Unlocking agricultural potential: an opportunity cost analysis in Brazil

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Introduction

- Although agricultural production in Brazil has increased, concerns have been raised about its environmental impacts.
- One of these concerns is related to Greenhouse Gas (GHG) emissions from agriculture and their relationship with climate change and global warming.
- Since the Kyoto Protocol, several global efforts have been made to reduce GHG concentrations and tackle global warming in Brazil and around the world.
- However, the challenge is still to reduce GHG emissions while maintaining production or even increasing it.

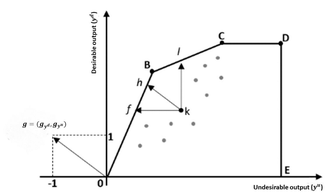
Objective

- I analyze the opportunity cost of reducing GHG emissions in Brazilian agriculture and the extent to which agricultural production can be increased while reducing emissions.

Methods

- Data Envelopment Analysis (DEA) with undesirable outputs.
- Directional Output Distance Function (DODF), accounting for agroecological heterogeneity using a metafrontier.
- Each municipality was grouped into a group that takes into account the municipality's main biome: Amazon, Caatinga, Cerrado, Atlantic Forest, *Pampa*, and Pantanal.
- The opportunity cost was estimated by calculating gradients of the municipality-level production possibility frontier (PPF) between GHG emissions and livestock and agriculture, conditioned on resources available.
- Model 1: $g = \left(g_{y^d}, -g_{y^u}\right) = (1, -1)$
- Model 2: $g = \left(g_{y^d}, -g_{y^u}\right) = (1, 0)$
- Model 3: $g = \left(g_{y^d}, -g_{y^u}\right) = (0, -1)$

Figure 1. Environmental Technology and Directional Distance Function



Data

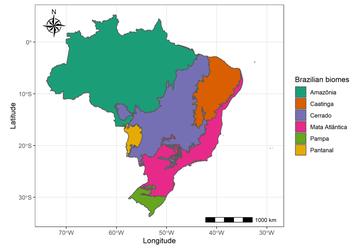
- The dataset of value of agricultural outputs and inputs by municipality from the 2017 Brazilian Agricultural Census and GHG emissions obtained from the Greenhouse Gas Emission Estimation System (SEEG).

Table 1. Descriptive statistics for outputs and inputs, 5280 Brazilian municipalities in 2017

Variables	Units	Mean	Std. Dev.	Min.	Max
Output					
Livestock's VP*	US$	8.946.058,53	16.609.005,06	11.709,97	313.171.422,36
Agriculture's VP*	US$	17.343.210,60	44.154.479,75	1.032,02	910.113.917,22
GHG Emission	CO2e	236.717,28	851.542,03	171,96	25.846.330,96
Input					
Land	Hectare	65.834,70	141.891,25	18,00	4.810.916,00
Capital	Units	378,79	587,33	0,00	7.401,00
Labor	No. of employees	2.678,88	2.831,64	28,00	44.190,00
Expenditure*	US$	14.799.122,09	32.576.629,05	32.574,92	530.951.287,01

Notes: *Monetary values were converted from Real (R$) to US Dollars (US$) considering an exchange rate of $R\$3.31$, that is, $US\$1 = R\$3.31$.

Figure 2. The geographic location of the Brazilian biomes



Results

- Model1: The average measured distance for the metafrontier is 0.75, indicating that, on average, a 75% increase in the average VP of livestock and agriculture and a 75% decrease in the average GHG emissions could be achieved if the observed efficiency were eliminated.
- This result differs when we analyze the group-specific frontier, in which the group of municipalities in the Pampa biome has a smaller average distance. For these municipalities, with the elimination of inefficiency, it would be possible to increase, on average, 15% of average desirable products while simultaneously reducing 15% of average GHG emissions. Despite intragroup variability, the Amazônia and Cerrado biomes have similar average inefficiencies. The same occurs for the Caatinga and Mata Atlântica biomes.
- Model 2: it is observed that the average measured metadistance is 5.41. This result indicates that it would be possible to expand, on average, 541% of the average VP of livestock and agriculture while keeping the undesirable output at the same level and without increasing inputs. Here, the result also differs when we analyze the group-specific frontier. The average distance for the municipalities in the Pampa biome has a smaller average distance while the municipalities in the Mata Atlântica biome have a greater average distance.
- Model 3: an average metadistance of 0.97 indicates that it is possible to reduce, on average, 98% of average undesirable output while keeping the desirable output at the same level and without increasing inputs. In this model, the results for the group-specific frontier are similar except for the Pampa biome, which has an average distance of 0.32.

