Crop Land Use Change Data and Modeling: Case Study of Brazil

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Objectives

• Examine recent changes in cropland area/yield in Brazil and role of biofuel crops using recent data

• Examine cropland change model specifications for GTAP simulations
Biofuel Land Use: Studies of Brazil

- Birur et al. (2008)
  - Similar loss of forest and pasture to sugarcane (7%)

- Wassenaar et al. (2007)
  - CLUE-s - Statistical simulation model for spatial distribution of national land use change in Central and South America: (2000-2010)
  - Pasture replaces 61% of deforested lands; soybean hotspots in Amazon Region

- Nassar et al. (2008)
  - Land use for sugarcane expansion in S. Central Brazil (2000-2007)
  - Remote sensing data: Other crops (53%), Pasture (45%)
  - 343 interviews: Corn/soy (23%), Pasture (65%), Other crops (10%)
  - Statistical model: Other crops (11%), Pasture (72%)

- Morton et al. (2006)
  - Mechanized cropland (mostly soybean) account for 11% and 17% of deforestation
Current Study: Data

• Sources
  
    http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html
    
    • Used 5-minute grid cell GIS data layers
    • Considered dominant ecosystems for 10 categories (aggregated to 6)
      – e.g., Mosaic = mixture of trees, crops, pasture and grassland
    • Focused on good to high land suitability for major crops under rain-fed and high input agriculture
      – Captures most of land under intermediate inputs
      – Rain-fed considers natural precipitation regimes
  
  – Agricultural Data (Brazil IBGE)  http://www.ibge.gov.br/english/
    
    • Municipal crop production, land area, yield and production value

• Data aggregated to 550 micro-regions
Data: Dominant Ecosystems

- **Woodland**: widespread
- **Forest**: Concentrated in Amazonia
- **Grassland**: Concentrated in middle region
- **Mosaic**: Transition areas
- **Cropland**: widespread

### Micro-Region Area Share
- 0.000
- 0.001 - 0.050
- 0.051 - 0.100
- 0.101 - 0.200
- 0.201 - 0.300
- 0.301 - 0.400
- 0.401 - 0.500
- 0.501 - 0.750
- 0.751 - 0.999
Data: Good to High Land Suitability

Sugarcane

Corn

Oilseeds

Roots

Cereals

Micro-Region Area Share

- 0.000
- 0.001 - 0.050
- 0.051 - 0.100
- 0.101 - 0.200
- 0.201 - 0.300
- 0.301 - 0.400
- 0.401 - 0.500
- 0.501 - 0.750
- 0.751 - 0.999
Data: Temporary Crops Land Use

- Total Use in 2002 ~56 million ha
- Net Area Increase 2002-2006: 7.8 million ha
  - Soybean: 5.8 million ha (~74%)
  - Sugarcane/Corn: About 1 million ha each
  - Other Grains: Net Decrease of 0.7 million ha
- Average yields have gone up for most crops
Data: Temporary Crops Land Use

Cropland Area (Ha)

-242,097 - -160,000
-159,999 - -50,000
-49,999 - -25,000
-24,999 - -3,000
-2,999 - 0
1 - 3,000
3,001 - 10,000
10,001 - 30,000
30,001 - 50,000
50,001 - 100,000
100,001 - 200,000
300,001 - 500,000
500,001 - 700,000
700,001 - 2,000,000

Harvested Area
Data: Temporary Crops Land Use

Harvested Area

Trend in Total Harvested Area

Change in Area
Data: Temporary Crops Yield

[Graph showing yield changes over years for different crops]

- **Yield**
  - Corn
  - Other Coarse Grains
  - Other Grains
  - OilSeeds
  - Other Crops
  - Sugarcane (2nd Axis)

- **Change in Yield**
  - 2002-2006

[Legend for graph bars: Corn, Other Coarse Grains, Other Grains, Sugarcane, OilSeeds, Other Crops]
Model: Cropland Allocation

