Modelling sustainable intensification in Brazilian agriculture

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Rafael Silva, SRUC and The University of Edinburgh

Supervisors:
Dominic Moran (SRUC)
Julian Hall (Edi Uni)
Luis Barioni (Embrapa)

Leading the way in Agriculture and Rural Research, Education and Consulting
Brazil’s “Grand Challenge”: the livestock-deforestation-climate Nexus (aka Sustainable Agricultural Intensification - SAI)

~ 1.3 G t CO₂-e
A key premise is: increase food production from existing farmland in ways that put less pressure on the environment and that do not undermine our capacity to continue producing food in the future.

Much conceptual literature (e.g., Garnett et al., 2013; Godfray et al., 2014; Tunner, 2011; Loos et al., 2014), but hardly any convincing empirically-based modelling.
Modelling Sustainable Agricultural Intensification

Economic Analysis of Greenhouse Gases from Livestock Emissions (EAGGLE) model
(De Oliveira Siva et al., 2015)

\[
\text{Max } z(x) = c^T x \\
\text{s.a } Ax \leq a \\
x \geq 0
\]

(a) CH4 and N2O from cattle;
(b) N2O from N fertilization;
(c) CO2 from deforestation
(d) CO2 from pasture degradation (sequestration);
(e) LCA factors for inputs and farm operations applied in land use change and restoration practices.

Pasture degradation

Pasture restoration

Soil organic carbon dynamics

GHGs

Whole cycle (cow–calf, stocking and finishing)

Regional scale
Policy (hence research) questions

1) What are the most promising sustainable agricultural intensification (SAI) measures in Brazil?

2) What is their mitigation potential incl. from avoided deforestation?

3) What is their cost?

4) Is it possible to reduce deforestation while increasing production? How?

5) Which measures to adopt to meet GHG reduction targets? What levels of adoption?

6) What happens if we reduce beef consumption?
### SAI measures identified in Brazil

<table>
<thead>
<tr>
<th>Mitigation Measure</th>
<th>Consists of:</th>
<th>Reduces emissions by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplementation:</td>
<td>Feeding cattle via grazing and a ration with a high energy content</td>
<td>Shorter animal life cycle by increasing weight gain</td>
</tr>
<tr>
<td>Concentrates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplementation:</td>
<td>Feeding cattle via grazing and a ration with a high protein content</td>
<td>Shorter animal life cycle by increasing weight gain</td>
</tr>
<tr>
<td>Protein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pasture Restoration</td>
<td>Improving pasture forage productivity by soil chemical and mechanical treatment</td>
<td>Avoiding the need for additional pasture land and increasing organic carbon sequestration</td>
</tr>
<tr>
<td>Feedlot Finishing</td>
<td>When cattle weight is around 80% of the slaughter weight it is removed from pasture and grass to feedlot on a diet with ration of balanced protein and energy content</td>
<td>Shorter animal life cycle by increasing weight gain</td>
</tr>
<tr>
<td>Nitrification Inhibitors</td>
<td>Applying nitrogen fertilizers coupled with nitrification inhibitors</td>
<td>Reduced conversion of nitrogen to the GHG nitrous oxide (nitrification)</td>
</tr>
</tbody>
</table>
Research questions: some answers...

1) What is the mitigation potential?
2) What is the cost?

COP21 - Brazil’s Intended Determined National Contribution (INDC) as an example of sustainable agricultural intensification

COP21, also known as the 2015 Paris Climate Conference

To achieve a legally binding and universal agreement on climate, with the aim of keeping global warming below 2°C.

**INDCs:** Mitigation targets and actions to reduce GHG emissions by 2030 (2020-2030)

- Reduction of GHGs by 37% below 2005 levels by 2025 and 43% by 2030.
- Zero deforestation in the Amazon by 2030!
- How?
- Through the restoration of 15 M ha (2020-2030)
Brazil’s Intended Determined National Contribution as an example of sustainable agricultural intensification

But where did the 15 Mha come from?

\[
R = \left( \frac{\alpha_d}{\alpha_C} - 1 \right) N_i - \lambda_d \Delta A
\]

90% of national beef production:
- Amazon (28.5%)
- Cerrado (37%)
- Atlantic Forest (23.5%)

How is restoration defined? (EAGGLE model)

Table 1: Description of pasture type formation (level of technology) and productivity (dry matter per area).

