Sustainability and Productivity: Are They Compatible?

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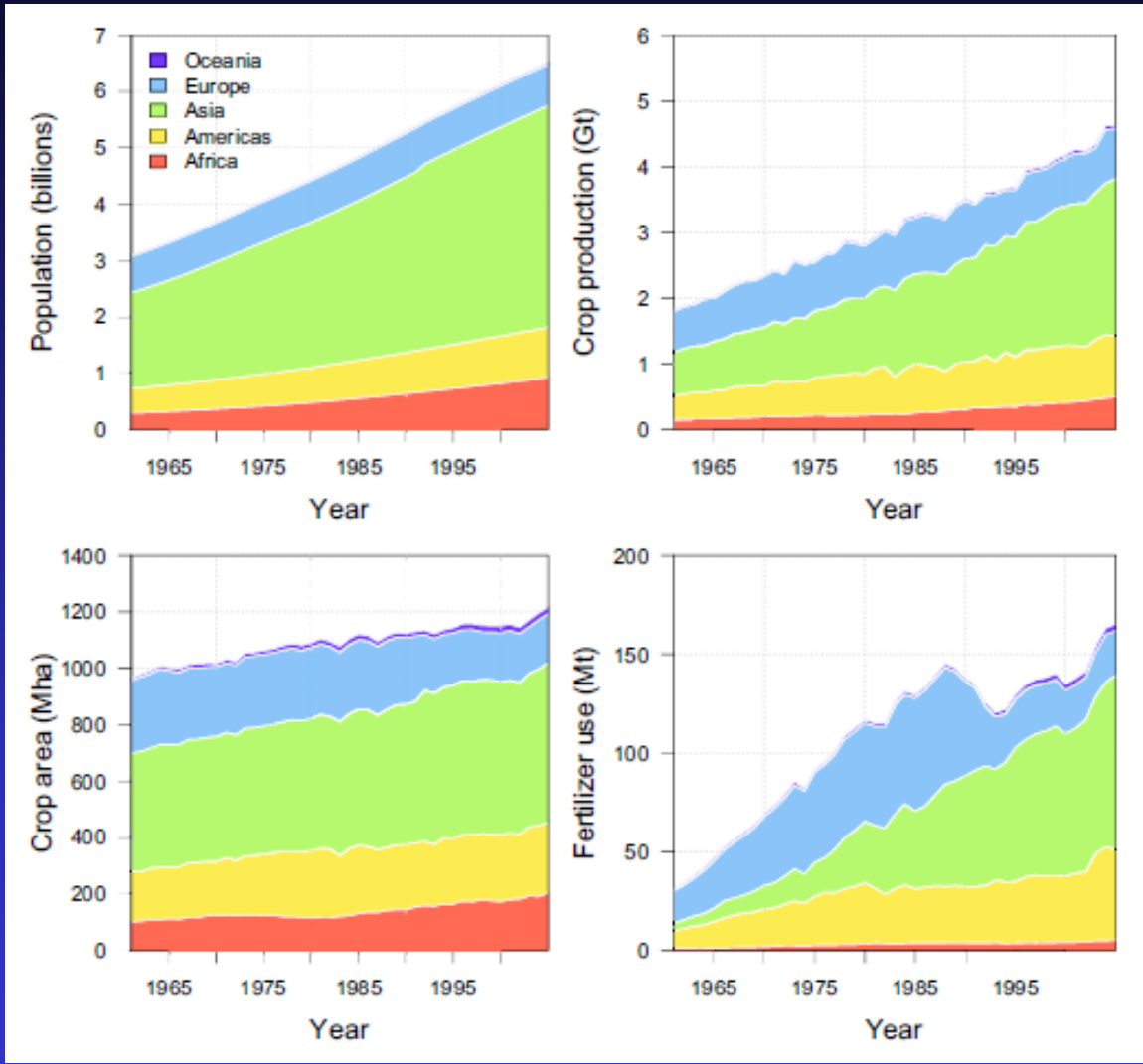
Population, Productivity and Inputs: 1961-2005

Population

Crop Production



Crop Area

Fertilizer

Burney et al. (2010) Greenhouse gas mitigation by agricultural intensification. PNAS www.pnas.org/cgi/doi/10.1073/pnas.0914216107

