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SOCIO-ENVIRONMENTAL AND LAND-USE IMPACTS OF DOUBLE-CROPPED MAIZE ETHANOL IN BRAZIL

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1. Context

Research question

- Bioenergy and BECCS are necessary in all scenarios to reach a maximum of increase of 1,5
- Maize industry is well stablished in the USA, but several mills are dependent on “non-renewable” energy sources for process.
- Assessments are widely disparate, however, with respect of using land for biofuel production without compromising food production, wildlife habitat, livelihoods of rural populations and ecosystem carbon stocks.
- Announcement of 1st stand-alone maize-ethanol mill in Brazil.
- **Would it make sense to produce maize ethanol in Brazil?**

Reference document: Nature Sustainability

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Socio-environmental and land-use impacts of double-cropped maize ethanol in Brazil

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Agricultural intensification, and particularly double cropping, has been suggested as a practical strategy to reconcile biofuel feedstock production with other land-use priorities. Here we assess ethanol production under conditions representative of current practice in the west central region of Brazil: maize grown as a second crop with soybean on land that formerly grew a single soybean crop, and energy processed from a combined heat and power plant using plantation-grown eucalyptus chips. For maize ethanol thus produced we find large reductions in greenhouse gas emissions compared to gasoline, and considerable economic and employment benefits at both local and national levels. We also calculate reduced land-use emissions with maize ethanol production compared to the situation without it. Our study thus documents an example of how the complex linkages of bioenergy to food production and security, environment and economic development can be—and indeed appear to be—managed for positive outcomes using current technology.

Biofuels are probably needed in order to stabilize climate[1–3] and offer potential benefits in terms of rural economic development[4,5]. Aggressive expansion of biofuel production is a prominent feature of Brazil's Nationally Determined Contribution responsive to the Paris Agreement[6], and is targeted by the recently initiated Brazilian biofuel program, Renovabio[7,8]. Assessments are widely disparate, however, with respect to the feasibility and desirability of using land for biofuel production without compromising food production, wildlife habitat, livelihoods of rural populations and ecosystem carbon stocks[9,10]. Recent studies reinforce the value of ecosystem services[11], and induced land-use change (LUC) arising from displacement of food production by biofuel feedstocks has contributed to this disparity[12]. Agricultural intensification and double cropping have been suggested as strategies that could reconcile biofuel feedstock production with other land-use priorities[13–17]. On-the-ground examples of biofuel production directly coupled to intensified land use are, however, scarce.

One such example, perhaps the largest to date, is unfolding in Brazil today in the production of ethanol from maize grown as a second crop with soybean on land that formerly grew a single soybean crop. This situation is quite different from the single-crop production of maize as practised in the United States, where winters are more severe. In addition to increasing production on existing agricultural land, production of maize as a second crop improves soil production and nutrient recycling[18].

The development and deployment of double cropping has led to the rapid expansion of grain production in west central Brazil (Fig. 1), particularly in Mato Grosso State (MT). Between 2006/2007 and 2016/2017, total maize production increased from 4 million tons to 29 million tons in MT, resulting in it becoming by far the largest grain-producing state in Brazil[19]. Essentially all (99%) of this additional maize is produced as a double crop.

Expanded production has not, however, been accompanied by commensurate development of logistical systems, resulting in inadequate road conditions[20], accumulation of maize stocks and in local prices far below international norms[21]. Infrastructural improvements are under way but will take time and are still far from complete. Simultaneously, imports of ethanol are rising to meet increasing domestic fuel demand in Brazil, particularly in the northern and northeastern regions[22,23]. Future logistical improvements to expand maize access to markets would also benefit ethanol logistics.

In light of this situation, local producers—together with the state government—are currently developing a programme to transform the region's maize surplus into ethanol and value-added products[24]. Growth of ethanol production capacity in both Brazil and the United States has occurred in the past, largely during windows of time during which economic conditions were advantageous and payback periods were short, and suggests that such windows need last for only a few years to motivate investment[25]. A previous study indicated that profitability of maize ethanol in Brazil is robust with respect to changes in corn prices[26].

Production of ethanol from maize in Brazil was initially adopted in 'flex' plants, using infrastructure available at existing ethanol plants during the summer when sugarcane is not harvested. Early studies indicated that the environmental benefits of sugarcane ethanol would not be jeopardized by maize ethanol production, while economic viability is higher in regions with corn supply at low prices and high demand for animal feed.[26] With the current high volumes of maize production and relatively low farm gate prices, aggressive investments in maize ethanol have been made. The first stand-alone maize ethanol plant started operation in 2017 (refs. [22,23]) and, within its first year of operation, the company initiated doubling of annual production capacity from 250 to 500 million l yr^{-1} based on favourable economics. Further investment is expected.

