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ECONOMIC AND SOCIAL IMPACTS OF DEGRADED PASTURE RECOVERY IN BRAZIL: results from the Low Carbon Emissions Plan (ABC Plan)

1. Introduction

The Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Emission Economy in Agriculture - ABC[1] Plan -, officially created by Decree 7390 of December 9, 2010, is among the Brazilian public policies aimed at tackling climate change. The main targets of the ABC Plan are the reduction of deforestation (especially in the Amazon); the recovery of degraded pastures; the adoption of no-till farming systems; and the increase of biological nitrogen fixation. The choice of these targets was based on three central aspects: (i) the scale of production activities; (ii) their economic importance; and, (iii) the efficiency of these actions in reducing GHG emissions.

The ABC Plan has national scope, and presented in its first stage a ten year' term (2010 - 2020). Regarding livestock, the Plan established among its goals the recovery of about 15 million hectares of degraded pastureland (RPD). Many different actions were carried out for that purpose, allowing the intensification of the activity and the adoption of more sustainable production practices.

In order to support the ABC Plan actions, a credit line called the ABC Program was created, with nine sub-programs. Among them is the ABC Recovery, which targets the funding of investments to recover degraded pastures (RPD). Among the nine subprograms, the RPD line attracted most of the resources available.

In spite of the importance of this unique environmentally-oriented credit program, no evaluation of its impacts was performed for this first period of implementation, and this is an effort on this direction. This paper contributes to the literature on environmental credit lines impacts on three main aspects. First, it uses a new pasture recovery data from satellite imagery for the evaluation. Second, it combines territorial

[1] Agricultura de Baixo Carbono in portuguese.

data with the ABC Program financial records to infer about social rates of return of the project for a historical period. Third, it uses a computable general equilibrium model with environmental capabilities for this task. To the best of our knowledge this is the first time the Program is analyzed with this methodology.

2. Methodology

The methodological approach involves the use of a General Equilibrium Model of Brazil (the TERM-BR model) based on previous work by Ferreira Filho and Horridge (2014). The TERM-BR model is a recursive, bottom-up, dynamic computable general equilibrium model that includes a detailed regional representation of Brazil, with 27 regions (26 states plus the Federal District), 110 products and 110 productive activities, 10 types of families (classified by family income bracket) and 10 types of work (classified by salary range).

From the point of view of its dynamic behavior, the model presents solutions for annual periods, evolving in time guided by a dynamic process that consists of four mechanisms:

- A stock-flow relationship between investment in a given period and capital stock in the following period;
- A positive relationship between sectoral investment and the respective rate of profit;
- A positive relationship between real wage variation and regional labor supply; and
- A positive relationship between deforestation in a given period and the available land stock for agriculture and livestock in the following period.

Through these mechanisms is possible, together with other hypotheses, to design a baseline for a given economy, that is, an inertial trajectory of growth in relation to which a second trajectory (policy trajectory), which differs from the first only in terms of the economic policy to be implemented, can be compared. The difference between the two trajectories is the effect of the policy under analysis.

The TERM-BR model has as particular characteristic a land use module and an associated GHG emissions module, described in more details below.

a. **The land use and GHG emissions in the TERM-BR model**.

The concept of transition matrices gives support to the model´s land use module. These matrices, elaborated by state and biome, make use of information obtained through satellite images for land use changes observed between 2002 and 2010 (Brazil, 2016). This information was processed to distinguish three major types of land use, Crops (CROP), Pastures (PASTURE) and Forestry (planted forests, FORESTRY), and a residual type identified in the model as UNUSED, which refer to native forests. These transition matrices are detailed by state (26 states plus the Brazilian Federal District) and, within each state, by six distinct biomes: Amazonia, Cerrado, Caatinga, Atlantic Forest, Pampa and Pantanal.

The transition matrix shows, for example, how many hectares (physical units of land) of the Cerrado biome in the state of Mato Grosso, which was natural vegetation in 2002, became Crops or Pasture in 2010, or remained as natural vegetation. The model has, therefore, for each biome in every state, a complete transition matrix. The data observed in the period mentioned above was processed to show the probability that each hectare under given use in a certain year will be in another use the following year.

These transitions are also price influenced. Transition from pastures or forests to crops, for example, accelerates with the growth of the relative prices of agricultural products. Moreover, the model is flexible enough to allow exogenous projections of the level of deforestation according to desired patterns. In this case, the Transition Matrix ensures information consistency, that is, the increase of pasture, crop and forestry area in a given year must respect the increase in the available area given by deforestation in the previous year.

The transition matrices, then, determine the total land available for each broad land use group (Crops, Pasture, Forestry and Unused). Once the amount of each aggregate category is determined, the model will allocate land among the activities within each category. Crop area, for example, will be allocated among the eleven agricultural activities of the model, through a CES (Constant Substitution Elasticity) function, based on the relative prices of the products of these activities.

