The Food-Climate Nexus

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Main Points:
1) Food and climate are now tightly coupled in both directions
2) Decoupling them isn’t easy and solutions are often counter-intuitive
3) The keys to scientific progress are to carefully quantify things, and make the proper comparisons.
The Food-Climate Nexus

Human Drivers and Feedbacks: Population, Income, Behavior, Policy, Technology

Avoid big negative impacts

FOOD

Energy

CLIMATE

Avoid big emissions of greenhouse gases

The Goal?
Answers are not obvious, because...

1) Many of the relationships between food and climate are still poorly quantified

2) Humans are constantly responding to biophysical constraints (at least those reflected in prices), and so provide an important feedback

3) Many studies measure things as “with” vs. “without” some action. The right comparison is “choice 1” vs. “choice 2”

   -For example, does it make sense to say that modern agriculture is responsible for 15% of greenhouse gas emissions?
It is true that modern practices involve emissions.
Also true that the sum total of these are ~15% of total greenhouse gas emissions

How much does modern agriculture contribute to greenhouse gas emissions?

To answer this, have to propose an alternative for comparison, such as:

A) All Organic  
B) All Local  
C) Use “traditional” technologies

Let’s consider for now what would have happened if we stopped intensifying in 1960
With less food, wouldn’t population slow?
With less food, wouldn’t population slow?
If we stopped intensifying in 1960, additional demand would be met by more expansion.

\[ \text{Yield} \]

\[ \text{Population} \]

\[ \text{Crop area} \]

\[ \text{Fertilizer use} \]

\( RW = \) real world

\( AW1 = \) no yield gain, but historical trends in population and living standards

\( AW2 = \) no yield gain, constant fertility rates and living standard since 1961

Burney et al. PNAS 2010
### Cropland Expansion Causes GHG Emission

<table>
<thead>
<tr>
<th>Biome</th>
<th>Biomass Carbon [t/ha]</th>
<th>Soil Organic Carbon [t/ha]</th>
<th>Source</th>
</tr>
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<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>
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<td>59</td>
<td>Gibbs</td>
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<tr>
<td>Tundra</td>
<td>1</td>
<td>1</td>
<td>Est.</td>
</tr>
<tr>
<td>Desert</td>
<td>1</td>
<td>1</td>
<td>Est.</td>
</tr>
<tr>
<td>Polar Desert/Rock/Ice</td>
<td>1</td>
<td>1</td>
<td>Est.</td>
</tr>
</tbody>
</table>
Total GHG Emission from real and alternate worlds

RW = real world
AW1 = no yield gain, but historical trends in population and living standards
AW2 = no yield gain, constant fertility rates and living standard since 1961

Burney et al. PNAS 2010
How much does modern agriculture contribute to greenhouse gas emissions?

• So intensification has actually resulted in a net decrease in emissions compared to a low intensity alternative.

• This is mainly because
  (1) people need to eat
  (2) poorer populations grow faster, even with higher death rates
  (3) clearing of land has a large climate effect

• The carbon savings were actually a bargain (about $10/ton CO₂)
What do we know about climate $\rightarrow$ food?

Human Drivers and Feedbacks: Population, Income, Behavior, Policy, Technology

- Avoid big negative impacts
- Avoid big emissions of greenhouse gases
- The Goal?
We know that climate is one of several factors that determine where we grow food.
But the key question is *how much* does it matter if climate changes (is it a 1% or 20% problem)?

By looking at how well crops do in different places or years, we can measure how important climate is:

Field trials

![Diagram showing average temperatures and maize yields](image-url)
Overall, temperatures are surprisingly important for crop yields

Field trials

- Rapid yield loss for $T>30^\circ$C ($\sim$1%/day)
- Strong dependence on moisture

Lobell et al. Nature Climate Change, 2011
We already see lots of changes occurring, and impacts \( \sim \$50B/yr \)

Lobell et al. 2011
A big remaining question is how people adapt