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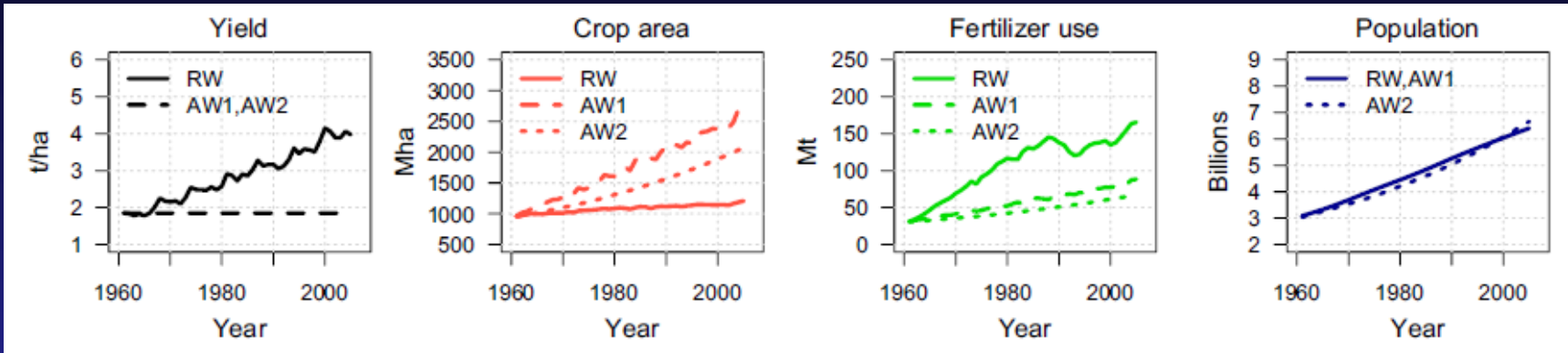
Population, Productivity and Inputs: 1961-2005



RW = Real world, or the actual changes in these parameters

AW1 = Alternative world scenario 1 = population, global economy, and sociopolitics evolved exactly as in the real world, but agricultural technology and farm practices remained as they were in 1961.

AW2 = Alternative world scenaro 2 = agricultural production increased only enough to maintain 1961 standards of living (per capita production)

Burney et al. (2010) Greenhouse gas mitigation by agricultural intensification. PNAS www.pnas.org/cgi/doi/10.1073/pnas.0914216107

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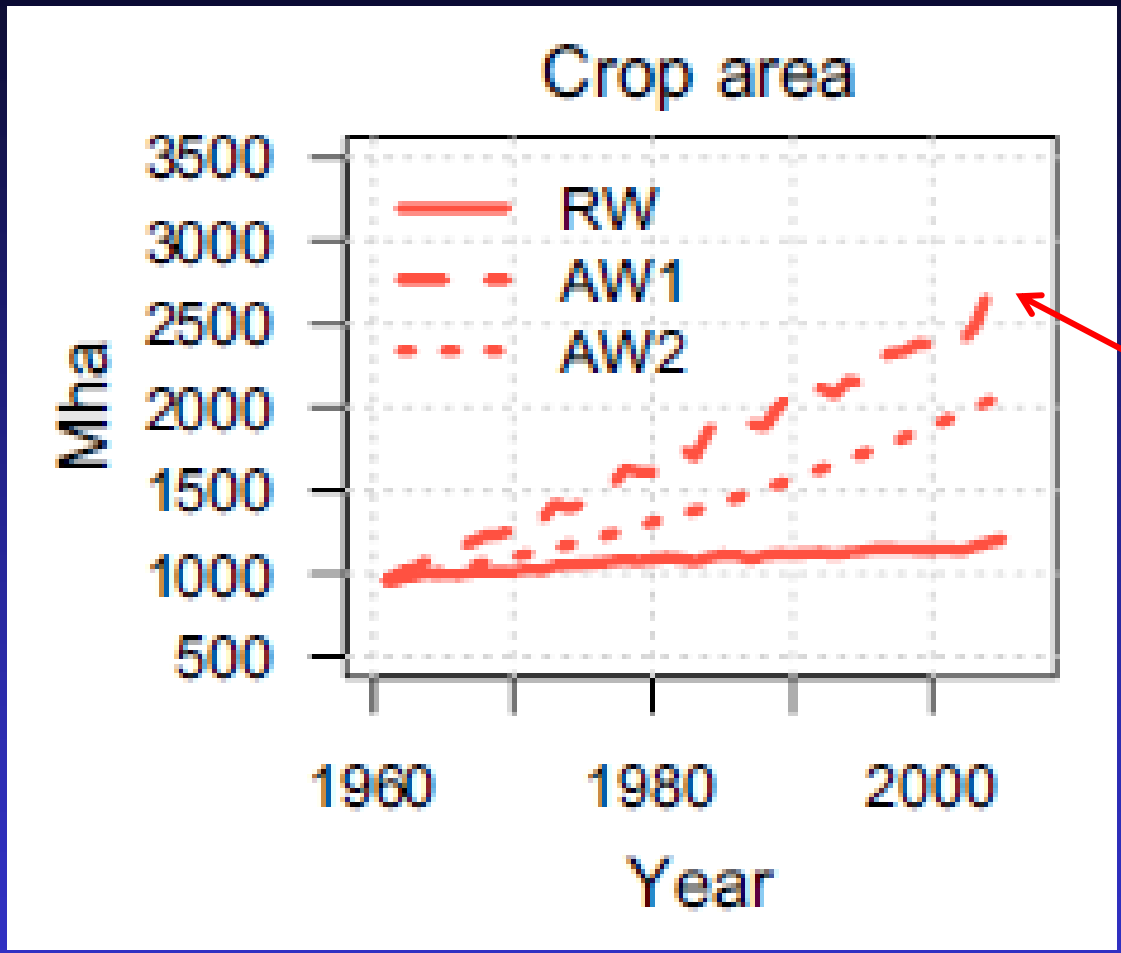
Crop Area Scenarios: 1961-2005



1,761 Mha more land required, or 1,514 Mha more than in the real world case.