The model has also two main emissions matrices that tracks all emissions in the economy. The first emissions matrix tracks emissions in all economy activities (except deforestation), where emissions are associated to each productive sector and final demand, and can be of two broad types (sources): emissions associated to fuel use and emissions associated to the level of activity of each sector (like fugitive emissions in mining, or CH4 emissions in livestock[2], for example). All emissions are accounted by the original GHG gases, and transformed to CO2 equivalents using the Global Potential Warming for 100 years (GPW-100) coefficients from the IPCC Fifth Assessment Report –SAR (IPCC, 2014).

All the above-mentioned emissions are in fixed coefficients in either fuel use or the level of sector activity. In the case of livestock, however, we have also accounted emissions in an alternative way, where emissions in livestock vary with pasture productivity variation. This is discussed further in the next section.

The second emissions matrix accounts for emissions in LUC, and is associated to the Transition Matrix in LUC discussed above. The GHG emissions matrix associated to the LUC module, then, shows observed emissions on transitions, by state and biome. This allows a detailed accounting of emissions on land use transitions, and the computation of sinks on forest restoration.

b. Productivity shock, investment and differential stock of soil organic carbon (SOC) between degraded pasture and recovered pasture

Degraded pastures have lower productivity than non-degraded pastures, thus supporting a lower productivity of cattle ranching activity. The calculation of this productivity differential, is critical for the results. In this paper we use estimates of differential productivity between degraded and non-degraded pastures of Rocha Jr, Gianetti, and Ferreira Filho (2022). Those authors applied an Output Distance Function method with Census data for 2017, at municipal level in Brazil, which allowed the estimation of the marginal productivity effect a degraded pasture recovery. The effects were first calculated at the municipal level, and then aggregated to the regional level used in the model.

With the marginal effect and the area of recovered pastures in the period is possible to compute the pasture productivity increase. This calculation was performed for two distinct datasets. The first dataset comprises the area of recovered pasture in the whole Brazilian territory, irrespective of the financing source, from the Laboratory of Imagery Processing and Geoprocessing (LAPIG, 2019). In this case, attention is drawn to an important aspect for understanding the results. As explained above, the model is

[2] Of particular interest for this paper is emissions in the "Activity" source in the livestock sector. In this case, emissions in both the herd and pastures are aggregated together.

calibrated based on the latest Brazilian Input-Output Matrix, which is for the year 2015. The data observed by LAPIG, however, refers to the period 2010-2018, i.e., a period of 9 years. Thus, it is necessary to adapt the available information to carry out the simulations. This is done as follows.

The total area of pasture in Brazil in the base year is 169 Mha. This area is estimated by state, based on the observed values of the 2006 and 2017 Agricultural Census, through a linear interpolation of the observed values (Table 1).

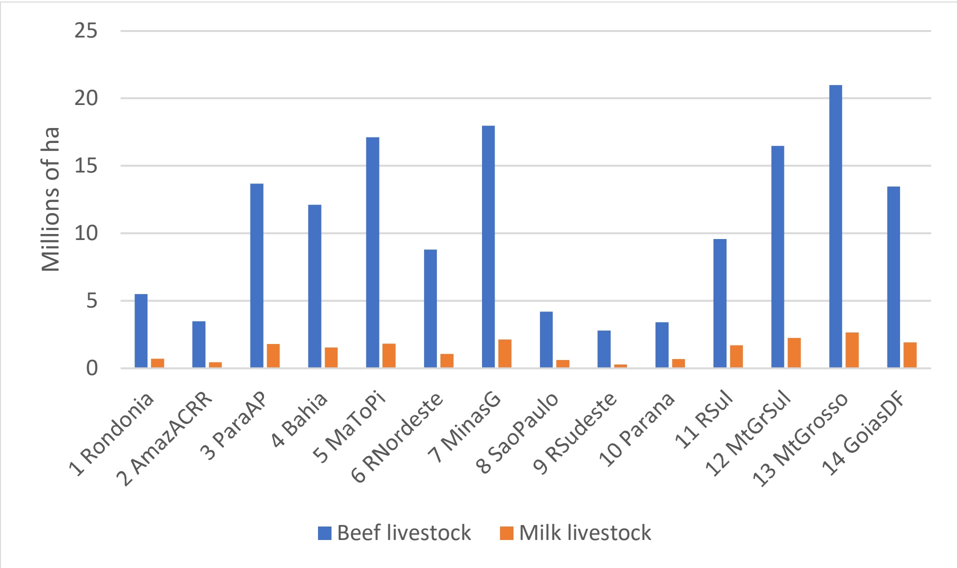

Figure 1. Area of pasture in Brazil. 2015. Millions of hectares.