Stand-alone facilities for ethanol production are expected to grow more rapidly than flex plants in MT. The provision of process energy in these facilities is based on integrated steam and electricity production using wood chips from rapidly growing eucalyptus plants as the primary fuel. For this representative scenario, we analysed

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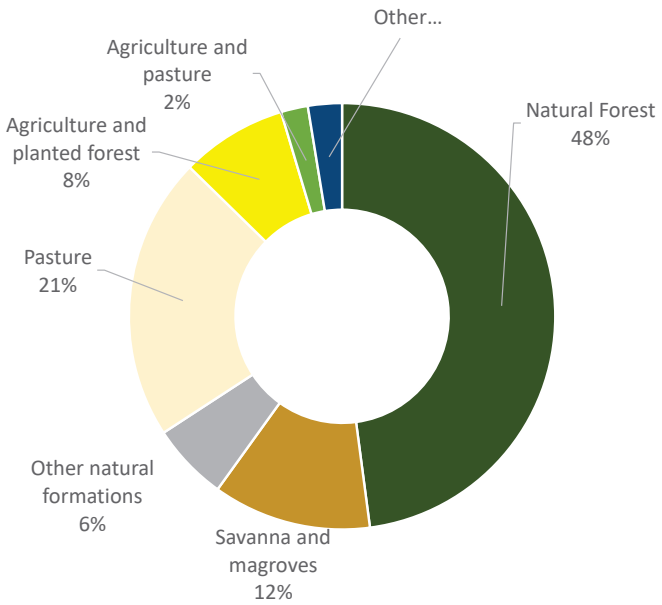
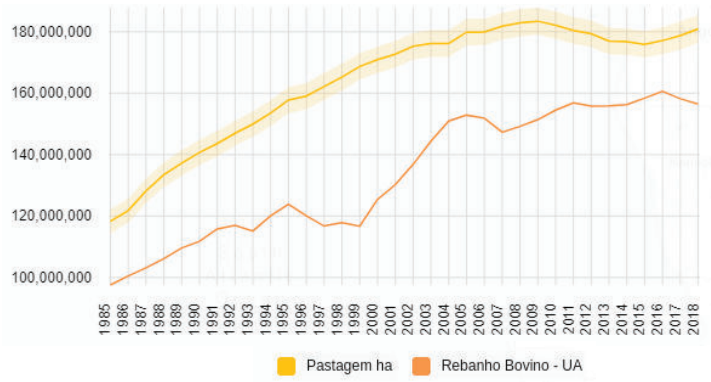
2. Land use in Brazil

Land use and land saving strategies in Brazil

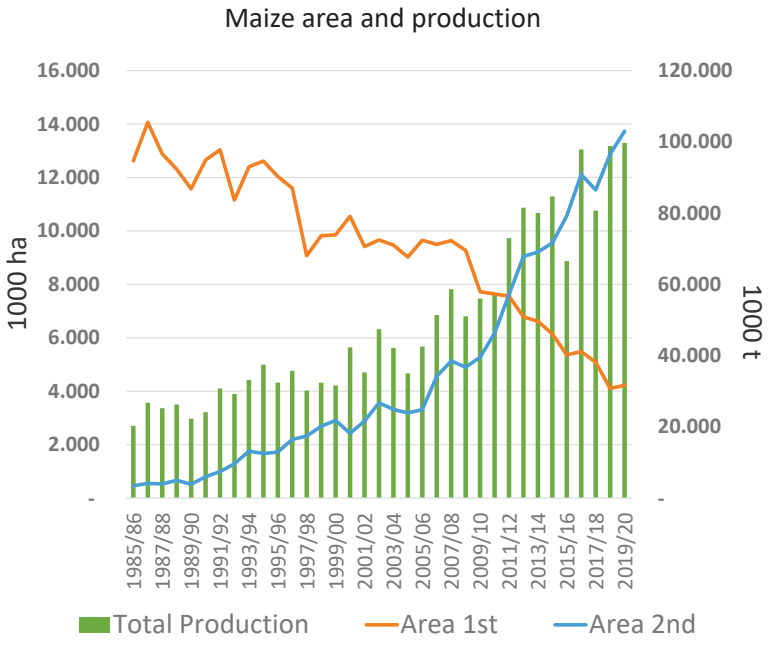


- **21% = 183** million hectares of pastureland in Brazil
- 95 million hectares of pasture with some degree of degradation
- Significant opportunities for land optimization
- 15 million of integrated systems



Source: Agroicone, based on MapBiomas, Rede iLPF and Pastagens. Org.

