“Quantifying and managing land use effects of bioenergy”

# Methodologies to measure direct and indirect land use effects of sugarcane bioethanol

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# The evolution of land use data and modeling

Bovine prod systems
Pasture data

...

Conversion of natural vegetation
"Land use post-deforestation"

**Explained expansion and competition effects (LUC model)**

Deforestation rate
Amazon, Cerrado, Mata Atlântica…

**Substitution Matrix (Allocation methodology)**

Suitability
Land cover
Legal Restrictions
**Integrated land availability dataset**

**Land use model**

Crop specific:
production; price; cost…

**Agricultural-economic model**

**Non GIS**
**GIS**
**Merged**

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# Improving GIS database and models:

# The BLUM model

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# Brazilian Biomes and BLUM Regions

Fonte: IBGE/MMA, 2004. Mapa de Biomas do Brasil

# Structure of the Supply and Demand Section

Source: ICONE.

# Land Supply Curve and Elasticities

Total area used for Agriculture is defined by the Agland elasticity (scale effect)

• The share of total area that is dedicated to agricultural production follows a function such as:

$$m_{lt} = \frac{A_{lt}}{A_l^T} = kr_{lt}^{\varepsilon_\eta^{A_l}} \Rightarrow m_{lt} = \frac{A_{lt}}{A_l^T} = kr_{lt}^{\alpha_{lt}\varepsilon_\eta^{A_l}} \quad \text{Where:} \quad \alpha_{lt} = 1 - \frac{A_{lt} - A_{l0}}{A_l^T}$$

$k$ is a parameter to be defined, $r_t$ is the average revenue of the region, $\varepsilon$ is the land supply elasticity. The parameter $\alpha_{lt}$ is positive, higher or lower than one and is defined in each $t$.

# Competition and TOTAL elasticities

Share of agricultural land that is dedicated to one product is defined by own return and (negatively) by the return of the other activities

$$s_{ilt} = f\left(r_{ilt}, r_{-ilt}\right)$$

• The area of each $i$ activity in region $l$ and time $t$ ($a_{ilt}$) is defined as $a_{ilt} = A^T m\left(r_{lt}\right) s_{ilt}\left(r_{ilt}, r_{-ilt}\right)$

Scale | Competition

Cross elasticities

$$\varepsilon_{r_{lj}}^{l,i} = \frac{\partial m_l\left(r_{lt}\right)}{\partial r_{lt}} \frac{\partial r_{lt}}{\partial r_{jlt}} \frac{r_{jlt}}{m_l\left(r_{lt}\right)} + \frac{\partial s_{ilt}\left(r_{ilt}, r_{-ilt}\right)}{\partial r_{jlt}} \frac{r_{jlt}}{s_{ilt}\left(r_{ilt}, r_{-ilt}\right)}$$

Own elasticities

$$\varepsilon_{r_{li}}^{l,i} = \frac{\partial m_l\left(r_{lt}\right)}{\partial r_{lt}} \frac{\partial r_{lt}}{\partial r_{ilt}} \frac{r_{ilt}}{m_l\left(r_{lt}\right)} + \frac{\partial s_{ilt}\left(r_{ilt}, r_{-ilt}\right)}{\partial r_{ilt}} \frac{r_{ilt}}{s_{ilt}\left(r_{ilt}, r_{-ilt}\right)}$$

# Evidences: GIS inputs for economic models

# Example of Sugarcane Direct Substitution: Remote Sensing

South-Central Region: Classes of Land Use Converted to Sugarcane, 2007 and 2008 (1,000 ha)

Source: CANASAT/INPE, published in Nassar, A.M., Rudorff, B. F. T., Antoniazzi, L. B., Aguiar, D. A., Bacchi, M. R. P. and Adami, M, 2008. Prospects of the Sugarcane Expansion in Brazil: Impacts on Direct and Indirect Land Use Changes. In: Sugarcane Ethanol: Contributions to Climate Change Mitigation and the Environment. Zuurbier, P, Vooren, J (eds). Wageningen: Wageningen Academic Publishers.

# Example of Expansion in the Amazon: Data from Soybean Moratorium Project

Amazon Biome: Deforestated Area under Monitoring from 2006 to 2008 by Land Use Classes (hectares)

Total area cleared monitored by the moratorium:
157,896 hectares

Source: Abiove e Globalsat (www.abiove.com.br).

# Deforestation on the Cerrado Biome

Polygons with deforestation characterized with agriculture or pasture (hectares, 2006/07)

| State | Agriculture (ha) | Pasture (ha) | Total (ha) | % of total area | % agriculture | % pasture |
|---|---|---|---|---|---|---|
| BA | 55,242 | 15,889 | 71,130 | 0.47% | 78% | 22% |
| GO | 17,808 | 28,095 | 45,904 | 0.14% | 39% | 61% |
| MA | 16,998 | 10,674 | 27,672 | 0.13% | 61% | 39% |
| MG | 9,584 | 18,403 | 27,986 | 0.08% | 34% | 66% |
| MS | 8,318 | 30,665 | 38,982 | 0.18% | 21% | 79% |
| MT | 76,967 | 96,315 | 173,282 | 0.48% | 44% | 56% |
| PI | 38,163 | 7,358 | 45,521 | 0.49% | 84% | 16% |
| SP | 4,955 | 2,793 | 7,748 | 0.10% | 64% | 36% |
| TO | 8,336 | 35,137 | 43,473 | 0.17% | 19% | 81% |
| **Total** | **236,371** | **245,329** | **481,698** | **2.24%** | **47%** | **53%** |