- Constant Elasticity of Transformation Model in GTAP
  - Compared current structure to alternative structures

\[
\ln \left( \frac{X_{i,t}}{X_t} \right) = c_i + \sigma \ln \left( \frac{P_t}{P_{i,t}} \right) + \sum_k \beta_{i,k} E_k
\]

Crops:
1 = Corn; 2 = Other Coarse Grains; 3 = Other Grains
4 = Sugarcane; 5 = OilSeeds; 6 = Other Crops

- \( X_t; X_{i,t}; P_{i,t} \) = Micro-region total temporary cropland, cropland under crop \( i \), and gross land returns ((1000R$/ha) for crop \( i \), respectively
- \( E_k \) = Other variables (dominant ecosystem, land suitability, etc)

- Results
  - Elasticity of Transformation (\( \sigma \))
    - Small, significant, but positive sign (expected sign is negative)
    - Single nesting of crops may hide price relationships in land allocation
    - Model has good fit to data, but structural coefficients incorrect
### Model: Cropland Allocation

- **Single-Level CET: Estimates**

<table>
<thead>
<tr>
<th>Equation</th>
<th>Coefficient</th>
<th>T-Stat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equation 1: Corn</strong></td>
<td></td>
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<tr>
<td>Elasticity of Transf.</td>
<td>0.114</td>
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<tr>
<td>2002 Base Term</td>
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<td><strong>Equation 2: Other Coarse Grains</strong></td>
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<td><strong>Equation 3: Other Grains</strong></td>
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<td>Sugarcane</td>
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<td>Wheat</td>
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<td><strong>Equation 4: Sugarcane</strong></td>
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<td>Elasticity of Transf.</td>
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<td><strong>Equation 5: OilSeeds</strong></td>
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<td>Wheat</td>
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<td><strong>Equation 6: Other Crops</strong></td>
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<td>Wheat</td>
<td>1.686</td>
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</tbody>
</table>

**R-Squared:** 30% and 92%
Model: Cropland Allocation

- Multi-Level Nested CET Model:

Crops:
1 = Corn
2 = Other Coarse Grains
3 = Other Grains
4 = Sugarcane
5 = OilSeeds
6 = Other Crops

\[
\ln \left( \frac{X_{n,l,t}}{X_{n,r,t}} \right) = c_n + \sigma_n \ln \left( \frac{P_{n,l,t}}{P_{n,r,t}} \right) + \sum_k \beta_{n,k} E_k
\]

(1)

\( n = \) sub-nest 1 – 5; \( l = \) left member of a nest; \( r = \) right member of a nest
Model: Cropland Allocation

• Multi-Level Nested CET Model: Results

  – Structure (1) has better fit to the data

  – Transformation elasticities
    • 4 of 5 have expected signs in both cases (negative)
    • Sub-nest involving Oilseeds has the positive sign under both structures

  • Oilseeds behavior may reflect non-price planting motives
    – Soybean planting as land preparation step when converting pasture to sugarcane (noted by Nassar et al 2008).
    – General rotation of legume crops with other crops for soil improvements
## Model: Cropland Allocation

- **Multi-Level Nested CET Model: Estimates (1)**

<table>
<thead>
<tr>
<th>Equation 1: Nest 1</th>
<th>Coefficient T-Stat</th>
<th>Equation 4: Nest 4</th>
<th>Coefficient T-Stat</th>
</tr>
</thead>
<tbody>
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<td>Elasticity of Transf.</td>
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<tr>
<td>2002 Base Term</td>
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<td>2002 Base Term</td>
<td>0.980 99.3</td>
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<tr>
<td><strong>Land Suitability</strong></td>
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<td><strong>Land Suitability</strong></td>
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<tr>
<td>Corn</td>
<td>0.422 7.0</td>
<td>Corn</td>
<td>0.838 13.0</td>
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<td>OilSeeds</td>
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<td>Wheat</td>
<td>2.077 39.0</td>
<td>Wheat</td>
<td>1.176 24.5</td>
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</table>