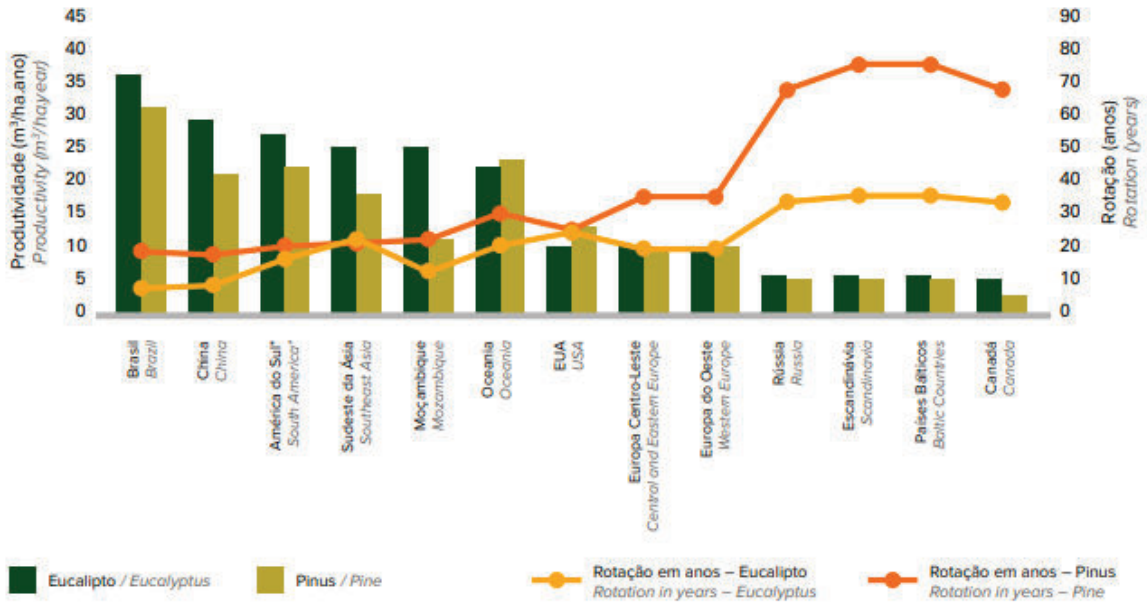
Land saving strategies: Intercropping soybeans and maize



Last 10 years:
Increase production 43 million t (+78%)
Decrease in area 3.5 million ha (-145%)

Source: Agoirocone, basaed on CONAB

Biomass yields



Eucalyptus yield:
- BR: 35 m3/ha.year
- USA: 10 m3/ha.year

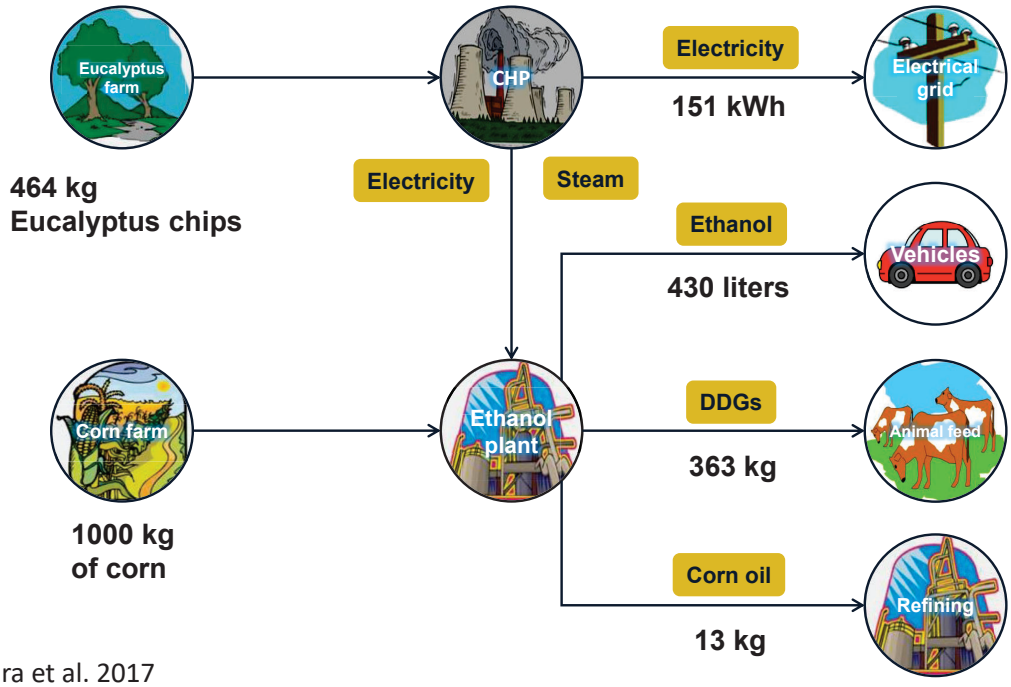
Eucalyptus rotation:
- BR: less than 5 years
- USA: 10 years