The average change in total pasture area observed by LAPIG for the period 2010-2018 is applied to the 2015 areas, by state. This value, however, must be adjusted to obtain, for the period 2015-2021, the same total variation in the area of pasture observed by LAPIG between 2010-2018, i.e., -1.37 Mha. This procedure preserves the regional distribution originally present in the LAPIG data, as well as the total amount of recovered pasture.

The second dataset comprises only the area covered by the ABC Program Loans, a much smaller area (Table 1). As it can be seen in the table, out of 19.42 Mha of recovered pastures in Brazil in the period, 4.1 Mha was funded by the ABC Program credit line. From this same dataset its also possible to estimate the investment costs necessary to recover one hectare of pasture, which is also used in the simulations.

These gains, in annual terms, can be seen in Table 1. In the policy simulation we also added a shock to beef and dairy cattle ranching investments, in proportion to the recovery of pasture in each region.

Table 1. Evolution of total pasture and recovered pasture areas, LAPIG and ABC Program (Mha) and estimated annual productivity gain (%) of cattle ranching in Brazil.

Region	Total pasture area (Mha) between 2010-2018 LAPIG	Area of recovered pasture between 2010-2018 (Mha) LAPIG	Annual productivity gains (%)	Area of pastures financed by the ABC Program in the RPD line between 2013-2020 (MAPA).	Annual productivity gains (%)
1 Rondonia	0.80	0,86	2,60	0.10	0.34
2 AmazACRR	1.13	1,25	2,40	0.04	0.25
3 ParaAP	0.87	0,72	0,28	0.17	0.16
4 Bahia	0.52	0,53	0,18	0.15	0.06
5 MaToPi	2.23	1,96	0,58	0.40	0.35
6 RNordeste	1.79	0,28	0,25	0.00	0.02
7 MinasG	-2.49	0,48	0,12	0.41	0.11
8 SaoPaulo	-1.52	-0,14	-0,41	0.17	0.56
9 RSudeste	-0.43	0,62	0,99	0.03	0.11
10 Parana	-0.40	0,39	1,47	0.09	0.40
11 RSul	-1.25	3,11	3,09	0.19	0.36
12 MtGrSul	-1.81	2,83	2,39	0.33	0.32
13 MtGrosso	-0.05	3,84	1,07	0.39	0.13
14 GoiasDF	-0.77	2,68	1,13	1.62	0.78
Total	-1.37	19.42		4.10	

Source: LAPIG and model results. MAPA – Ministry of Agriculture.

The gains estimated for the total (Brazil) area of pasture recovered are naturally larger than those of the ABC Program, since they refer to the total area recovered estimated by LAPIG, and not only to that funded by the Program's financing.

It should be noted that the relationship between the area of pasture recovered and productivity gains is not linear, due to the specificities of each region. As can be seen in Table 1, the state of São Paulo showed a reduction in the area of good quality pastures between 2010-2018, which determines a drop in productivity in the region. There was also an overall reduction in pasture area in the state, as presented earlier. With this, the aggregate productivity of beef cattle ranching in São Paulo presents a negative value when calculated by LAPIG data, but positive when calculated by ABC Program funding data.

Finally, the impact of Degraded Pastures Recovery on SOC fixation was incorporated using the productivity-emissions elasticities of Gianetti and Ferreira Filho (2023) (Table 2). As mentioned before, the variation in GHG emissions will be reported both without this effect (original emission accounting method) or including SOC fixation (alternative emission accounting method). Since all GHG productivity-emissions elasticities are negative, they imply mitigation of GHG emissions, so the alternative method should result in lower levels of GHG emissions than the original method.

Regional differences in GHG productivity-mitigation elasticities are due to both the different marginal productivity effects of degraded pasture recovery estimated by Rocha Jr. Gianetti and Ferreira Filho (2022), and the heterogeneous SOC sequestration capacities of Brazilian regions given soil types, landscapes, climate, and pre-existing pasture quality (Sanderman et al., 2020).

Table 2. Elasticity of productivity-GHG

Region	**Livestock**	**Raw milk**
Rondonia	-0.002	-0.004
AmazACRR	-0.001	-0.003
ParaAP	-0.002	-0.012
Bahia	-0.030	-0.052
MaToPi	-0.060	-0.122
RNordeste	-0.039	-0.025
MinasG	-0.070	-0.020
SaoPaulo	-0.011	-0.009
RSudeste	-0.063	-0.024
Parana	-0.021	-0.009
RSul	-0.074	-0.047
MtGrSul	-0.021	-0.153
MtGrosso	-0.019	-0.100
GoiasDF	-0.014	-0.012

3. Results

This section presents the results of the simulations performed. Initially, the most relevant macroeconomic results are presented in Table 3.

Table 3. Macroeconomic variables. Variation % in relation to the baseline, accumulated in 2021.

