Estimating new cropland yields

A review of the latest Purdue/Argonne analysis of carbon emissions from corn ethanol

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Measuring “ETA”

- Among the many dozens of changes and improvements made by the Purdue group, a key one is in the estimation of the relative change in yield for new cropland versus existing cropland in each region and agro-ecozone (AEZ) on the globe. This ratio is referred to as “Eta”
Measuring “ETA”

\[
\frac{Y_0}{Y_{\Delta}} = \frac{2}{3}
\]

Previous GTAP analysis
Measuring “ETA”

For all regions
For all AEZs

Previous GTAP analysis

Current cropland $Y_0$
New cropland $Y_{\text{delta}}$
Measuring “ETA”

\[
\frac{Y_0}{Y_{\Delta}} = 42
\]

Life, the universe and everything

Too arbitrary?
New approach uses “fundamentals” to estimate yield potential of new and existing cropland.
Measuring “ETA”

\[
\frac{Y_0}{Y_{\Delta}} = f(AEZs, \text{etc})
\]
Terrestrial ecosystem model

- Process based ecosystem model for simulating carbon and nitrogen fluxes between land and atmosphere
- Developed by The Ecosystem Center at the Marine Biology Lab in Woods Hole, MA
- Lobell: “Well-respected”
**Terrestrial ecosystem model**

- Net Primary productivity (NPP)

\[ \text{NPP} = \text{Mg C per ha per year} \]

\[ \text{C}_{\text{photosyn}} - \text{C}_{\text{respiration}} - \text{C}_{\text{decomposition}} \]
Terrestrial ecosystem model

Key drivers

- Average monthly climate (precipitation, temperature, cloud)
- Soil texture
- Elevation
- Vegetation—generic C4 crop
- Water availability
An important caveat—this a natural ecosystem model, NOT a managed agro-ecosystem model
\[
\frac{Y_0}{Y_{\text{delta}}} \sim \frac{\text{NPP}_0}{\text{NPP}_{\text{delta}}} = f(\text{AEZs, etc})
\]
The 18 Agro-ecozones
The 18 Agro-ecozones

Figure 5. The SAGE global map of the 18 AEZs

- Tropical
- Temperate
- Boreal
TEM estimates of average NPP

NPP for current cropland in each AEZ (Mg C/ha/y)

- Increasing growing degree days
- Increasing moisture regime

<table>
<thead>
<tr>
<th>AEZ</th>
<th>1</th>
<th>2</th>
<th>3</th>
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Increasing growing degree days
Increasing moisture regime
TEM estimates of ETA

USA Eta values vs AEZ

So America Eta values vs AEZ

Europe 17 Eta values vs AEZ
Our discussions

<table>
<thead>
<tr>
<th>Questions/Issues</th>
<th>Comments/Observations/Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift from average crop to specific crop productivity</td>
<td>This would be an improvement, but no immediate plans for this work. <em>(Not a showstopper?)</em></td>
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<tr>
<td>Is there a match between GTAP and TEM land data sets and assumption?</td>
<td>As far as we can tell, yes—there is a one to one correspondence</td>
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<tr>
<td>Should account for differences in productivity of forest versus grassland</td>
<td>This would be an improvement, but no immediate plans for this work. <em>(Not a showstopper?)</em></td>
</tr>
<tr>
<td>Concern about yields on new land that are higher than current yields</td>
<td>There is no clear consensus on this issue. There are reasons for why yields could well be higher <em>(Brazil)</em></td>
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</table>
Lobell/Gurgel comments

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<tr>
<th>David Lobell</th>
<th>Angelo Gurgel</th>
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<tbody>
<tr>
<td>It is likely that non-used lands that have high NPP are not in use because of other biophysical or economic constraints</td>
<td>CET captures economic contraints, while Eta only considers biogeophysical aspects of land productivity</td>
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<tr>
<td>Do the cross-country patterns in productivity from TEM match what is in the GTAP database? This is a test they could do with the current results.</td>
<td>Comparison is not straightforward between GTAP yields and NPP. Isn't it possible to look for correlations within region/AEZs between yield in GTAP and predicted NPP?</td>
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<td>No explanation of why new estimates of Eta are so much higher than earlier estimates</td>
<td>There is a big shift in this analysis from a highly arbitrary guesstimate to a science (model) based estimate</td>
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<td>Only consider abandoned farmland</td>
<td>Complex issue</td>
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There is always room for improvement

- Other NPP models based on biogeophysical processes
- Use of specific crop production models
- Soil quality effects
- Accounting for regional management practices including nutrient management and water management strategies
- More detailed breakdown of ag-ecozones
Short term recommendation

- The revised Eta values for new cropland yield represent a significant improvement over previous arbitrary global assumptions.

- While further work with other NPP models and crop models will help to further validate and provide context for current findings, the degree of improvement over previous analysis warrants considering adoption of these new estimates.

- This recommendation applies to Eta/TEM methodology. Overall findings in the Purdue study are affected by many other (more important?) assumptions.
Continuing refinement

- Compare GTAP yield and NPP results for directional consistency (?)
- Consider management practice effects
A statistical vs physical model

- Statistical model of crop productivity $f(\text{climate, soil, moisture, management})$
- Update of Ramankutty data
- Equally divide up harvested land area into 100 climate “bins” based on precipitation, growing degree days, etc (vs 18 AEZs)
Thinking about yield gap
A statistical vs physical model

• Adding management practices

• Non linear logistical model of nitrogen fertilizer rate effects

• Overman and Scholtz 2002
A statistical vs physical model

Maize

observed yield: Monfreda et al. 2008

tons/ha

0 2 4 6 8 10
A statistical vs physical model

modeled yield: global mean

Maize

 tons/ha

0 2 4 6 8 10
A statistical vs physical model

Maize

modeled yield: bin mean

tons/ha

0 2 4 6 8 10
A statistical vs physical model
A statistical vs physical model

observed yield: Monfreda et al. 2008

Maize

tons/ha

0 2 4 6 8 10
This is an analysis could be applied to cropland extensification over the next few months.