An analysis of "Failure to Yield" by Doug Gurian-Sherman, Union of Concerned Scientists

Wayne Parrott, Professor. Institute of Plant Breeding, Genetics & Genomics, and Department of Crop & Soil Sciences, University of Georgia. Updated 2 April 2010

The report by the Union of Concerned Scientists rightly differentiates between *intrinsic yield* (what the crop could produce) and *operational yield* (what the crop actually produces). The premise of the report is that GM crops are a bad means to achieve global agricultural sustainability simply because they have not affected intrinsic yield. Surprisingly, while the report mentions 'wealth of data on yield under real-world conditions' it fails to use these data. The report focuses on corn and soybean, omitting the extensive data available from cotton and canola. Finally, the report focuses on the US, omitting the results from the rest of world. Collectively, these omissions in the UCS report serve to distort the actual situation.

Operational vs Intrinsic yield

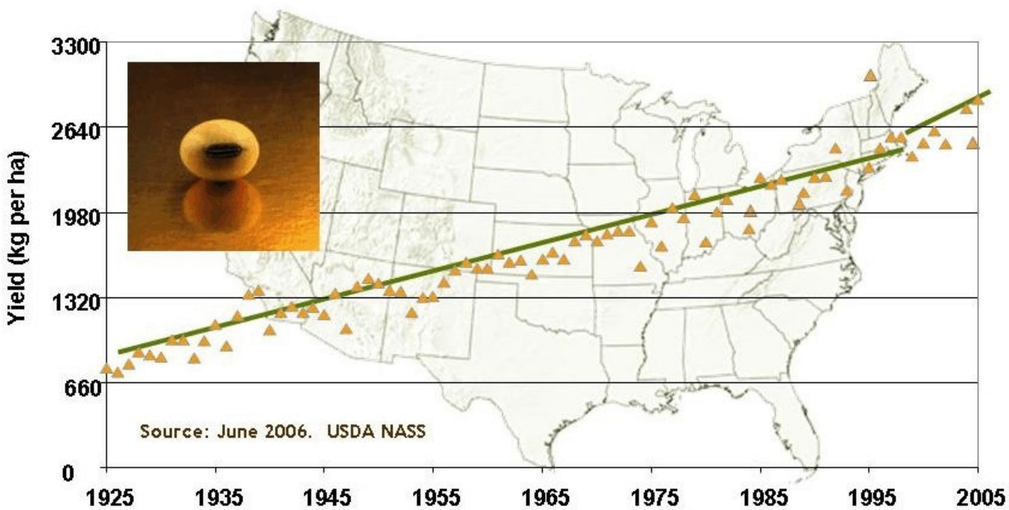
The first premise of plant breeding and genetics is that it is necessary to stop the losses before it is possible to move forward– In other words, it is necessary to get to the point where Intrinsic Yield (IY) equals Operational Yield (OY). Historically, pests and unfavorable growing conditions mean that IYs are almost never achieved, yet the UCS report downplays the importance of OY.