Suitable in less suitable soils

Source: Ibá

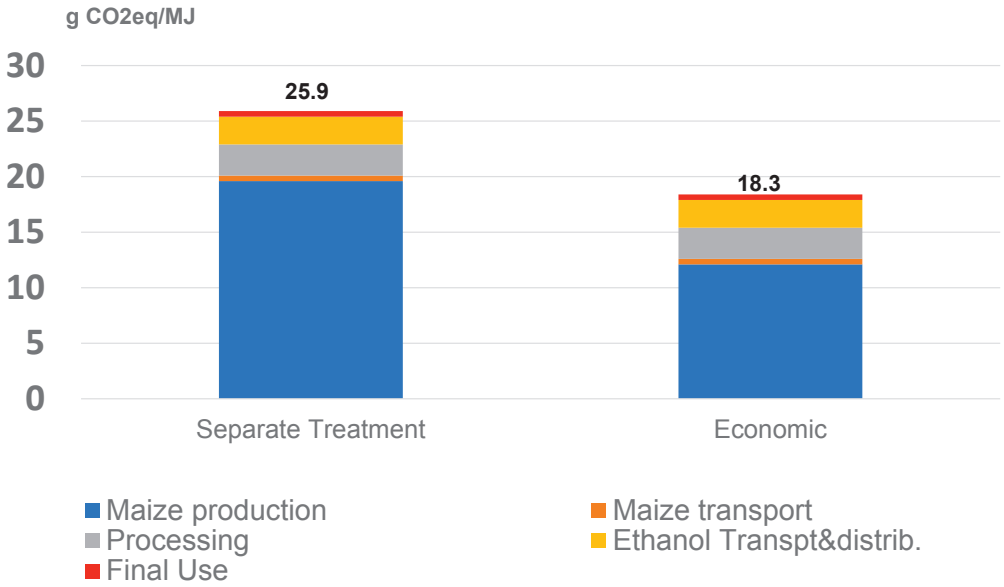
3. LCA results

Mass and energy flowchart



Source: Moreira et al. 2017

Results attributional approach



- **Maize production is responsible for the bulk of emissions**
- Significantly **low processing emissions** due to the use of renewable biomass.

79% reduction compared to gasoline

US could be somewhat similar if used biomass.

Energy allocation in the industry. Agricultural inputs dividing systems and economy allocations.

Source: Moreira et al. 2020

3.2 Consequential LCA (Land use)

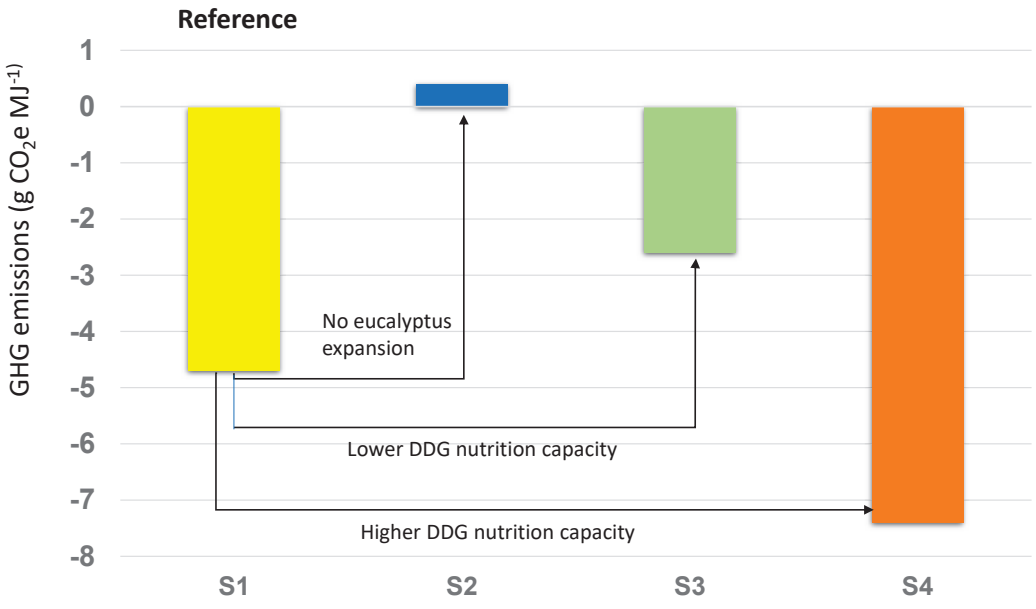
Including land use (consequential approach)