Variable	Variation %

	SCEN1 (LAPIG)	SCEN2 (ABC)
Household expenditure	0,46	0.11
Investiment (real)	1,26	0.34
Exports (volume)	-1,10	-0.3
Imports (volume)	0,53	0.14
GDP (real)	0,31	0.07
Real wages	0,53	0.13

Source: model results

The pasture productivity increases has as its first general effect an increase in domestic income. This effect can be seen in Table 3 in terms of the increase in real household consumption as well as in real GDP. Real GDP is 0.31% higher than the baseline due to the recovery of degraded pasture. This is a high value for a policy of a sectoral nature. To give some perspective, the total amount invested by the ABC Program in pasture recovery was R$8,131.6 million current reais, in the period 2010-2020 (ABC Program). These values should be converted to 2015 values for comparison with the model data. Deflating that total amount by the IGP-DI of each respective year gives a figure of R$7,586.1 million in 2015 values.

The GDP of the Brazilian economy in 2015 was approximately R$6,049,605 million. Thus, the observed increase, accumulated over 2021, of 0.31% of the GDP in SCEN1 and 0.07% in SCEN2 represents a social (GDP) gain of R$16,938.9 million in SCEN1 and R$4,235 million in SCEN2, respectively, at 2015 values. For SCEN2 it is possible to calculate the social rate of return of the ABC Program using the RPD line, once both the amount invested and the social return (GDP) are known. Thus, each Real (Brazilian currency) invested by the ABC Program in pasture recovery returned R$0.56 to the Brazilian economy, a social return rate of 56% in the period. On average, the return would have been 6.54% per year, in real terms. These data illustrate the importance of productivity increases for the economy, as well as of the investments that allow this increase.

Still for comparison purposes, Santos and Ferreira Filho (2017), when analyzing the expansion in the production and use of ethanol and biodiesel, as a replacement for part of the fossil fuels, based on the scenario projected by the National Energy Plan 2030, estimated that the GDP gain would be 0.033%, accumulated in 2030. Assunção and Souza (2018), when analyzing rural credit policy in Brazil, estimated that a 1% increase in the volume of credit for agriculture would raise the agricultural sector GDP by 0.17%. Borges and Parré (2018), on the other hand, estimated that the effect of rural credit on agricultural GDP was 0.2%, in an analysis for the period from 1999 to 2018.

Similarly, Stocco et al (2020) estimated at 0.43% the real GDP gain from closing 50% of the productivity gap in beef cattle ranching in Brazil, also cumulative to 2030; while Silva and Ferreira Filho (2018) showed that the Bolsa Família and Benefício de Prestação Continuada (BPC) cash transfer programs would have resulted, in the period 2005 to 2012, in a real GDP increase of 0.31%, under the assumption that the policy would be funded from abroad. Therefore, the gains from pasture recovery estimated in this study are comparable with other important sectoral policies in Brazil.

The observed increase in domestic absorption is accompanied by a real exchange rate appreciation, with corresponding gains in the external terms of trade. This leads to a decline in aggregate exports as well as an increase in imports. Exports related to livestock (beef), however, increase significantly (14% relative to the baseline, accumulated in 2021). The aggregated regional results are heterogeneous, resulting from the differential evolution of cattle ranching and pasture recovery in each region (Table 4).

Table 4. Regional macroeconomic variables. Variation % in relation to the baseline, accumulated in 2021.

	Household consumption	Real investment	Exports (volume)	Imports (volume)	Real GDP	Real wages
1 Rondonia	1,89	5,28	-2,68	1,28	2,46	1,72
2 AmazACRR	0,55	1,15	-2,55	0,26	0,43	0,61
3 ParaAP	-0,21	0,23	1,03	0,22	0,37	-0,04
4 Bahia	-0,23	0,24	-0,70	0,16	0,20	-0,03
5 MaToPi	-0,38	0,50	-0,68	0,20	0,43	-0,14
6 RNordeste	-0,05	0,45	-0,71	0,25	0,19	0,13
7 MinasG	0,49	1,00	-2,05	0,49	0,30	0,49
8 SaoPaulo	0,41	0,78	-1,30	0,41	0,10	0,44
9 RSudeste	0,34	0,41	-1,70	0,38	0,08	0,39
10 Parana	0,79	2,27	0,31	0,84	0,38	0,80
11 RSul	1,20	2,56	-0,38	0,78	0,55	1,13
12 MtGrSul	0,55	1,44	-2,22	0,51	1,20	0,55
13 MtGrosso	-0,08	1,91	-1,43	0,61	1,01	0,01
14 GoiasDF	0,17	0,90	-1,59	0,47	0,38	0,18

Source: model results.

Results show real GDP growth in all states as a result of the increase in simulated productivity. This increase appears even in the state of São Paulo, where there was a drop in estimated productivity, as seen before. This happens because the rise in national income, and the consequent rise in demand and production, compensate for that sectoral drop in beef cattle ranching, which has a relatively small weight in the state's economy.