<table>
<thead>
<tr>
<th>Equation 2: Nest 2</th>
<th>Coefficient T-Stat</th>
<th>Equation 5: Nest 5</th>
<th>Coefficient T-Stat</th>
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<tbody>
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<td>Elasticity of Transf.</td>
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<tr>
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<td>2002 Base Term</td>
<td>0.797 49.3</td>
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<tr>
<td><strong>Land Suitability</strong></td>
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<td><strong>Land Suitability</strong></td>
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<td>Corn</td>
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<td>OilSeeds</td>
<td>1.260 11.4</td>
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<td>Sugarcane</td>
<td>0.811 7.8</td>
<td>Sugarcane</td>
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<td>Wheat</td>
<td>1.587 25.1</td>
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<td>1.836 18.2</td>
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<table>
<thead>
<tr>
<th>Equation 3: Nest 3</th>
<th>Coefficient T-Stat</th>
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<tbody>
<tr>
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<tr>
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<td>1.141 20.3</td>
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<td>1.169 14.8</td>
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<td>Wheat</td>
<td>-0.903 -20.1</td>
</tr>
</tbody>
</table>

**R-Squared: 30% and 91%**
## Model: Cropland Allocation

- **Multi-Level Nested CET Model: Estimates (2)**

### Coefficient T-Stat

#### Equation 1: Nest 1
- Elasticity of Transf.: 1.492 (33.5)
- 2002 Base Term: 0.778 (71.2)

#### Land Suitability
- Corn: -0.556 (5.1)
- OilSeeds: 0.582 (5.5)
- Sugarcane: -0.405 (2.8)
- Wheat: 0.550 (6.2)

#### Equation 2: Nest 2
- Elasticity of Transf.: -0.362 (-7.1)
- 2002 Base Term: 0.255 (15.6)

#### Land Suitability
- Corn: 0.565 (3.7)
- OilSeeds: 0.709 (5.2)
- Sugarcane: -0.775 (4.3)
- Wheat: 2.872 (26.7)

#### Equation 3: Nest 3
- Elasticity of Transf.: -0.354 (-12.5)
- 2002 Base Term: 0.966 (106.4)

#### Land Suitability
- Corn: 0.663 (7.8)
- OilSeeds: 0.288 (3.2)
- Sugarcane: -5.498 (-46.2)
- Wheat: 2.663 (36.3)

#### Equation 4: Nest 4
- Elasticity of Transf.: -0.058 (-2.0)
- 2002 Base Term: 0.996 (66.8)

#### Land Suitability
- Corn: 1.008 (12.6)
- OilSeeds: -0.107 (-1.3)
- Sugarcane: 1.437 (12.8)
- Wheat: -0.719 (-11.6)

#### Equation 5: Nest 5
- Elasticity of Transf.: -0.469 (-12.4)
- 2002 Base Term: 0.925 (69.7)

#### Land Suitability
- Corn: 0.751 (8.6)
- OilSeeds: -0.027 (-0.3)
- Sugarcane: 2.770 (19.8)
- Wheat: 1.335 (21.0)

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**R-Squared: 23% and 82%**
Conclusion

- Most cropland expansion occurred in areas where mosaic ecosystems were dominant
  - This reflects continuation of longer-term conversion trends
  - Need for more precise data on composition of mosaic cover

- Land suitability and ecosystems heterogeneous across Brazil
  - Needs to be reflected in detailed policy analysis

- Cropland expansion/contraction is widespread
  - Soybean represents 75% (sugarcane 12%) of recent cropland expansion in Brazil
  - Sugarcane expansion is concentrated in South, which has large areas of fallow/pasture land
    - This study supports others showing sugarcane land expansion is more than 90% from pasture and other crop land

- Cropland distribution
  - A case is made for different specification of cropland allocation structure in GTAP
  - Estimated elasticities would be useful for Brazil
End

Thank You

Further details:
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