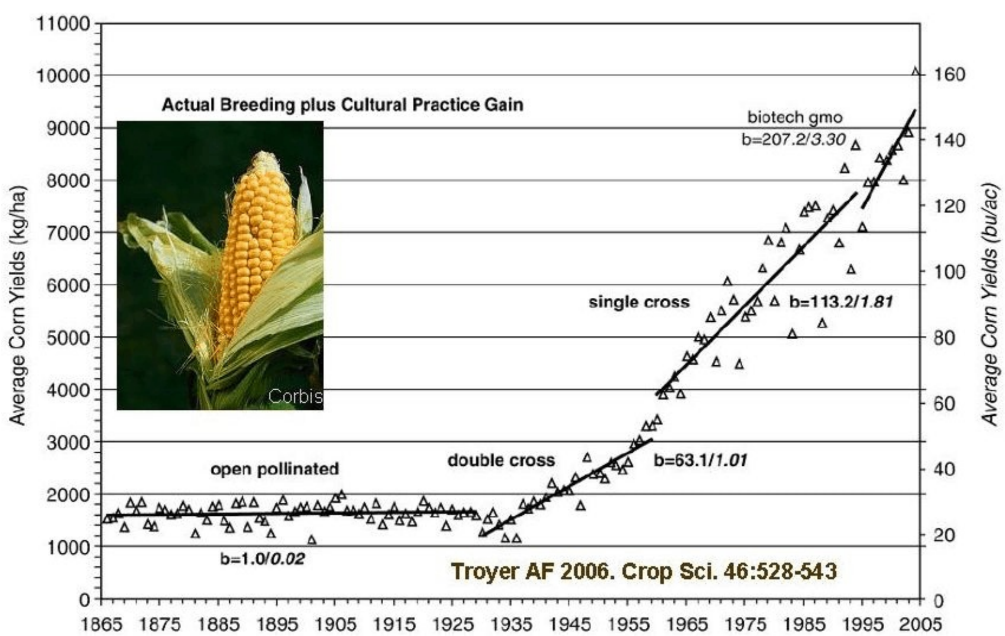
Estimates by of preharvest losses around the world (ie, the difference between IY and OY) are staggering. The table below presents estimates of percent pre-harvest losses on a global basis for three major crops. The 1967 estimates are particularly high, and might reflect the lack of appropriate cultural options to mitigate losses:

	Corn	Wheat	Rice
Cramer, 1967			
Weeds	37	40	23
Insects	36	21	58
Diseases	27	39	16
Oerke et al., 1994			
Weeds		12	30
Insects		6	14
Diseases		15	16

- The point is that substantial contributions to yield and world food security can be made simply by increasing OY. As such, the first generation of GM crops have made substantial contributions towards increasing OY by decreasing losses to weeds and insects.

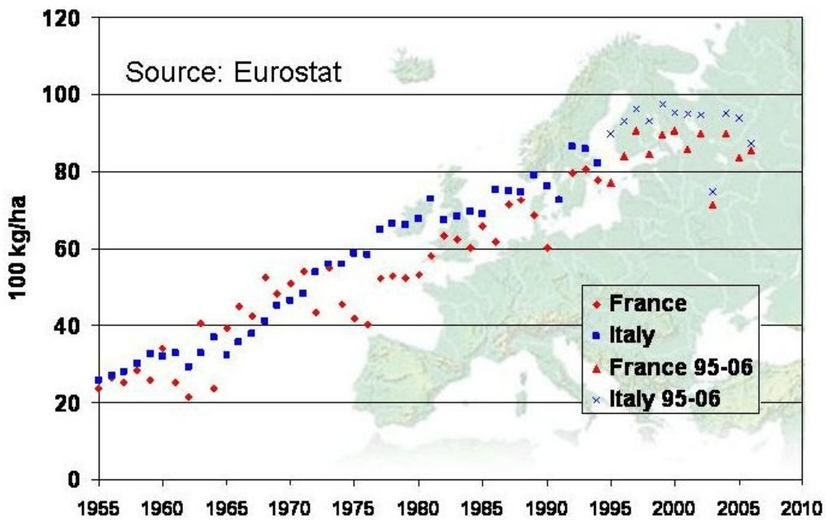
What have yields really done?
In the United States, corn and soybean yields have been increasing at a steady rate as a result of improved genetics and improved cultural practices (keeping in mind that changes in genetics make changes in cultural practices possible). What is evident is that yield has increased at a faster rate in the biotech era. The combination of better pest and weed control resulting from the GM traits and breeding have helped farmers harvest the benefits (i.e., OY, which is the bottom line). The next two graphs illustrate the point for soybean (top) and corn (bottom):





