Corn yields and climate: Their inseparable futures

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US Average Corn Yield since 1900 (Bu/Acre)
Main points for today

1) High corn yields have been, and will continue to be, an essential way to limit emissions of greenhouse gases

2) Maintaining high corn yields will be a lot easier with a pro-active approach to dealing with the challenges of climate change
US Average Corn Yield since 1900 (Bu/Acre)
Commercial Fertilizer Use per Acre of Cropland

Pounds per Acre

Motivation

✓ Modern agricultural is certainly a source of greenhouse gases

✓ Many use this to conclude that modern agriculture is “bad” for climate, but that is a BIG jump in logic

✓ For the latter, the only fair thing is to compare it to specific alternatives.
The actual history of agriculture since 1960

✓ Large increases in population and food production
The actual history of agriculture since 1960

Production increases were mainly from yields, not expansion.
The actual history of agriculture since 1960
This is especially the case for cereals
The actual history of agriculture since 1960

Associated with this intensification, there has been a significant amount of GHG emissions
The actual history of agriculture since 1960

Associated with this intensification, there has been a significant amount of GHG emissions

Paustian, Keith, et. al., “Agriculture’s Role in Greenhouse Gas
So what were the possible alternatives?

✓ What would world have looked like without agricultural advancements?

✓ An impossible question, but can at least spell out the implications of different assumptions.
The counter-factual histories of agriculture since 1960

\( W = \) real world
\( W1 = \) no yield gain, but historical trends in population and living standards
\( W2 = \) no yield gain, constant fertility rates and living standard since 1961
### Cropland Expansion Causes GHG Emission

**Map depicting the global distribution of biomes.**

<table>
<thead>
<tr>
<th>Biome</th>
<th>Biomass Carbon [t/ha]</th>
<th>Soil Organic Carbon [t/ha]</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical Evergreen Forest</td>
<td>210</td>
<td>72</td>
<td>Gibbs</td>
</tr>
<tr>
<td>Tropical Deciduous Forest</td>
<td>132</td>
<td>72</td>
<td>Gibbs</td>
</tr>
<tr>
<td>Temperate Broadleaf Evergreen Forest</td>
<td>100</td>
<td>101</td>
<td>Houghton</td>
</tr>
<tr>
<td>Temperate Needleleaf Evergreen Forest</td>
<td>160</td>
<td>101</td>
<td>Houghton</td>
</tr>
<tr>
<td>Temperate Deciduous Forest</td>
<td>135</td>
<td>101</td>
<td>Houghton</td>
</tr>
<tr>
<td>Boreal Evergreen Forest</td>
<td>90</td>
<td>155</td>
<td>Houghton</td>
</tr>
<tr>
<td>Boreal Deciduous Forest</td>
<td>90</td>
<td>155</td>
<td>Houghton</td>
</tr>
<tr>
<td>Evergreen/Deciduous Mixed Forest</td>
<td>145</td>
<td>101</td>
<td>Houghton (Est.)</td>
</tr>
<tr>
<td>Savanna</td>
<td>43</td>
<td>55</td>
<td>Gibbs</td>
</tr>
<tr>
<td>Grassland/Steppe</td>
<td>8</td>
<td>59</td>
<td>Gibbs</td>
</tr>
<tr>
<td>Dense Shrubland</td>
<td>69</td>
<td>59</td>
<td>Gibbs</td>
</tr>
<tr>
<td>Open Shrubland</td>
<td>31</td>
<td>59</td>
<td>Gibbs</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Total GHG Emission from real and alternate worlds

$W = \text{real world}$

$W1 = \text{no yield gain, but historical trends in population and living standards}$

$W2 = \text{no yield gain, constant fertility rates and living standard since 1961}$
The real world has fewer GHG, how much was the cost per ton CO₂ avoided?
Summary so far

✓ Modern agricultural is likely a lot better for climate than lower yielding alternatives

✓ Investments in high yields have historically been a bargain from a climate perspective

✓ This does not say that high yields aren't possible with less emissions than currently achieved

✓ This also doesn't speak to any environmental impacts other than climate.
How to Continue Raising Yields?

✓ In general, higher yields will require better tuning cultivars and management to the specific conditions of a given site and year.

✓ A new challenge is that future conditions will likely differ from past conditions in the Corn Belt.
How does weather affect corn yields?

U.S. Corn Yields, 1866-2002

We can examine what weather changes drive these variations.

How does weather affect corn yields?

Corn yields are surprisingly sensitive to temperatures above ~86 °F (30 °C).

Panel A: Corn Yields – Time Series

\[ y = 0.136 - 0.00605x \]

(5.67) (6.58)

Panel B: Corn Yields – Cross Section

\[ y = -0.089 - 0.00561x \]

(1.80) (7.47)

Comparing different years

Comparing different counties
How does weather affect corn yields?

current example

Bloomberg

Corn, Soybean Prices Rise on Speculation Heat in August Damaged U.S. Crops

Jeff Wilson - Aug 12, 2010

Corn futures rose the most in almost two weeks and soybeans gained on speculation that the recent dwest heat wave will mean smaller production than the record crops predicted today by the government.