Burney et al. (2010) Greenhouse gas mitigation by agricultural intensification. PNAS www.pnas.org/cgi/doi/10.1073/pnas.0914216107

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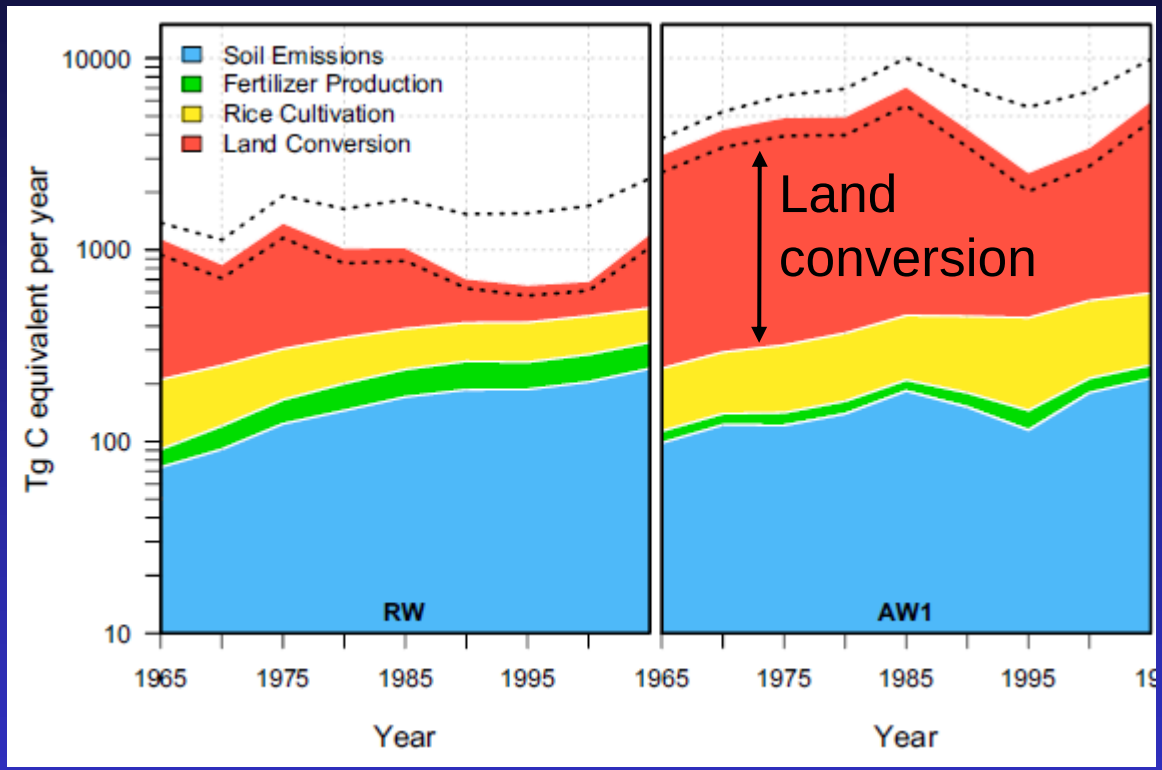
Greenhouse Gas Scenarios: 1961-2005



With yield increases since 1961

With 1961 technology

161 Gt of carbon emissions avoided due to yield increases, or 34% of the total emitted by humans between 1850 and 2005.

Burney et al. (2010) Greenhouse gas mitigation by agricultural intensification. PNAS www.pnas.org/cgi/doi/10.1073/pnas.0914216107

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Are Sustainability and Productivity Compatible?

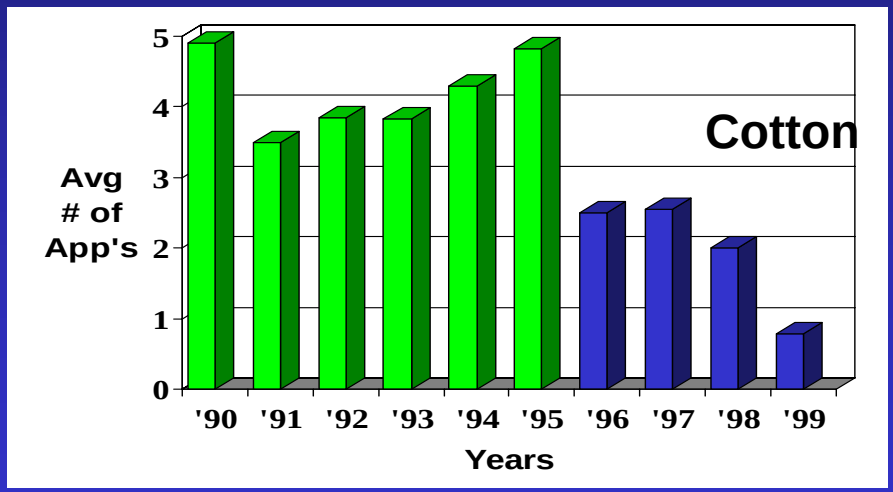
It is evident from this study and many more like it that high productivity is essential for sustainability while still feeding the human population, and that productivity per unit area is the best way to preserve wild lands and biodiversity while reducing the environmental impacts of agriculture.