Table 2. Estimated Average Directional Distance

Group	Model 1	Model 2	Model 3
Amazônia	0.58	0.98	0.94
Caatinga	0.81	1.89	0.94
Cerrado	0.59	1.23	0.87
Mata Atlântica	0.84	4.64	0.93
Pampa	0.14	0.22	0.30
Brasil (metafrontier)	0.75	5.41	0.97

How much can we increase agricultural production while also reducing greenhouse gas emissions?

- Considering the results of Model 1, it is possible to observe that the groups of municipalities present different results.
- Among the biomes, Mata Atlântica and Caatinga show the largest percentage changes in outputs and the Pampa biome presents the smallest change.
- The projections of group-specific frontier indicate that Brazilian municipalities can increase the value of production (agriculture + livestock) by 67.64% and reduce GHG emissions by 61.84%. These values are higher when considering the metafrontier for the Model 1, which indicates that desirable and undesirable products can increase and decrease, respectively, by 75.06%.
- In general, all models, although in different magnitudes, indicate benefits either by expanding the value of production, or by reducing emissions, or both.

Table 3. Projections for the desirable and undesirable products for each model

		Observed	Model 1	Model 2	Model 3
			Projected		
Amazônia	y_1^d	15,583,828.09	25,737,056.56	35,455,737.40	
	y_2^d	18,585,993.04	30,695,202.19	42,286,149.77	
	y_1^u	1,376,138.48	479,552.08		86,229.30
Caatinga	y_1^d	3,724,896.65	6,862,358.85	12,919,479.49	
	y_2^d	2,605,100.08	4,799,363.11	9,035,562.65	
	y_1^u	40,110.85	6,325.68		2,325.45
Cerrado	y_1^d	14,202,514.86	23,512,712.03	34,419,900.93	
	y_2^d	34,501,718.52	57,118,684.99	83,615,172.77	
	y_1^u	304,486.36	104,885.93		31,308.37
Mata Atlântica	y_1^d	7,431,597.82	13,861,850.45	56,326,018.42	
	y_2^d	14,275,421.43	26,627,350.08	108,197,142.74	
	y_1^u	80,260.06	10,814.37		5,243.42
Pampa	y_1^d	11,667,712.74	13,433,085.30	14,714,974.14	
	y_2^d	43,799,864.22	50,426,962.43	55,239,093.00	
	y_1^u	271,595.62	230,502.09		184,825.70
Brasil (Metafrontier)	y_1^d	8,946,058.53	15,968,923.89	63,094,937.08	
	y_2^d	17,343,210.60	30,958,036.90	122,318,535.91	
	y_1^u	236,717.28	50,888.67		5,878.69

Notes: y_1^d is Livestock's VP; y_2^d is Agriculture's VP; and y_1^u is GHG emissions

Opportunity cost

- It is possible to observe a wide range of opportunity costs (or shadow prices) between biomes.
- For example, for the Amazônia biome, we found that, on average, US $25.17 in value of agricultural and livestock production is given up for every ton of CO2e reduced.
- For the Mata Atlântica, on average, US $1,415.03 in value of agricultural and livestock production is given up for every ton of CO2e reduced.

Table 4. Average Revenue Foregone for CO2e reduced

	Opportunity Cost ($/t of CO2e)
Amazônia	25.17
Caatinga	331.53
Cerrado	257.05
Mata Atlântica	1,415.03
Pampa	150.22
Brasil (Metafrontier)	646.60

Conclusion

- Although the economic literature has demonstrated that Brazilian agricultural growth has sustained productivity gains in recent decades, studies investigating its environmental sustainability and eventual constraints are still necessary.
- The results from this approach complement the recent literature on Brazilian agricultural production by providing information on how agricultural production can be raised despite the environmental impacts of reducing (GHG emissions).
- We found that the projections of group-specific frontier indicate that Brazilian municipalities can increase the value of production (agriculture + livestock) by 67.64% and reduce GHG emissions by 61.84%. These values are higher when considering the metafrontier, which indicates that desirable and undesirable products can increase and decrease, respectively, by 75.06%.
- The opportunity cost of reducing GHGs varied widely among biomes, from 25.17 US$/tCO2e to 1,415.03 US$/tCO2e. For the metafrontier, the value of agricultural and livestock production sacrificed for every ton of CO2e reduced was, on average, 646.60 US$/tCO2e.

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