Crop production, cropland use, and land intensification in economic models

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1. Introduction

Several recent publications have shown that land intensification in crop production (defined as harvest frequency and measured by the ratio of harvested area (H) over area of available cropland (A)) has increased across the world due to expansion in multiple cropping and/or conversion of unused cropland to crop production (for example see Ray and Foley (2013)). The expansion in harvest frequency, if persists in the future, could absorb a portion of future increases in demand for cropland. To evaluate the potential economic and land use impacts of improvements in harvest frequency, we need to introduce this source of land intensification in the existing economic models which currently misrepresents it.

2. Objectives

The existing economic models, in particular the large scale global Computable General Equilibrium (CGE) models are not designed to properly represent improvements in land intensification in crop production and capture their economic and land use implications. This paper discusses this issue, offers a method to introduce land intensification in CGE model, and makes some simulations to represent its economic and land use impact.

3. Intensification in Cropland: Recent Evidence

The ratio of total harvested area over cropland by region.

China and India: Harvested is larger than available cropland but H/L followed an increasing path over time

Brazil & S. America: Harvested area is less than available cropland but H/L followed an increasing path over time

Canada and European Union: Harvested area is less than available cropland but H/L followed an increasing path over time due to reduction in area of available cropland

4. Intensification in Economic Models

Regarding all of these improvements, the economic models which represents different crop sectors, cannot take into account intensification in crop production in three ways:
- Intensification due to using more of non-labour inputs, such as inputs to which farmers substitute for increased demand. This is an appropriate remedy to solve the problem. An example of this approach is that of Nelson et al., (2010). “Food security, farming, and climate change: past, present, and future” European Journal of Agronomy 32, 189–203.
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5. Why traditional demand approaches can be implemented to represent improvements in harvest frequency in G1 models, but not in G2 models

An improvement in harvest frequency occurs due to:
- Expansion in multiple cropping,
- Returning idled cropland to crop production,
- Reduction in area of available cropland

An improvement in harvest frequency may be due to:
- Expanding the pool of available land,
- Expanding the pool of available land

6. An option to introduce improvements in harvest frequency in a G2 model

An improvement in harvest frequency increases the pool of land on the existing cropland, an option is to introduce this type of improvement. This is possible if one can:
- Introduce a productivity factor in the supply side of a typical G2 model
- Introduce a productivity factor in the supply side of a typical G2 model

7. Land supply nesturing structure in GTAP-BIO Model

8. Cropland supply in GTAP-BIO with no multiple cropping and no idled land

A nested Constant Elasticity of Transformation (CET) function allocates land among its alternative uses in this model.

The relationship following the supply of crop to the alternative uses is:

\[ Y_i = \frac{w_i}{\sum w_j} \]

where \( w_i \) and \( w_j \) are the values of the alternative uses. These values are defined and endogenously estimated for each region and crop. The ratio of total harvested area over cropland is:

\[ \frac{Y_i}{A_i} \]

This ratio represents changes in land supply and land use when prices change. The model is then revised to handle the price impacts as well.

9. Cropland supply in GTAP-BIO with multiple cropping and idled land

To introduce improvements in harvest frequency a new production function for crop is:

\[ Y_i = \frac{w_i}{\sum w_j} \]

The model determines the size of alfalfa endogenously using:

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10. Simulation Scenarios

To show the importance of including improvements in harvest frequency in demand for new cropland the following simulations were tested using the GTAP-BIO model with and without intensification using the GTAP-BIO 2011 database as presented in Taheripour et al (2017):

- Expansion in US corn ethanol by 1.07 BGs (from 13.93 BGs in 2011 to 15 BGs)
- Expansion in US ethanol biodiesel by 0.5 BGs
- Expansion in US soybean biodiesel by 0.5 BGs
- Expansion in US sugar cane ethanol by 1.07 BGs
- Expansion in US sugar cane ethanol by 1.07 BGs

Induced land use changes for these biofuels were calculated as the absence and absence of improvements in harvest frequency.

11. Simulation Results

Changes in harvested area and cropland for corn ethanol (in 1000 hectares) : Less cropland needed with intensification.

13. References