The states of Rondônia, Mato Grosso do Sul, and Mato Grosso presented the largest increases in regional GDP, showing that the recovery of pasture had, for these states, greater relative importance than in other states. This happens because in these states cattle ranching, besides presenting an increase in productivity, also has a larger share in the respective regional economies (Figure 2), which magnifies its impact on local GDPs: regions with more diversified economies tend to present a smaller increase in GDP, as is the case of the states in the Southeast and South regions of Brazil[3].

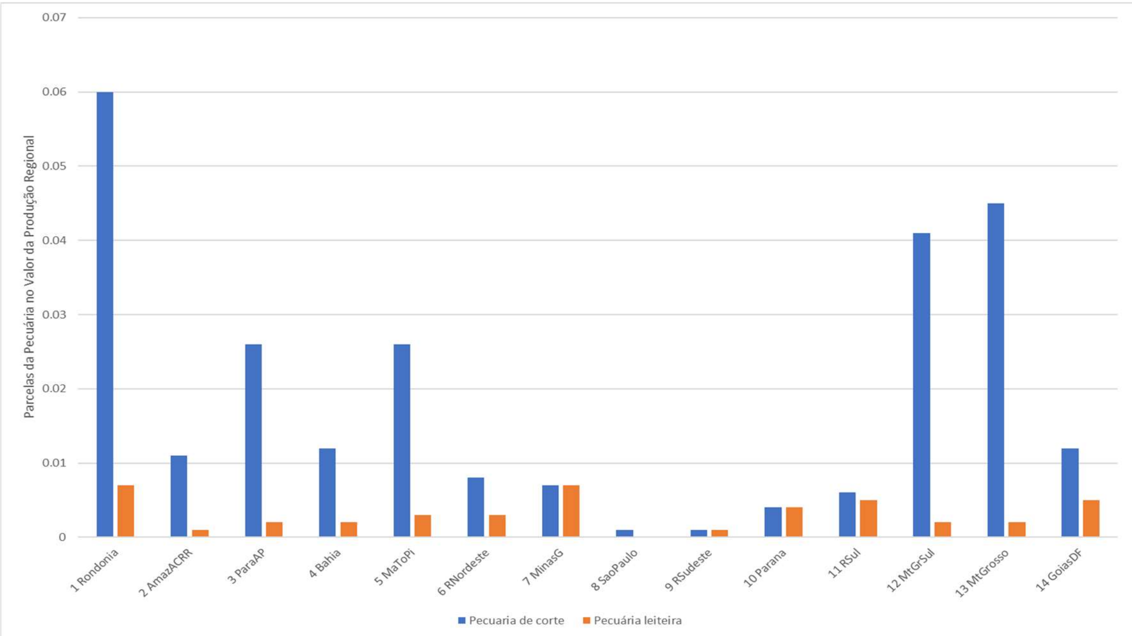

Figure 2. Share of livestock in the value of total regional production. 2015.

The increase in productivity of cattle ranching allowed by the increase in the recovery of degraded pasture generated a significant additional increase in its production (Table 5). In CEN1, ranching production increased in almost all regions, with the exceptions of beef cattle ranching in the state of São Paulo, and dairy cattle ranching in some states of the North and Northeast regions. In the case of the state of São Paulo the reason is the already mentioned drop in productivity in livestock. In the

[3] São Paulo, RSudeste, Parana, RGSul.

case of the other regions (ParaAP and Bahia), these are regions where dairy cattle production is very small in relation to beef production: competition for land between the two activities cause land substitution away from dairy toward beef cattle. Although both activities became more capital intensive after the increase in productivity, this increase in capital use was not sufficient, in the case of dairy cattle, to compensate for the decrease in the use of the land, thus reducing production in those regions.

Table 5. Regional production of livestock. % variation in relation to the baseline, accumulated in 2021.

	SCEN1		SCEN2	
	Beef cattle	Milk cattle	Beef cattle	Milk cattle
1 Rondonia	17.27	9.86	2.14	1.24
2 AmazACRR	15.87	10.99	1.55	0.75
3 ParaAP	1.92	-1.50	0.99	0.00
4 Bahia	1.43	-1.30	0.44	-0.37
5 MaToPi	4.47	0.75	2.24	1.04
6 RNordeste	10.95	5.70	0.37	-0.53
7 MinasG	1.20	0.20	0.93	0.44
8 SaoPaulo	-1.22	-5.25	3.81	2.54
9 RSudeste	8.68	4.47	1.04	-0.04
10 Parana	12.87	6.09	3.37	1.71
11 RSul	25.82	13.86	2.97	1.39
12 MtGrSul	15.42	10.32	1.99	0.72
13 MtGrosso	6.86	2.04	0.81	-0.26
14 GoiasDF	8.19	3.62	5.19	3.68

Source: model results.