What can plant breeding and agricultural biotechnology contribute to sustaining and increasing productivity while not increasing the inputs required?

Insect-resistant Crops Reduce Insecticide Use

"The efficacy of Bt maize and cotton against major pest species has been associated with an estimated136.6 million kg global reduction in insecticide active ingredient used between 1996 and 2006 (29.9% reduction)."
Naranjo (2009) CAB Reviews 4: No. 011.
www.cababstractsplus.org/cabreviews

Council for Biotechnology Information



J.P. Carpenter and L.P. Gianessi (2001) Agricultural Biotechnology: Updated Benefit Estimates. National Center for Food and Agricultural Policy. www.ncfap.org

The Organic Center www.organic-center.org
Critical Issue Report: The First Thirteen Years

www.organic-center.org

"Bt cotton continues to perform well."
C. Benbrook, 2009

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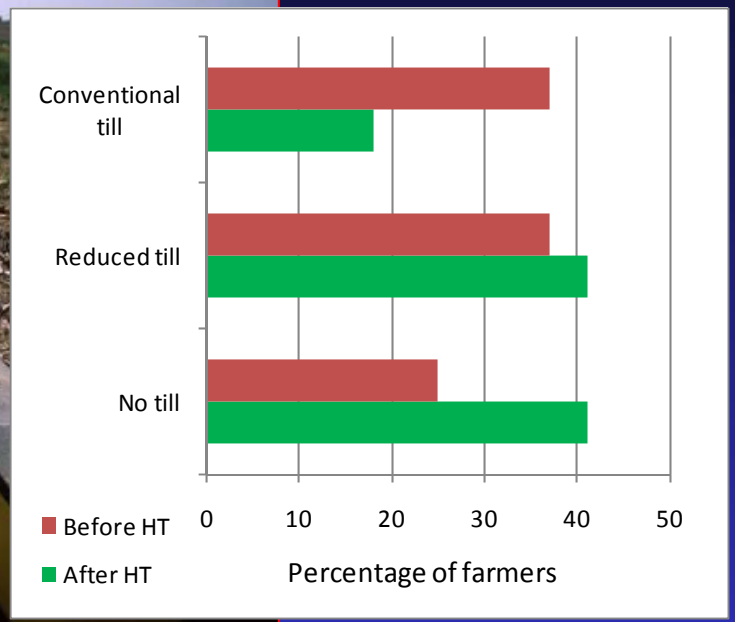
Herbicide-Tolerant Crops Promote Soil Conservation



Herbicide tolerant crops reduce the need for plowing to control weeds, saving fuel and reducing carbon loss from soils.

The adoption of herbicide-resistant crops has increased the percentage of farmers using no-till and reduced-till farming systems.

Conservation Tillage Information Center (2002) Purdue University. www.ctic.purdue.edu
Givens et al. (2009) Weed Technology 23: 150-155.

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Agricultural Sustainability Assessment

- To identify criteria for sustainable agriculture that are open to a diversity of technologies; and
- To support the implementation of production systems that lead to broad performance improvements against these criteria.

http://www.keystone.org/spp/environment/sustainability/field-to-market

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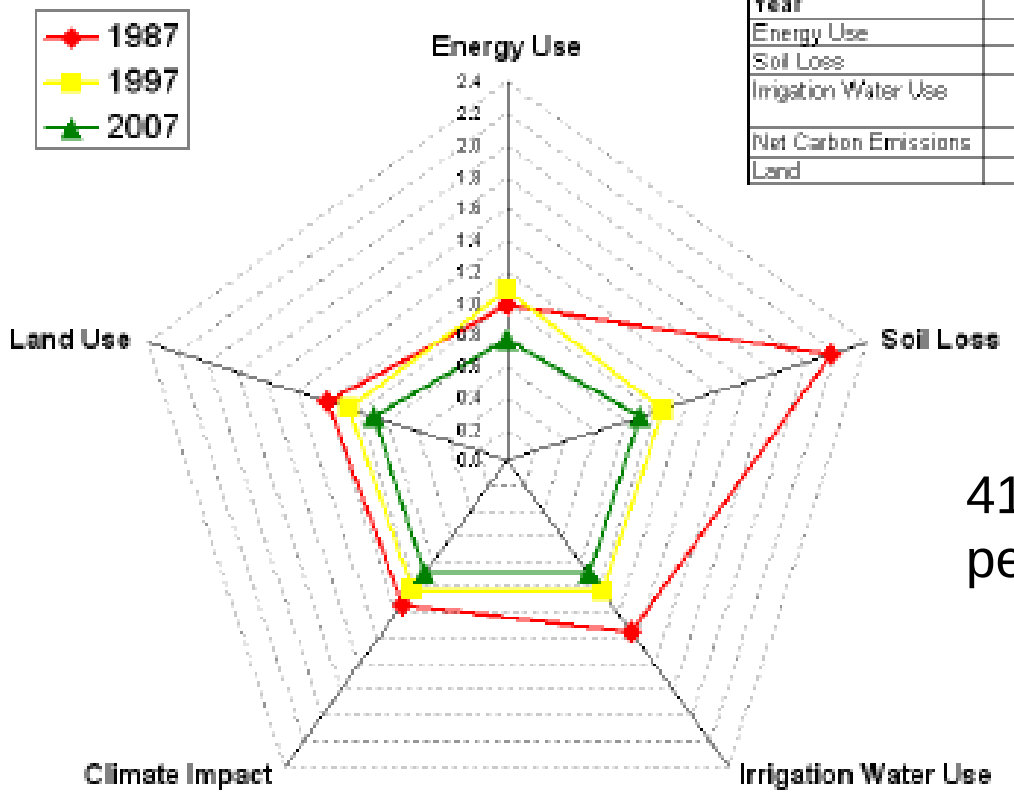
Corn Efficiency Indicators

