Historical Evaluation of the GCAM Agriculture and Land Use Model: Comparing Crop Production and Harvested Land Area to Recent History

October 2, 2013

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This research was supported by the Office of Science of the U.S. Department of Energy as part of the Integrated Assessment Research Program.
GCAM Model Evaluation Effort

- Broad effort to evaluate GCAM model behavior against history.
  - Including major aspects such as economic choices in the energy and agricultural system, changes in the terrestrial system, emissions.

- This effort serves multiple objectives:
  - One is simply the evaluation itself, providing appropriate and useful level of model validation for a long-term integrated assessment model.
  - Improve transparency and understanding to the community about how the model operates given key assumptions.
  - Serves as a learning exercise for identifying modeling approaches and data that are most critical for long-term modeling and areas that could be improved.

- The analysis presented here is on one aspect: evaluating the economic agriculture production and land allocation modeling versus recent history.
Approach

- We have constructed a set of model test cases for running GCAM annually in historical years (back to 1990 for this presentation, although we have also begun exploring back to 1970s).

  - For this presentation, we assume that population, income, technology, and crop yields are known in each modeled year – so that the evaluation can isolate the economic choice of crop production and land use.

- We compare GCAM modeled historical global and regional crop production and harvested land area to FAO data for some major crops.

- We consider major reasons why some results fit well with history and some do not.
  - What reasons for differences may be important for our long-run modeling?
### Evaluation Cases

<table>
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<tr>
<th>Case</th>
<th>Description</th>
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<tbody>
<tr>
<td>GCAM 1990 Base</td>
<td>GCAM Calibration to 1990 as Base Year. GCAM is run forward annually for 20 years. GCAM makes annual land allocations given data for population, income, and crop yields.</td>
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<tr>
<td>GCAM 1990 Base +RFS</td>
<td>Same as GCAM 1990 Base, but the US Renewable Fuels Standards are imposed (which would not have been knowable in 1990)</td>
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<tr>
<td>GCAM Core</td>
<td>GCAM is calibrated first to 1990 and then to 2005. GCAM is run in typical time steps: 1990, 2005, and then 5-year periods. To isolate impact, increase in RFS to 2010 is not included.</td>
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- Agriculture and land use calibration is performed with a multiyear average around the base year rather than exactly to the base year.
Global production levels are primarily driven by our modeling of agricultural demand (though land does have an impact).

- Demands for food grains, fiber, non-food demands for agriculture, meat, feed, forest products, bioenergy.
- We have typically assumed global markets for crops.

Human demands are modeled based on base year data and on changes in future population, income, and crop prices.

- We assume very or perfectly price-inelastic demands for food crops.
- Meat demand is assumed to vary by income and price.
- Forest Product demand varies with income and price.
- Demand among pasture and feed crops for meat varies with costs.
- Bioenergy demand is linked economically with the energy system.
Global Wheat Production

- Historical production grows steadily with some annual variability.
- GCAM cases miss the annual variability but capture the trend.
- GCAM with 1990 base year is not much different from GCAM Core.
Historical land area is fairly constant, reflecting growing yields, with annual variability.

GCAM run annual has variability due to yield variability, while GCAM Core shows the long-term trend.
The GCAM 1990 Base clearly misses demand growth when it is not told about the RFS.
The GCAM Core captures the trend much better, but still needs to account for growth in RFS beyond 2005.
Evaluation of Regional Production and Land Use

- GCAM Regional Production and Land Use in GCAM is directly driven by the approach to economic land use allocation.

- Non-linear functions are used to represent distributions of profits for competing uses of land (logit or logistics equations).
  - These functions are readily calibrated. Future periods deviate from history to the extent that changes in key economic drivers (such as demand growth, yields, policies) change relative prices from history.
  - These non-linear profit functions reflect diminishing returns to expansion.
  - There is no need to place constraints on economic land allocation to avoid over-optimization in model years as there often is with linear optimization models.

- GCAM typically assumes a global integrated market for ag products.
  - Unlike models that use “Armington” approaches, historical trade preferences are not calibrated into future periods.
  - Production among regions is based on comparative advantage relationships rather than on absolute advantage or regional demand.
GCAM 1990 Base does respond to the annual variability, closely in some years but over-responding in others. Need to look at land use to interpret.

GCAM Core captures the long-term trend well.
Regional Wheat Harvested Land Area: USA

- Downward trend reflects general yield growth in all cases.
- GCAM annual land area results appear more volatile than the historical data.
In these GCAM cases, it is assumed that the actual yield is known (for all crops) within each year. Therefore land allocation will respond more than history.

Modeling instead on yield expectations would give different results.
GCAM Annual results match well when actual yields show little annual volatility.
General Observations

- The GCAM Core approach appears to capture the average production and land use trends well, both globally and regionally.

- The Base 1990 Case did reasonably well against 20 years of data.
  - Of course it could not reflect an unknown future policy driver like the RFS, but it did show that it could evaluate such a future policy when assumed.

- Although trying to make GCAM match each historical year is not a necessary or fruitful path for improving the long run modeling capability, doing so proved very instructive.
  - Shows that GCAM will reflect adaptation to long-term changes in yield.
  - Running GCAM annually versus history provided insight into modeling future scenarios in which expected crop yields differ from actual yields.

- Next steps include looking at total cropland and other land uses.