In SCEN2 the effect is positive for beef cattle ranching in all regions, and negative for dairy cattle ranching in Bahia, Rest of the Southeast and Mato Grosso. In the case of Bahia and Mato Grosso the reasons are the same as mentioned above, i.e. small participation of dairy cattle relative to beef in the regions. In the case of the RSudeste what happens is that productivity growth is relatively lower, making the activity relatively less competitive.

The increase in cattle ranching productivity has impacts on the supply of food in the economy. The food price index drops 0.77% in real terms in SCEN1 and 0.19% in SCEN2. This index includes not only primary agricultural products, but also processed food, which are the products demanded by families. The productivity increases allows the producion the same amount of product with less use of productive resources.

The reduction in the food price index in general, and not only in livestock, occurs through two main channels. The first relates more directly to livestock products. Productivity gains in livestock are passed on through prices to the other stages of the livestock production chain (the downstream sectors, or the food processing industries), reducing the prices of its products. The second effect is more complex, and takes place through the factor markets: the increase in productivity of cattle ranching releases resources (land, labor and capital) for other sectors of the economy, which can then expand more easily. This is a general equilibrium effect, and one that has important consequences for environmental analysis, as will be seen later. The variation of prices and exports for selected agriculture-related products, for the SCEN1 case, can be seen in Table 6.

Table 6.Scenario 1: Prices, exports and value of production of selected products. % change from baseline, accumulated over 2021.

Products	Prices	Exports	Exported share of production	Value of production
Rice, Wheat and Other cereals	0,10	-3,27	0,08	-0,84
Corn	-0,18	-1,60	0,47	-1,40
Cotton	-0,38	-0,59	0,53	-0,99
Soybean	-0,18	-1,46	0,67	-1,27
Other annual crops	-0,01	-1,92	0,02	-0,27
Coffee	-0,24	-1,15	0,70	-1,15
Livestock	-14,34	101,73	0,02	-5,57
Hogs	0,23	-5,77	0,00	2,43
Poultry and eggs	0,23	-4,20	0,02	1,69
Meats	-4,07	13,99	0,22	0,57
Other food	-0,65	-0,37	0,13	-0,55
Other agroindustry products	0,07	-3,38	0,14	-0,61

Source: model results.

As discussed earlier, technical progress in cattle ranching generates, in the model, an exchange rate appreciation, which affects exports in general. Data in Table 6 show that exports from the livestock and meat sectors grow significantly[4]. Since the productivity shock happens in the primary sector, the increase in meat exports, even in the presence of exchange rate appreciation, is a result of the pass-through of part of the

[4] However, the value of live animal exports by the livestock sector are very small as a share of total production in the base year. That percentage change, therefore, is a large change over a small base.

gains from cattle ranching to the downstream economic sectors, mostly the meat production sector.

From the point of view of the value of agricultural and agribusiness production, other interesting aspects emerge from the analysis of Table 6. The table shows results well established in the general literature on technological progress in agriculture (Cochrane, 1958): the fact that the gains are transferred to society. The value of beef cattle production falls by 5.57%, since prices fall in greater proportion than the increase in production. The opposite, however, happens with the meat sector, a direct user of livestock production, where the value of production increases by 0.57%. Technological gains in agriculture, then, are transferred to the society through price mechanisms in the economy.

As seen previously, aggregate household consumption in the Brazilian economy grows in the simulations, in real terms. A more detailed analysis of household consumption, stratified by income brackets, however, reveals a more complex picture (Table 7). In this table, families (consumption units) are stratified by family income bracket, with each income bracket having a particular consumption basket, which may still vary according to region.

Table 7. Real consumption and consumer prices. Variation % in relation to the baseline, accumulated in 2021.

	CEN1		CEN2	
Household income group	Household consumption (real)	Consumption bundle price index	Household consumption (real)	Consumption bundle price index
1 POF1 (mais pobres)	-0,79	-0,41	-0.21	-0.10
2 POF2	0,13	-0,35	0.03	-0.09
3 POF3	0,26	-0,31	0.06	-0.08
4 POF4	0,39	-0,28	0.09	-0.07
5 POF5	0,46	-0,25	0.11	-0.07
6 POF6	0,43	-0,13	0.11	-0.03
7 POF7	0,49	-0,13	0.12	-0.03
8 POF8	0,56	-0,16	0.14	-0.04
9 POF9	0,54	-0,05	0.13	-0.01
10 POF10 (mais ricos)	0,61	-0,04	0.14	-0.01

Source: model results.

The consumer price indexes fall for all income brackets, but fall more for the poorest families in the economy (POF1), in both scenarios. These indexes are particular to each income group, that is, they take into account the composition of each consumption basket. It is interesting to note, however, that model results show a drop in real consumption for the poorest families (POF1), in both scenarios, while it increases for all other families (although, as seen in before, the aggregated result is an increase in real consumption nationally).