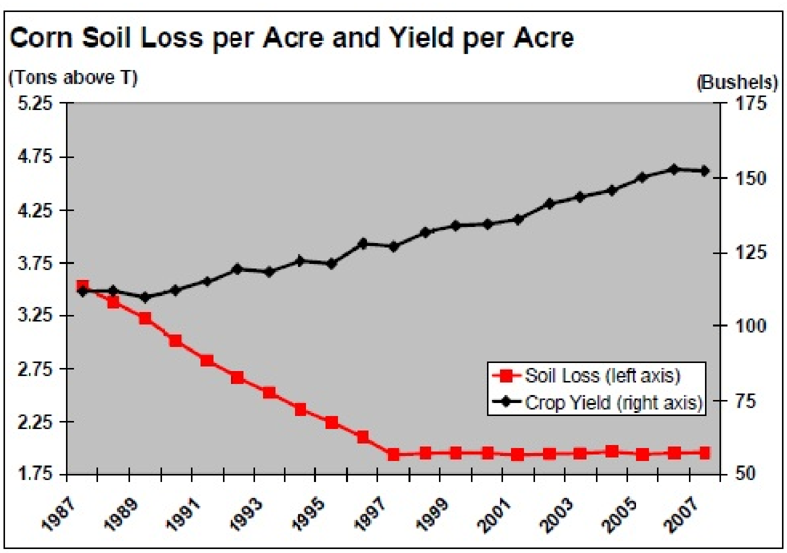
An effective way to judge the contributions of GM to OY is to compare yield increases in the US- which has embraced GM corn, with that in Europe. The chart below gives corn yields for

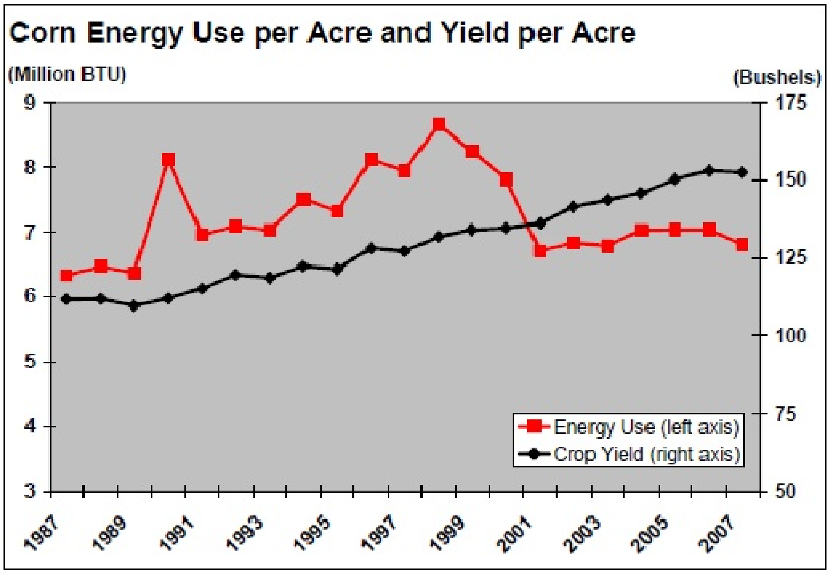
France and Italy. While France grew limited amounts of GM maize, Italy grew none. Note that in marked contrast to yield increases in the US, yields in France and Italy have leveled off.



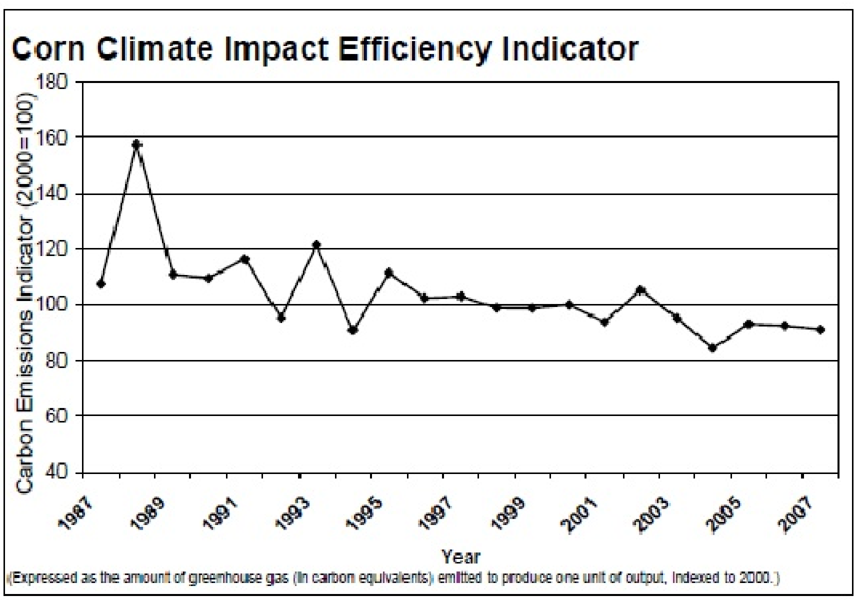
GM crops and sustainability
A major factor on the cultivation of GM crops is that their cultivation since 1997 has had a profound impact on agronomic practices. A comprehensive study on the effect of current agronomic practices on sustainability was recently released by the Keystone Center.