Corn Efficiency Indicators (Per Unit of Output, Index 2000 = 1)



Year	2000	Unit
Energy Use	0.057	Million Btu/bushel
Soil Loss	28.7	Pounds soil/bushel
Irrigation Water Use	5.6	Thousand gallons/incremental bushel due to irrigation
Net Carbon Emissions	3.0	Pounds Carbon/bushel
Land	0.013	Acres/bushel

41% yield increase per acre

(Values are expressed as 5-year centered averages.)

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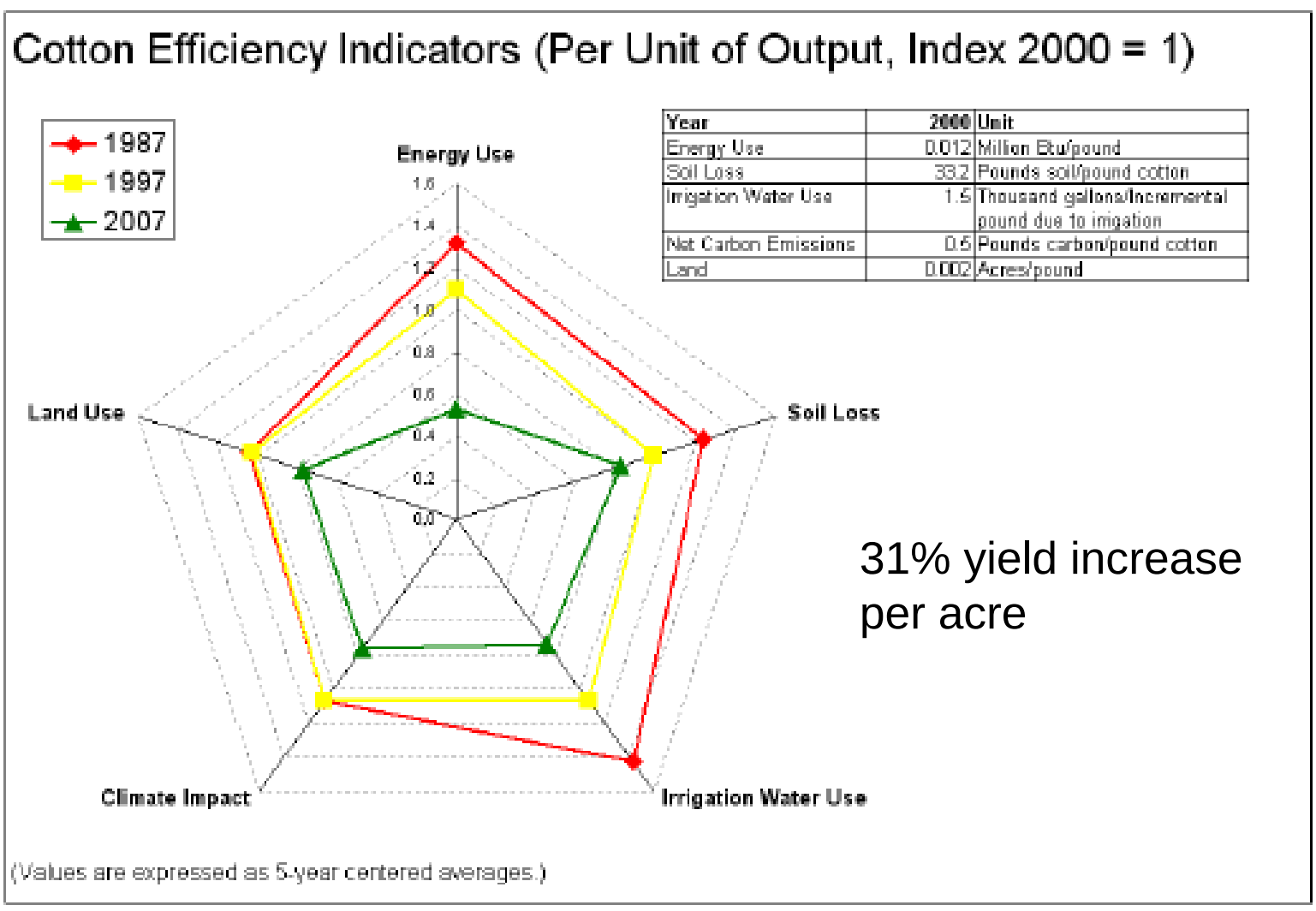
Cotton Efficiency Indicators