This happens because consumption is not only determined by the consumption bundle prices, but also by the variation in household income. The drop in the consumption of the poorest families occurs because cattle ranching is particularly intensive in the use of the least qualified workers in the economy, which are those that make up the largest part of the incomes of the poorest families (Table 8).

Table 8. Employment shares (payroll) by sector of agricultural and ranching activity and by type of work.

	Occupational wage group										
	OCC1	OCC2	OCC3	OCC4	OCC5	OCC6	OCC7	OCC8	OCC9	OCC 10	
Rice, Wheat and other cereals	0,02	0,46	0,30	0,10	0,04	0,02	0,01	0,01	0,01	0,02	1
Corn	0,03	0,44	0,27	0,11	0,05	0,03	0,01	0,01	0,02	0,04	1
Cotton	0,01	0,23	0,32	0,17	0,09	0,05	0,03	0,02	0,03	0,05	1
Sugarcane	0,02	0,27	0,29	0,20	0,08	0,04	0,02	0,01	0,02	0,05	1
Soybeans	0,02	0,33	0,31	0,15	0,07	0,04	0,02	0,01	0,02	0,05	1
Other annual crops	0,06	0,49	0,19	0,08	0,03	0,03	0,02	0,02	0,03	0,07	1
Oranges	0,07	0,58	0,19	0,06	0,03	0,02	0,01	0,01	0,01	0,04	1
Coffee	0,12	0,62	0,16	0,05	0,02	0,01	0,01	0,00	0,01	0,01	1
Other permanent crops	0,09	0,62	0,14	0,05	0,02	0,01	0,01	0,01	0,01	0,04	1
Livestock (beef)	0,10	0,54	0,21	0,06	0,02	0,02	0,01	0,01	0,01	0,03	1
Livestock (milk)	0,09	0,58	0,20	0,05	0,02	0,01	0,01	0,01	0,01	0,03	1
Hogs	0,04	0,56	0,23	0,06	0,03	0,02	0,01	0,01	0,01	0,02	1
Poultry and eggs	0,03	0,59	0,17	0,06	0,04	0,02	0,02	0,01	0,02	0,04	1

Source: model results.

Workers classified as OCC1 (the least qualified, or lowest paid, in the economy) make up approximately 10% of the cattle ranching payroll. The size of Brazilian beef cattle ranching, on the other hand, makes this sector responsible for 4.5% of all OCC1 employment in the economy (a figure that drops to 1.3% when it comes to dairy farming, and to just 0.9% in the case of soy, for example). Workers in this category (OCC1) make up the largest part of the income of the poorest families (POF1). The technological change (increase in productivity) in ranching affects the demand for primary factors, particularly the factor in which the activity is intensive, that is, low skilled labor, reducing its demand.

That result, however, is not uniform in the territory. The observed drop in real consumption in the POF1 family income category is determined mainly by the respective drop in the states/regions of Rondônia, ParaAP, Bahia, MaToPi, RNordeste and MinasG, in addition to MtGrosso and GoiasDF, in both scenarios. In those regions the share of OCC1 type jobs in total regional employment is relatively higher (Figure 3). This means that this type of job is relatively more abundant in those regions, where the drop in demand leads to a more intense drop in wages.