One of the greatest trends in production has been the widespread adoption of no-till agriculture, with associated changes in erosion prevention and soil loss, energy consumption, and other parameters.

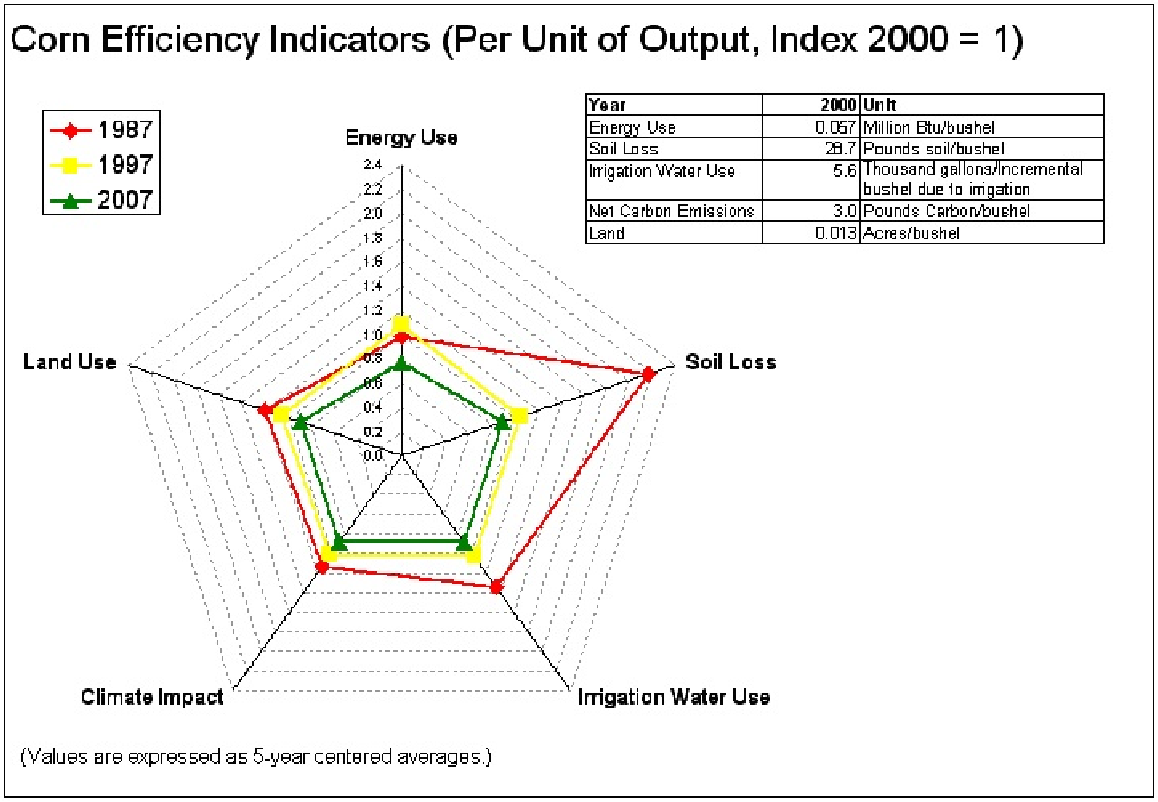




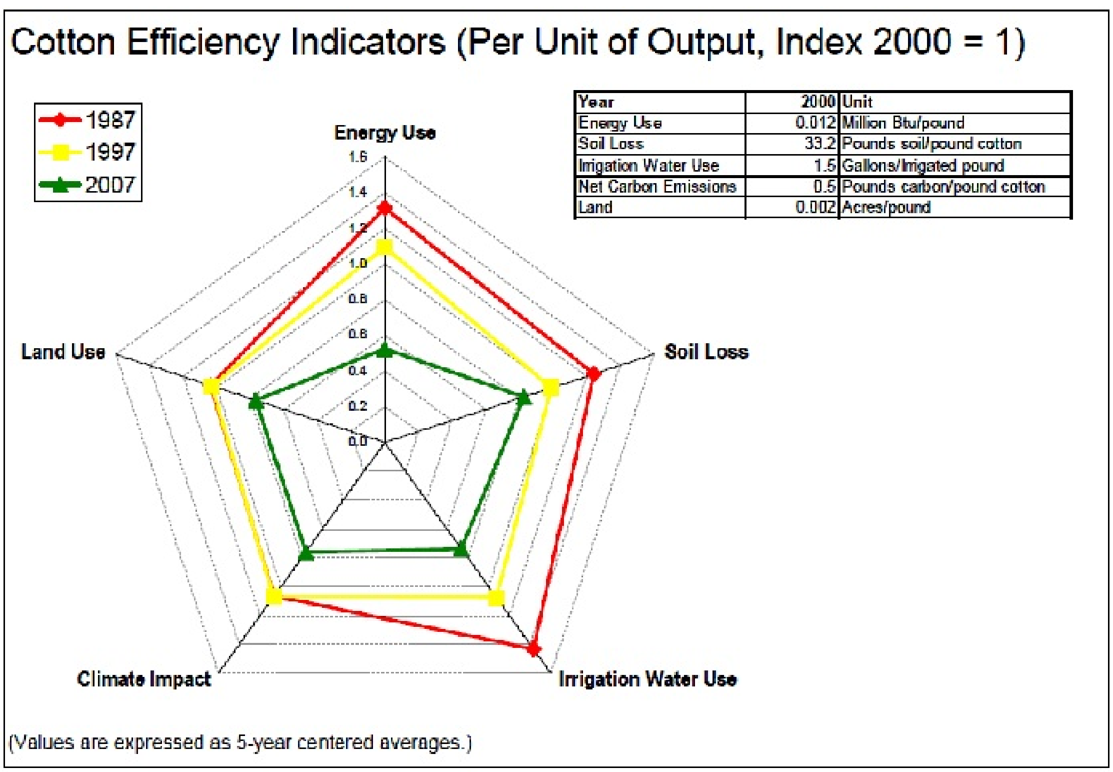
Increased yields and decreased fuel consumption indicate that less greenhouse gasses are being emitted per unit of crop produced:

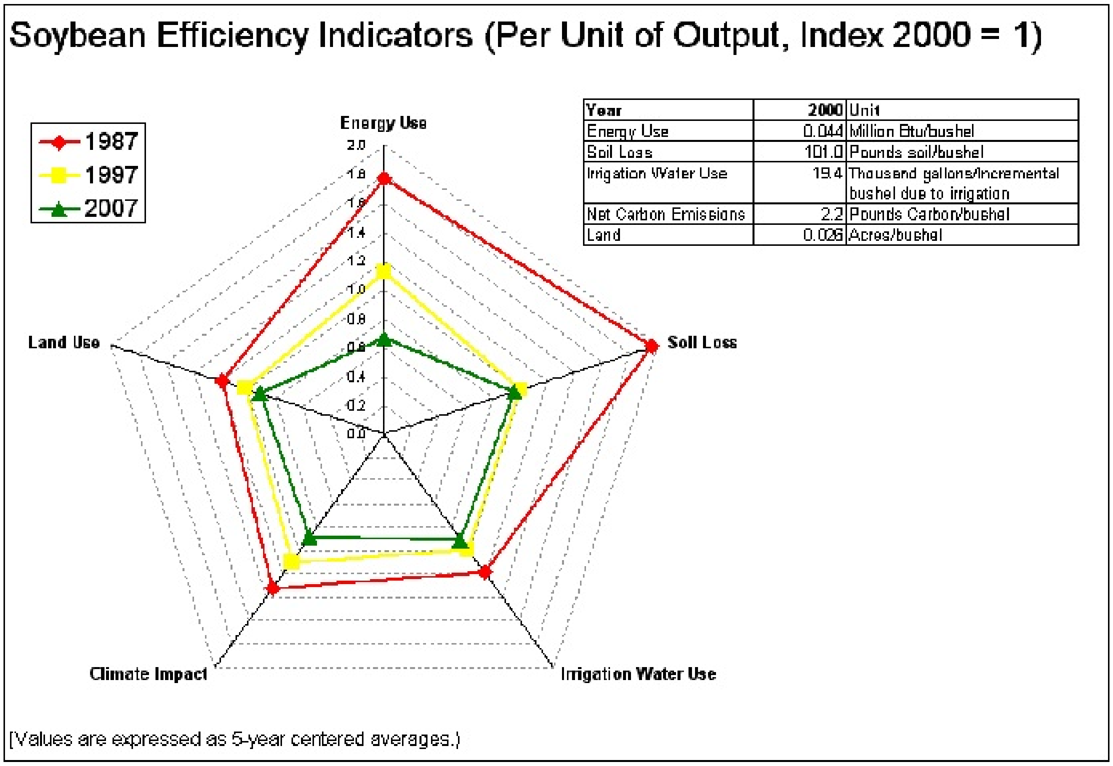


When all these parameters are considered collectively, it is possible to calculate efficiency (and thus sustainability indicators) for each crop. In the case of corn, note the greater efficiency indices in 2007 relative to 1997. The year 1997 represents the dawn of the GM crop era:

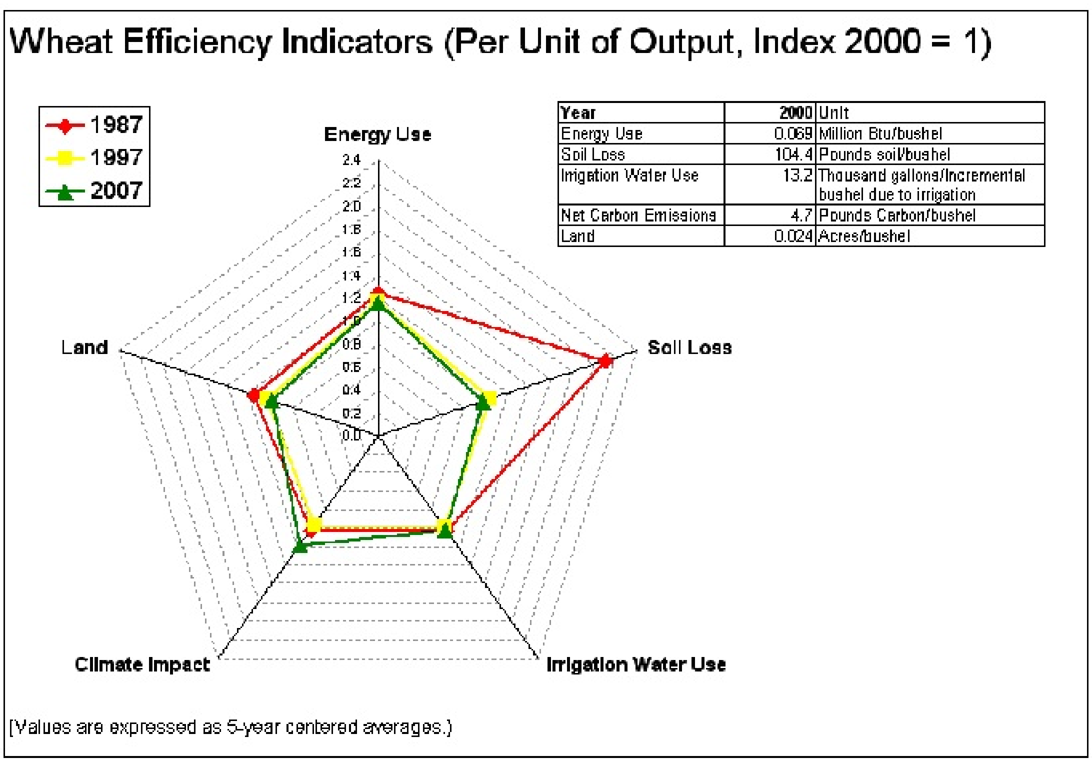


Similar gains can be seen in other crops that have a high level of GM adoption. Here are the sustainability indicators for cotton and soybean:





An effective way in which to gauge the contribution of GM to sustainability is to compare the gains that GM crops have made in sustainability indicators as compared to the gains in non-GM crops. For example, the sustainability indicators for wheat– which has no GM version on the market, have stagnated for the past decade:



Summary statistics for corn, cotton, soybean and wheat: Changes are between 1987 and 2007. Corn, cotton and soybean were largely GM by 2007, while wheat remains totally non-GM. In general, the yield increases and sustainability indicators have been greater for the GM crops, while progress for wheat has lagged behind or failed to make progress.

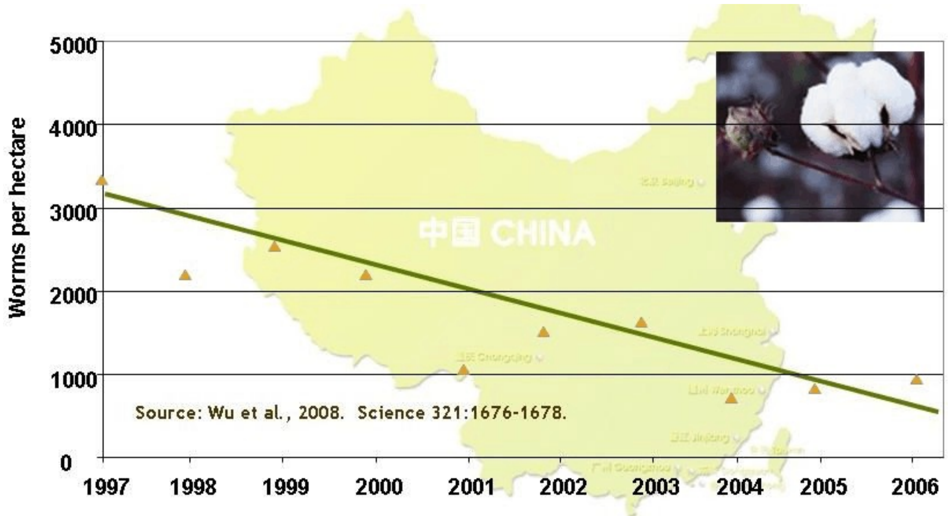
	Corn	**Cotton**	**Soybean**	**Wheat**
Yield per acre (% increase)	41	31	29	19
% decrease in land per bushel (corn, soybean or wheat) or lb (cotton)	37	25	26	17
% decrease in soil loss per bushel or lb	69	34	49	50
% decrease in energy use per bushel or lb	37	66	65	9
% change in greenhouse gas emissions per bushel or lb	-30	-33	-38	+15

The take-home message from these data is that both cultural and genetic changes are necessary to make progress on sustainability indicators. In principle, wheat has benefitted from improved cultural practices over the past decade as have corn, soybean, and cotton. The lack of progress in wheat over the past decade serves to illustrate the point that cultural practices alone are not sufficient– genetics are necessary too!

Other sustainability indicators

Sustainability has social, environmental and economic aspects. Ultimately, farmers farm for profit, and greatest profit is not always associated with greatest yield. When it comes to yield, there is a point at which the cost of additional inputs is no longer compensated by the additional yield. Since GM crops can require less inputs (e.g., reduced plowing (and thus fuel for tractors), insecticides, and the number of herbicide applications) they provide a level of convenience (even the UCS report acknowledges this) which improves the quality of life in rural areas. They also can represent a substantial reduction in the cost of production, which increases the profitability in rural areas. Finally, the need for reduced agrochemicals results in reduced environmental impact where ever GM crops are grown. All these benefits have been discussed elsewhere (Brookes and Barfoot 2006), so they will not be discussed here.

