviewed literature on the impact of GM crop technology.
- This work adds to this literature.
- Papers from this work available on open access at GM Food and Crops journal.


- I encourage you to read these papers and references cited in them and draw your own conclusions.