Most relevant effects:

- Higher 2nd maize demand: effects on maize market +
- Higher forestry (eucalyptus) area: expansion of carbon stocks -
- Coproduction of DDG: displacement of feed -
- Indirect effects (indirect displacement) + and -
- Market mediated effects (substitution between products and technologies, increase in beef demand) + and -

Model: Brazilian Land Use Model (stand-alone version of model used by US-EPA)

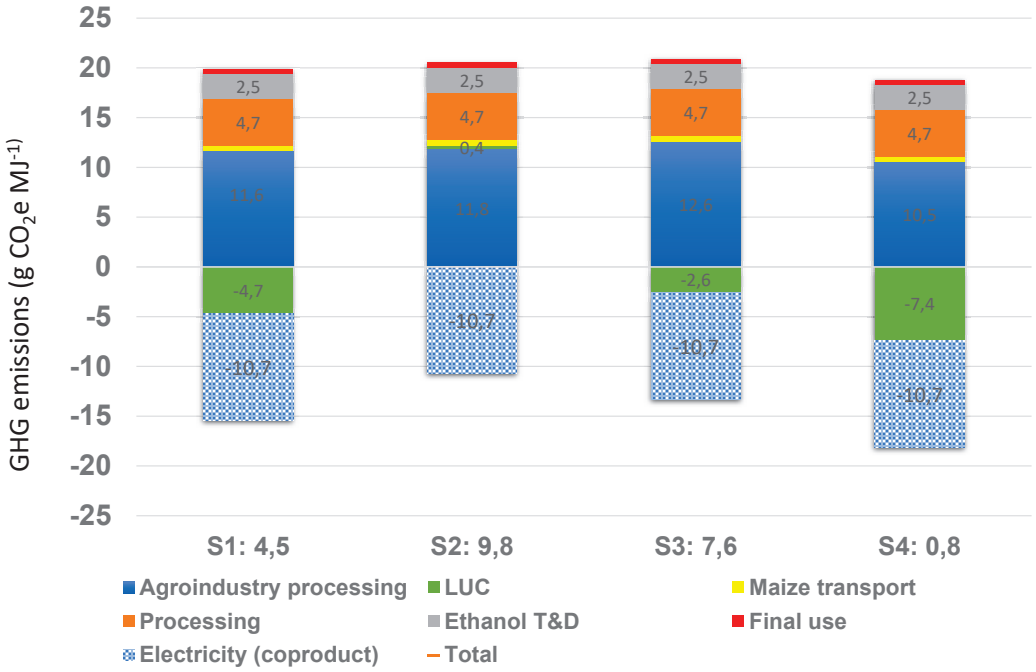
Including land use (consequential approach)



- **All iLUC results are negative or close to zero.**
- Eucalyptus expansion has significant contribution
- Higher DDG efficiencies displaces larger amounts of soybean areas for feed production

Source: Moreira et al. 2020

Consequential approach: final results



- Reference scenario reaches 4.5 g CO2/MJ.
- Emissions from maize production and processing are the most relevant, but low.
- Significant credits from centricity surplus and iLUC.
- All scenarios are below 10g CO2/MJ. One scenario is **close to zero.**

Source: Moreira et al. 2020

4. Recent developments

First stand alone corn ethanol mill in Brazil.

Start-up: Aug. 2017

240 million liter of ethanol
+ DDG
+ Bioelectricity
+ corn oil

Source: FS-Bioenergia

Recent developments

- Site specific data showed even lower GHG emissions due (**best anhydrous ethanol score in RenovaBio** – 138 mills)
- Negative emissions becomes a real possibility
- Company has doubled installed capacity of the 1st mill, started a 2nd mill and a third mill is envisaged.
- Other companies entering the market.
- Significant upfront investments (industry, but also crops and forest)
- Brazil is currently revising RenovaBio targets due to COVID-19.
- **How to redirect investments to high environmental performance fuels, away from fossil?**

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