The use of GM is having positive benefits beyond the field edges. For example, the use of GM cotton in China has lowered the amount of cotton bollworms, to where damage (and hence need to apply insecticide) in fields of soybean, peanut and corn has gone down:



Why not organic?
Overall, the claims that organic yields can be sustained is highly dubious, and there is no relationship between IY and organic production. Rather than debate the particulars of whether organic production can maintain high yields, it is easier to point out that the UCS paper fails to address key issues for organic production. Chief among these is the source of nitrogen. Right now, organic nitrogen (i.e., fixed by legumes & other sources, accounts for somewhere between 40 to 60% (Smil, 2002) of the total nitrogen in the diet. The remainder comes from synthetic (non-organic) fertilizer. To replace synthetic nitrogen fertilizer with organic, it would be necessary to greatly increase the amount of farmland needed to grow legumes and animal feed– perhaps as much as 3x more land would have to be placed under production. Such a dramatic expansion of farm land would have very negative consequences on environmental quality and sustainability.

Summary
The current generation of GM crops were designed to preserve OY, and have succeeded in doing so around the world. Furthermore, they have made substantial contributions to sustainability indicators and have succeeded in decreasing the agricultural footprint in the environment. These factors alone are enough to justify the use of GM crops as part of an overall strategy for agricultural development around the world.

Parting thought: Why haven't the gains been greater?
The major traits deployed in GM crops thus far- such as resistance to viruses, herbicides, and insects-- are clearly directed at OY. It is unfair, then, to complain about the lack of increase in IY as is done in the UCS report.

Besides the currently marketed traits, there are numerous examples of many other traits that could contribute to increases in OY in crops. These include tolerance to abiotic stress, such as heat, drought, salt and cold tolerance, and resistance to bacterial, fungal and virus diseases. Unfortunately, the current regulatory regime is completely disproportional to the risk. As a result, only select genes in select crops would have great enough usage to generate enough revenues to cover the cost of deregulation.

To the extent to which groups like UCS have advocated prohibitive and disproportional regulations, they are responsible for the lack of even greater achievements in OY and perhaps even in IY. In fact UCS is on the record as opposing engineered stress tolerance in crops (see the UCS comments on the proposed rule changes for Importation, Interstate Movement, and Release Into the Environment of Certain Genetically Engineered. These are available at http://www.ucsusa.org/assets/documents/food_and_agriculture/UCS-comments-GE-rule.pdf). As mentioned at the beginning, such a stance by UCS is untenable and contradictory– yield losses caused by adverse growing conditions defeats the purpose of having a higher IY– that is why it is so important to increase OY, and increasing OY is done with resistance to biotic and abiotic stresses–i.e., adverse growing conditions.

In the end, after helping prevent scientific advances with GM crops, UCS is not in a good position to be calling GM crops a failure because their scientific advances have not been greater.

Literature Cited.

Brookes G and P Barfoot. 2006. Global impact of biotech crops: socio-economic and environmental effects in the first ten years of commercial use. AgBioForum 9:139-151.

Cramer HH 1967. Plant Protection and World Crop Production, Farbenfabriken Bayer AG-Leverkusen

Gurian-Sherman D. 2009. Failure to yield: evaluating the performance of genetically modified crops, Union of Concerned Scientists

The Keystone Center. 2009. Environmental Resource Indicators for Measuring Outcomes of On-Farm Agricultural Production in the United States, First Report.

Oerke E-C, H-W Dehne F Schönbeck, A Weber. 1994. Crop production and crop protection : estimated losses in major food and cash crops. Elsevier, London.

Smil V 2002. Nitrogen and food production: proteins for human diets. AMBIO 31:126-131

Troyer AF 2006. Adaptedness and heterosis in corn and mule hybrids. Crop Sci. 46:528-543

Wu K-M, Lu Y-H, Feng H-Q, Jiang Y-Y, and Zhao J-Z. 2008. Suppression of cotton bollworm in multiple crops in China in areas with Bt toxin–containing cotton. Science. 321:1676-1678.