Year	2000	Unit
Energy Use	0.012	Million Btu/pound
Soil Loss	33.2	Pounds soil/pound cotton
Irrigation Water Use	1.5	Thousand gallons/Incremental pound due to irrigation
Net Carbon Emissions	0.5	Pounds carbon/pound cotton
Land	0.002	Acres/pound

31% yield increase per acre

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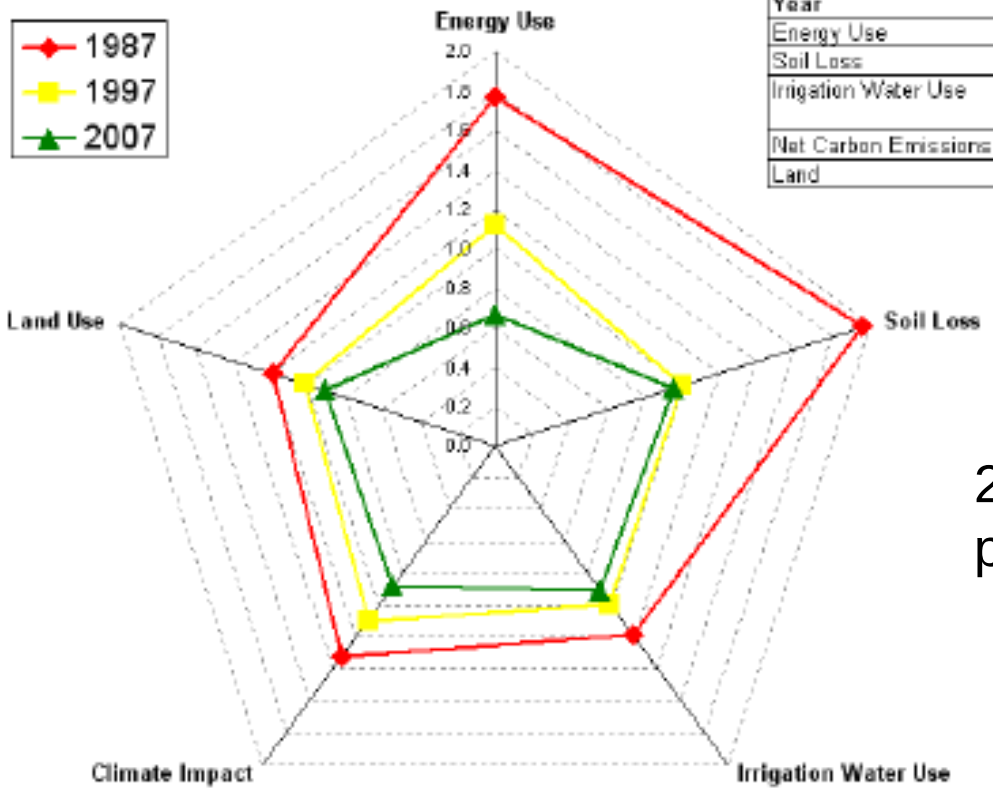
Soybean Efficiency Indicators

Soybean Efficiency Indicators (Per Unit of Output, Index 2000 = 1)



Year	2000	Unit
Energy Use	0.044	Million Btu/bushel
Soil Loss	101.0	Pounds soil/bushel
Irrigation Water Use	19.4	Thousand gallons/incremental bushel due to irrigation
Net Carbon Emissions	2.2	Pounds Carbon/bushel
Land	0.026	Acres/bushel

29% yield increase per acre

(Values are expressed as 5-year centered averages.)

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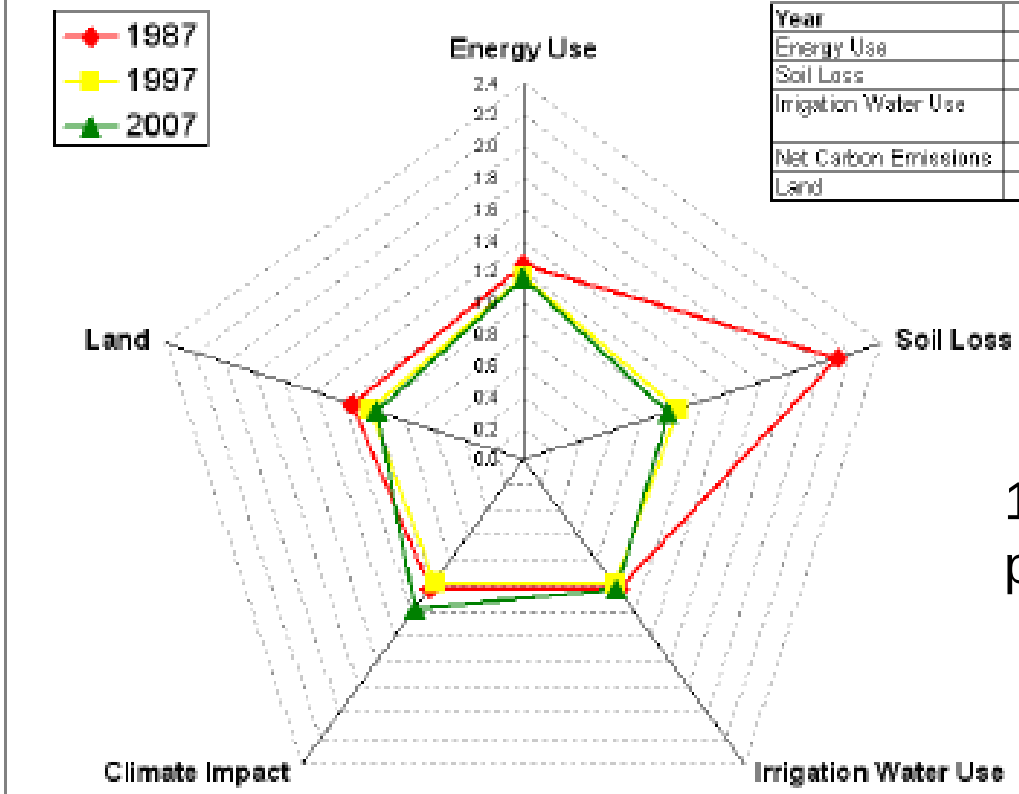
Wheat Efficiency Indicators