<table>
<thead>
<tr>
<th>Pasture</th>
<th>Pasture formation (short description)</th>
<th>Cost (US$ 2012 per hectare)</th>
<th>Productivity (tonnes of dry matter per hectare)</th>
<th>Soil carbon equilibrium (tonnes per hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>mowing+dolomitic limestone + single phosphate + brachiaria seeds + micronutrients + 90kg of N</td>
<td>767</td>
<td>19.6</td>
<td>84.3</td>
</tr>
<tr>
<td>B</td>
<td>mowing+dolomitic limestone + single phosphate + brachiaria seeds + micronutrients + 45kg of N</td>
<td>617.1</td>
<td>17.6</td>
<td>82.7</td>
</tr>
<tr>
<td>C</td>
<td>mowing+dolomitic limestone + single phosphate + brachiaria seeds</td>
<td>367.7</td>
<td>12.6</td>
<td>62.3</td>
</tr>
<tr>
<td>D</td>
<td>mowing +dolomitic limestone + single phosphate</td>
<td>137.1</td>
<td>8.7</td>
<td>45.2</td>
</tr>
<tr>
<td>E</td>
<td>Mowing</td>
<td>42.5</td>
<td>5.8</td>
<td>32.4</td>
</tr>
<tr>
<td>F</td>
<td>No intervention</td>
<td>0</td>
<td>3.9</td>
<td>26.1</td>
</tr>
</tbody>
</table>
### Results:

4) Is it possible to reduce deforestation while increasing production? how?

5) Which measure to adopt to meet GHG reduction targets? What level of adoption?

<table>
<thead>
<tr>
<th>Model</th>
<th>Area 2020 (Mha)</th>
<th>Area 2030 (Mha)</th>
<th>Demand 2020 (Mt)</th>
<th>Demand 2030 (Mt)</th>
<th>Recovered area (M ha) from 2020-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCRA</td>
<td>157.5</td>
<td>146.5</td>
<td>11.43</td>
<td>13.15</td>
<td>15.2</td>
</tr>
<tr>
<td>EAGGLE</td>
<td>157.5</td>
<td>146.5</td>
<td>11.43</td>
<td>13.15</td>
<td>18.2</td>
</tr>
</tbody>
</table>

Table 2: Area and demand (main models inputs) and results comparing DCRA and EAGGLE models.

The mitigation potential of the zero deforestation target by 2030:

**630 Mt CO$_2$-e**
But other authors have suggested managing demand ...


But they assume fixed emissions per kg of meat..
Decoupled Livestock-Deforestation

Baseline demand

- Fossil fuels
  - CO₂
- Enteric fermentation
  - CH₄
- Excreta
  - N₂O
- N Fertilizers
- SOC stocks

↑↓CO₂

SOC
Decoupled Livestock-Deforestation

Lower demand

- ↓ GHG from cattle and processes
- ↓ SOC sequestration

Fossil fuels
CO₂

SOC

↑CO₂

Enteric Fermentation

CH₄

Excreta

N₂O

N Fertilizers

SOC stocks

same area
Decoupled Livestock-Deforestation

Higher demand

- ↑ GHG from cattle and processes
- ↑SOC sequestration

Fossil fuels

SOC

CO₂

N₂O

CH₄

Enteric fermentation

Excreta

↓CO₂

SOC stocks

~75% of C

same area
Results:
7) What happens if we reduce beef consumption?
“Grass is greener with higher demand”

Demand 30% lower by 2030 → net GHG 10% higher
Demand 30% higher by 2030 → net GHG 10% lower

De Oliveira Silva et al. (2016). Increasing beef production could lower greenhouse gas emissions in Brazil if decoupled from deforestation, *Nature Climate Change*
7) What happens if we reduce beef consumption?

Percentage changes in accumulated emissions (2006-2030) as a function of demand scenarios under CLD and DLD.
Conclusions

- In the Brazilian *Cerrado*, reduced consumption could actually remove the incentive for grassland improvement and therefore lead to higher emissions.

- Shifting to less meat-dependent diets would help curb climate change, but it is important to understand the nature of different production systems before concluding that reduced consumption will have the same effects in all systems.
De Oliveira Silva et al. Developing a nationally appropriate mitigation measure from the greenhouse gas GHG abatement potential from livestock production in the Brazilian Cerrado. Agric. Syst. 140, 48–55.

Increasing beef production could lower greenhouse gas emissions in Brazil if decoupled from deforestation (Silva et al. 2016)
Chapters: proposed papers

- Brazil’s Intended Determined National Contribution (INDC) as an example of sustainable agricultural intensification. (PNAS)

- Optimizing pasture restoration for sustainable beef production systems in Brazil. (American Journal of Agricultural Economics)
Thanks!

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Rafael.silva@sruc.ac.uk
Deforestation and Demand

Decoupled Livestock-Deforestation (DLD) scenario:

The same deforestation projections irrespective of consumption levels.

Coupled Livestock-Deforestation (CLD) scenario:

Deforestation projections are sensitive to variations in beef demand.
But is it feasible? What does empirical data show?

Pasture area and production estimates (FAO, IBGE).

Source: PRODES (INPE)
Cerrado: The Brazilian savannah

Responds for at least 34% of national beef production

Fig. 1: Brazilian Central Cerrado (green)

Fig. 2: Cerrado baseline demand (DBAU) and varied demand projections that correspond to percentage variation by 2030 in relation to DBAU.
Long term GHG emissions analysis for the demand scenarios. (A) annual net GHG emissions and (B) percentage changes in accumulated GHGs.
But is it feasible? What does empirical data show?

Pasture area and production estimates (FAO, IBGE).

Source: PRODES (INPE)