August has gotten off to the second-warmest start since 1960, T-Storm Weather LLC said today in a report. Another forecaster, Commodity Weather Group LLC, said about 25 percent of the U.S. soybean-growing area won’t get enough rain for proper plant development over the next two weeks, and that the dryness could harm a third of the Midwest should rain miss sections of Illinois this weekend, as expected.
How will climate change?

Climate change is different than weather. Most places have seen significant warming already, but not all. In my opinion, skepticism about climate change often tracks local experience with recent weather.

Trend in Growing season average temperature for maize (°C change 1980-2008)
How will climate change?

The science is clear. All major growing regions are likely to warm.

Expected °C change in average temperature relative to 1960-1990 for an “A2” emissions scenario
U.S. corn yields could be heavily impacted by climate change, because current varieties are quite sensitive to temperature and insensitive to CO$_2$.
Will private sector easily adapt?

Pioneer Hi Bred readies drought tolerant corn

By Dan Piller On February 26, 2010 @ 8:25 am In Business, Green Fields: Agriculture and Energy | No Comments

[1]Although they don’t want to be held to an exact date, Pioneer Hi-Bred executives say there is a chance they may be in the market this fall with a new drought-tolerant strain of hybrid corn.

The new corn would be sold primarily in the Corn Belt, said that Pioneer has been working on drought tolerance in corn for years and has “a significant respect for the challenge it represents.”

Company chief executive officer Hugh Grant said during a recent visit to Des Moines that his company has found drought tolerance to be a difficult nut to crack. He warned that drought tolerance is likely to be an “aha” moment.

“We will probably be a family of drought tolerant seed products rather than one big new invention suddenly comes out from behind the curtain,” Grant said.

manager. Sales for the 2011 planting season begin with the opening of the seed marketing season which begins on Labor Day.
Will private sector easily adapt?

✓ To some extent, yes. But will it be enough to avoid big impacts?

✓ There are some unique effects of heat, aside from drought, that have received much less attention from companies.

✓ There is some evidence that heat sensitivity actually increased with adoption of single-cross hybrids.
Thank you for your attention!

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Figure 3: Precipitation Shocks in Indiana 1901-2005

Notes: Graph shows weather shocks (deviations from averages) for total precipitation during the growing season March-August. State level averages are shown as diamonds. The range of weather shocks among Indiana’s counties is shown as boxplots: The box give the 25%-75% quartile range, the median is shown as a solid line, and whiskers extend to the minimum and maximum. A locally weighted regression of the state
Figure 2: Shocks in Extreme Heat in Indiana 1901-2005

Notes: Graph shows weather shocks (deviations from averages) for degree days above 29°C during the growing season March-August. State level averages are shown as diamonds. The range of weather shocks among Indiana’s counties is shown as boxplots: The box gives the 25%-75% quartile range, the median is shown as a solid line, and whiskers extend to the minimum and maximum. A locally weighted regression of the state average (bandwidth of 10 years) is shown as a bold line.
Robert Byrd to Coal Constituents, 2009:

To deny the mounting science of climate change is to stick our heads in the sand ... The future of coal and indeed of our total energy picture lies in change and innovation. In fact, the future of American industrial power and our economic ability to compete globally depends on our ability to advance energy technology."
To deny the mounting science of climate change is to stick our heads in the sand ... The future of crop yields and indeed of our total agriculture picture lies in change and innovation. In fact, the future of American agricultural power and our economic ability to compete globally depends on our ability to advance cropping technology."

Thank you for your attention!
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Will private sector easily adapt?

Appendix A8: Nonlinear Relation Between Temperature and Yields For Various Geographic Regions

Graphs at the top of each panel display changes in log yield if the crop is exposed for one day to a particular 1°C temperature interval where we sum the fraction of a day temperatures fall within each interval. The 95% confidence band, after adjusting for spatial correlation, is added as grey area for the polynomial regression. The three panels from left to right, respectively, only use northern, middle, and southern counties in the estimation of the coefficients. Curves are centered so the exposure-weighted impact histograms at the bottom of each panel display the average temperature exposure among all counties data.
The Growth in Fertilizer Use

In the past 10 years, the use of fertilizer in the developing world has increased by about 10 million tons. This has lowered the price of food and allowed farmers in many countries to improve their yields. However, the increase in fertilizer use has also led to "dead zones" in the oceans, where excess nitrogen has caused harmful algae blooms that deplete oxygen from the water.

*Data for these regions are for 2003-06 and the 10-year change is from 1996-97.

Sources: International Fertilizer Industry Association; "Fertilization and Hypernutrition in Coastal Ecosystems: A Global Assessment of the State of Knowledge," Mindy Solomon, Suzie Greenhalgh, Robert Diaz and Zachary Sugg (World Resources Institute).