Year	2000	Unit
Energy Use	0.069	Million Btu/bushel
Soil Loss	104.4	Pounds soil/bushel
Irrigation Water Use	13.2	Thousand gallons/Incremental bushel due to irrigation
Net Carbon Emissions	4.7	Pounds Carbon/bushel
Land	0.024	Acres/bushel

19% yield increase per acre

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Impact of Biotech Crops

AgBioForum, 11(1): 21-38. ©2008 AgBioForum.

Global Impact of Biotech Crops: Socio-Economic and Environmental Effects, 1996-2006

AgBioForum, 12(2): 184-208. ©2009 AgBioForum.

Global Impact of Biotech Crops: Income and Production Effects, 1996-2007

Graham Brookes and Peter Barfoot
PG Economics, Ltd., Dorchester, UK

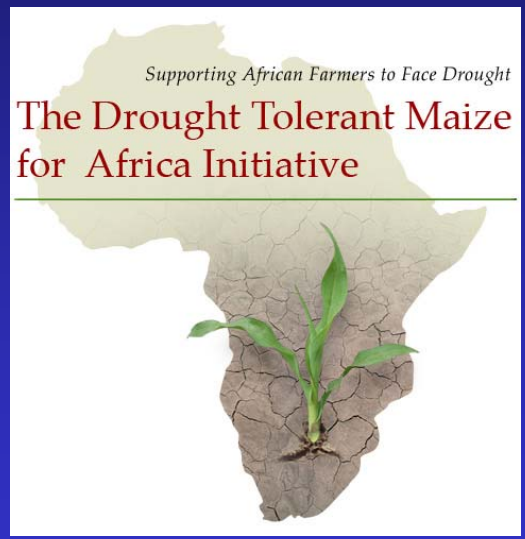
- Total economic benefits: $44.1 billion
- Half of the benefits went to farmers in developing countries
- Overall, 6% yield increase in corn, 13% in cotton
- 286 million kg less pesticide active ingredient used
- 15.4% reduction in overall environmental impact
- 15 billion kg reduction in greenhouse gas emissions

Other Traits in the Pipeline

- Farmer benefits
  - Yield
  - Drought tolerance
  - Nitrogen use efficiency
- Processor/animal feed benefits
  - Improved protein quality
  - High oil
- Consumer benefits
  - Low linolenic oils
  - Less hydrogenation and trans-fats
  - High omega-3 and omega-6 oils
  - Increased vitamin and antioxidant content
- Biofuels
  - Oil and starch composition
  - Carbohydrate conversion efficiency

Biotech Programs for Africa

- Multivitamin maize (A, B, and C)
- Maize streak virus resistance
- Drought tolerant maize for Africa
- Africa Biofortified Sorghum
- BioCassava Plus



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Bt Eggplant in India

- 2nd largest vegetable crop
- 40% losses to fruit and shoot borers
- 40 insecticide sprays per season

- Bt eggplant will reduce insecticide use 40% and double yields
- Improve worker health
- Reduce pesticide residues for consumers

- India's Genetic Engineering Approval Committee (GEAC) has recommended the environmental release

- Strongly opposed by anti-GM activists

- Environment Minister did not approve release and put a moratorium on it until "public confidence" could be increased.