| State | Agriculture (ha) | Pasture (ha) | Total (ha) | % of total area | % agriculture | % pasture |
|---|---|---|---|---|---|---|
| BA | 83,404 | 8,648 | 92,052 | 0.61% | 91% | 9% |
| GO | 6,756 | 29,525 | 36,281 | 0.11% | 19% | 81% |
| MA | 20,196 | 17,580 | 37,775 | 0.18% | 53% | 47% |
| MG | 27,253 | 44,735 | 71,988 | 0.22% | 37% | 63% |
| MS | 28,609 | 19,991 | 48,600 | 0.22% | 59% | 41% |
| MT | 35,501 | 31,755 | 67,256 | 0.19% | 52% | 48% |
| PI | 27,000 | 1,064 | 28,064 | 0.30% | 96% | 4% |
| SP | 3,848 | 0 | 3,848 | 0.05% | 100% | 0% |
| TO | 7,961 | 50,508 | 58,469 | 0.23% | 13% | 87% |
| **Total** | **240,528** | **203,806** | **444,334** | **2.10%** | **54%** | **46%** |

Source: ICONE (original GIS data from LAPIG);

# Results

# Weighted Average Profitability

- Weighted average profitability used for calculating scale and land supply elasticities;
- GIS evidences: LAPIG results for the Cerrados, Soybean Moratorium for the Amazon;
- Secondary results: Nassar et al. (2010), land allocation methodology

| Regions | Activities | % Deforestation | Crops | % Crops |
|---|---|---|---|---|
| **South** | Crops | 44 | Corn | 54 |
| | | | Soybean | 30 |
| | | | Cotton | 0 |
| | | | Rice | 3 |
| | | | Dry Bean | 13 |
| | Sugarcane | 1 | | |
| | Pasture | 55 | | |
| **Center West Cerrado** | Crops | 42 | Corn | 53 |
| | | | Soybean | 45 |
| | | | Cotton | 0 |
| | | | Rice | 1 |
| | | | Dry Bean | 2 |
| | Sugarcane | 3 | | |
| | Pasture | 56 | | |
| **Northeast Cost** | Crops | 20 | Corn | 49 |
| | | | Soybean | 0 |
| | | | Cotton | 3 |
| | | | Rice | 3 |
| | | | Dry Bean | 46 |
| | Sugarcane | 7 | | |
| | Pasture | 73 | | |

| Regions | Activities | % Deforestation | Crops | % Crops |
|---|---|---|---|---|
| **Southeast** | Crops | 39 | Corn | 20 |
| | | | Soybean | 74 |
| | | | Cotton | 0 |
| | | | Rice | 1 |
| | | | Dry Bean | 5 |
| | Sugarcane | 2 | | |
| | Pasture | 59 | | |
| **North Amazon** | Crops | 7 | Corn | 29 |
| | | | Soybean | 69 |
| | | | Cotton | 0 |
| | | | Rice | 0 |
| | | | Dry Bean | 2 |
| | Sugarcane | 0 | | |
| | Pasture | 93 | | |
| **Northeast Cerrado** | Crops | 64 | Corn | 20 |
| | | | Soybean | 34 |
| | | | Cotton | 33 |
| | | | Rice | 3 |
| | | | Dry Bean | 10 |
| | Sugarcane | 0 | | |
| | Pasture | 36 | | |

Source: calculated by the authors

# Methodology for Elasticities' Calculation

- Calculating Land Supply Elasticities for each region
  - Deforestation of the Cerrado and Amazon biomes combined with positive variation of profitabilities – all regions except Northeast Coast
  - Northeast Coast was calculated using total agricultural land for the period
  - Elasticities at the point, average of the period 2002-2009
- Own Elasticities based on the literature
- Competition Elasticities Matrices: calculated using competition ranking for each region
  - Example for competition ranking for the Center-West Cerrado Region

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Corn | Soybean | Pasture | Rice | Dry Bean | Cotton | Sugarcane |
| Soybean | Pasture | Corn | Rice | Dry Bean | Cotton | Sugarcane |
| Cotton | Pasture | Soybean | Corn | Dry Bean | Rice | Sugarcane |
| Rice | Pasture | Soybean | Corn | Dry Bean | Cotton | Sugarcane |
| Dry Bean | Corn | Soybean | Pasture | Rice | Cotton | Sugarcane |
| Sugarcane | Pasture | Corn | Soybean | Rice | Cotton | Dry Bean |
| Pasture | Soybean | Corn | Rice | Cotton | Dry Bean | Sugarcane |

Source: calculated by the authors

# Elasticities

- Land Supply Elasticities: $\varepsilon_{rl}^{Al}$

| Regions | Previous Version | Updated Version |
|---|---|---|
| South | 0.057 | 0.002 |
| Southeast | 0.067 | 0.007 |
| Center West Cerrado | 0.180 | 0.031 |
| Northern Amazon | 0.250 | 0.103 |
| Northeast Coast | 0.010 | 0.056 |
| Northeast Cerrado | 0.100 | 0.066 |

Source: calculated by the authors

- Own Elasticities not changed, based on literature.
- Scale and Competition elasticities recalculated based on new land supply elasticities and on competition ranking.
- New elasticities matrices for each one of the six regions in BLUM: very different from previous version.

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# Final Remarks

- Different land uses have different expansion characteristics
- Data limitations are important, but significant improvements have been achieved
- Expansion characteristics should be taken into account as soon as data becomes available.
- BLUM model is now calibrated with GIS data from 2002 to 2009.
- Further disaggregation of results is desirable,
    - Check the consistence of the macro results
    - Better inputs for other studies (GHG emissions, infrastructure, water resources..)
- Integration of economic and biophysical models is also desirable, but the methodological challenge is significant.

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