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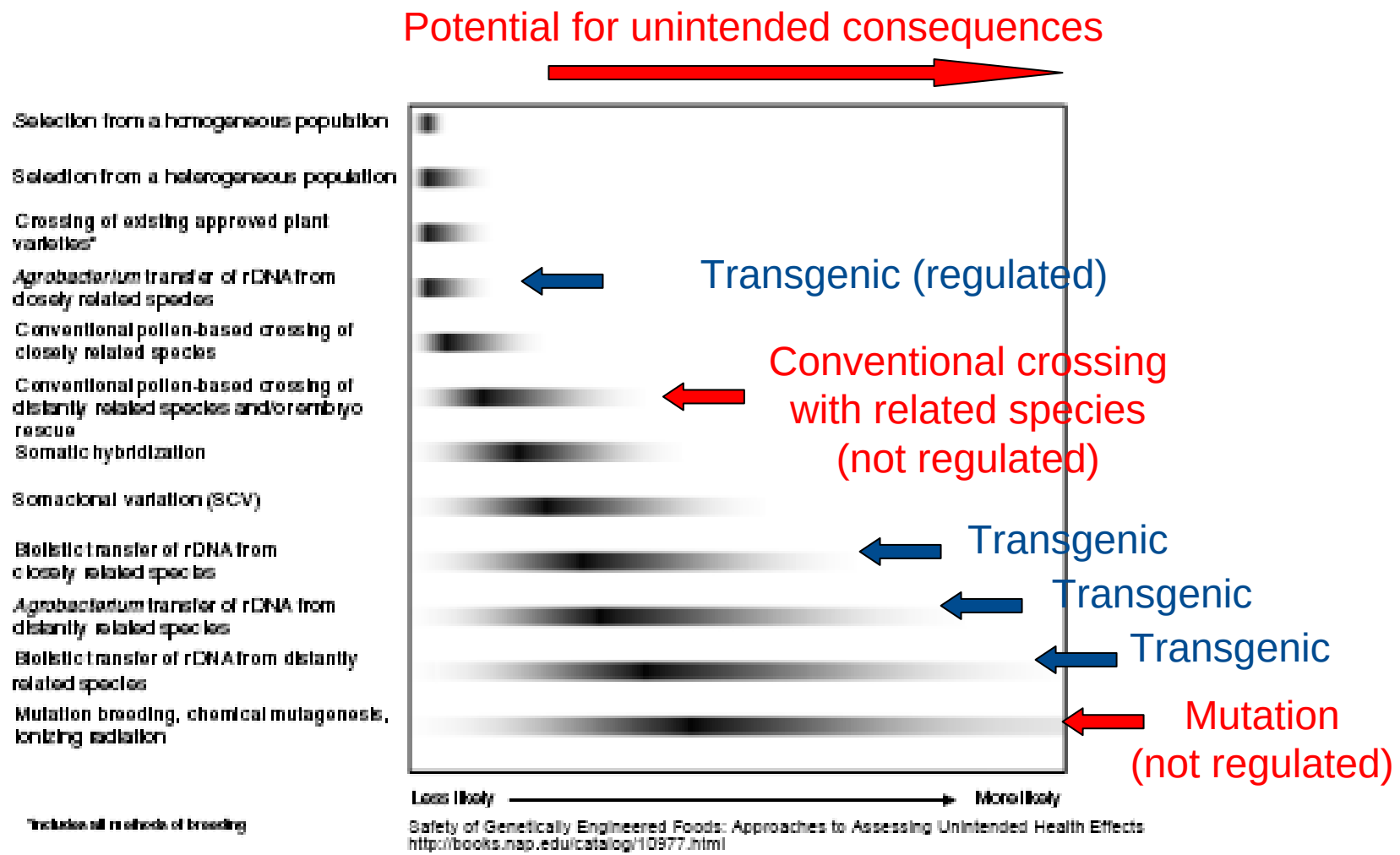
Hurdles for New Biotech Crops

- Market resistance
  - Lack of acceptance throughout marketing chain
- Development and Regulatory costs
  - Costs are high relative to potential seed or nursery sales
- International regulatory issues
  - Asynchronous approvals
  - Lack of uniformity of regulations
  - “Adventitious (unintended) presence” issue
  - Need to channel products
- Active opposition by some groups
  - Public relations activities
  - Court challenges
  - Vandalism of trials

Safety of Genetic Engineering



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Three Agencies Regulate Biotech Crops

The US Dept. of Agriculture determines whether the crop is safe to grow. For example, is it a threat to become a weed; what are its growth and flowering characteristics?

The Food and Drug Administration determines whether the crop is safe to eat. Is it substantially equivalent to other crops with respect to composition, nutrition, allergenicity, digestibility, etc.?

The Environmental Protection Agency regulates crops that have pesticidal properties. Are they safe for humans, for non-target organisms, and for the environment?

Safety Data Requirements for Registration of Biotech Crops

Product description (7 items)
Molecular characterization (17 items)
Toxicity studies (as necessary) (5 items)
Antibiotic resistance marker genes (4 items)
Nutritional content (7+ items)
Substantial equivalence with parent variety
Literature review and background
Allergenicity potential
Similarity to natural toxicants
Anti-nutritional effects
Protein digestibility
Environmental aspects (5 items)
Germination, growth, flowering studies (8 items)
Ecological impact (5 items)

None of this is required for traditionally bred crops.
No documented health or safety issues with GM crops.

Opportunities for New Biotech Crops

- Specifically target traits that will promote sustainability
  - Nitrogen use efficiency
  - Nitrogen fixation
  - C4 photosynthetic pathway
  - Stress tolerance
  - Yield
- May be the only option to counter the fear campaign by anti-GM groups.

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Closing Questions

- Do we have a moral obligation to try to feed the global population?
  - If so, productivity is essential.
- Do we have a moral obligation to preserve the environment?
  - If so, productivity is beneficial.
- Should we utilize safe technologies that increase agricultural productivity and efficiency and enhance sustainability?
  - If so, then we should be investing in agricultural research and using biotechnology.