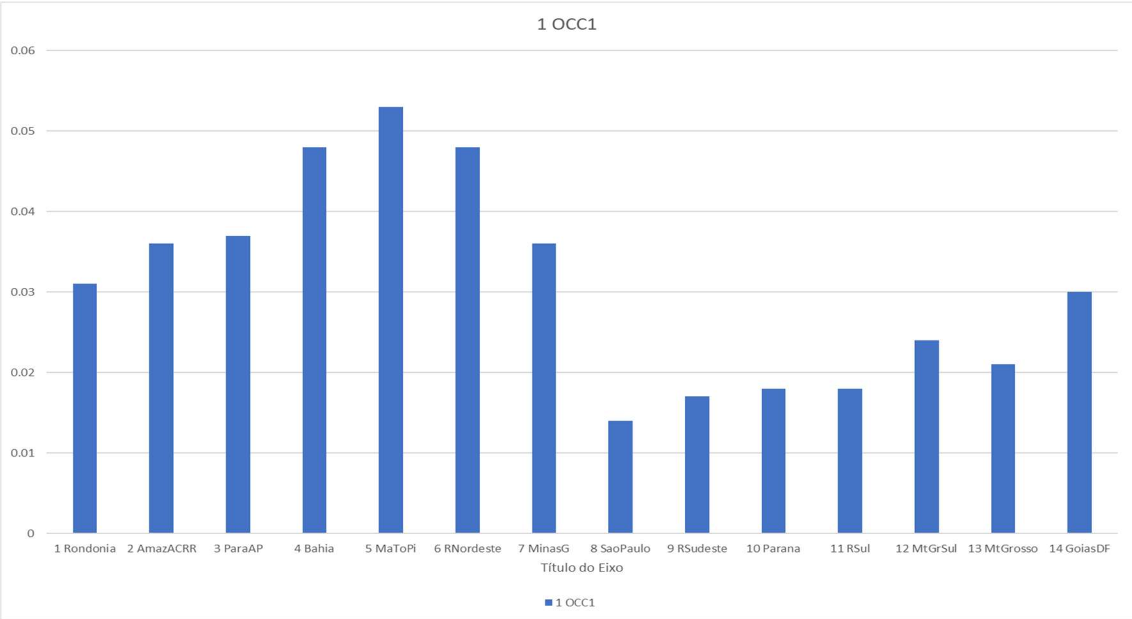

Figure 3. Share of OCC1 labor in total regional employment.

The fall in demand for that type of labor (OCC1), caused by technological change in a sector that is relatively intensive in its use (livestock farming), then, is what causes the real income of the families where those workers are located (POF1) to fall, reducing their real consumption. As the regions where this occurs present relatively small increases in GDP (Table 4), the increase in production of other economic activities does not fully compensate for the effect of the drop in OCC1 in ranching, resulting in a relatively higher (negative) income effect for that category of worker in these regions. This is an important for economic policy purposes: policies that have a beneficial effect at the national level, as is the case of the change analyzed here, frequently have differentiated effects at the regional level, which must be considered.

4. THE ENVIRONMENTAL EFFECTS OF RAISING PRODUCTIVITY IN CATTLE RANCHING.

In addition to economic effects, environmental effects are also important in the analysis of economic policies. In this paper the effects on greenhouse gas (GHG) emissions are addressed. Initially, it should be considered that in the case of livestock, most emissions occur in the form of methane, associated with the digestive process in the animal rumen. These emissions are responsible, in the model's database, for approximately 98% of total emissions (in terms of carbon equivalent) of livestock activity. Note that these emissions are not associated with the use of fuels, but rather with the level of activity: the larger the herd, the greater the associated emissions. Thus, it is to be expected that the gain in productivity of pasture, by increasing its production, also increases the respective emissions.

A controversial aspect to be taken into consideration when discussing technological change through pasture recovery is the increase in the carbon storage capacity of the soil. This effect - which is not yet taken into account by the IPCC in accounting for removals - can be significant, as demonstrated by Stocco et al (2020). Thus, the results presented here for emissions will show two different measures: one that does not account for soil carbon (SOC) stock increases, and one that does account for that accumulation (identified as an alternative measure in this text). The aggregated values can be seen in Table 9.

Table 9. Emissions; and "per capita" emissions. % change from baseline, accumulated in 2021.

	SCEN1	SCEN2
Production: beef livestock	8,77	1.91
Production: milk livestock	4,74	1.12
Total emissions (%)	2,24	0.49
Total emissions (%, alternative)	-0,29	-0.06
Per capita emissions (%)	2,24	0.49
Per capita emissions (%, alternative)	-0,29	-0.06

Source: model results.

Data displayed in Table 9 show that the increase in production of cattle ranching is associated with an increase in aggregate emissions from the Brazilian economy. Total emissions would have increased by 2.24% in SCEN1, while per capita emissions follow the same pattern as total emissions (since the population is kept fixed in the policy simulation, relative to the model's baseline). Thus, an increase of 2.24% in "per capita" emissions is observed, a value that changes to a reduction in those emissions (-0.29%)

when the alternative criterion is considered. The same pattern (in smaller magnitudes) can be observed in the SCEN2 case.

Another important aspect to be considered is emissions intensity, defined as the amount of emissions per unit of output, since the drop in this intensity points to a production with increasing sustainability. This information can be seen in Table 10.

Table 10. Emissions intensity (emissions per unit of production) in Brazilian ranching. Variations (%) in relation to the baseline, accumulated in 2021.

	SCEN1		SCEN2	
	Without SOC	Alternative	Without SOC	Alternative
Beef Livestock	-0,14	-9,67	- 0.04	-2.09
Milk Livestock	-0,36	-5,86	- 0.10	-1.34

Source: model results.

Emissions per unit of output are reduced when measured by either of the two criteria used here, and in both scenarios. The reduction, of course, is much greater when the alternative criterion is considered, that is, when the variation in the accumulation of carbon in the soil due to pasture improvement is also computed. This shows that Brazilian cattle raising is developing with an increasing sustainability pattern, where emissions per unit of product have been reduced due to the improvement in pasture quality.

It should be noted that the above values may be underestimated, i.e., the intensity of emissions may have been reduced even more than estimated. The reason is that, in the alternative method, the model computes the accumulation of carbon in soil, but not the reduction in emissions by animals as pasture quality improves (improved digestibility). This is an aspect of the problem that has not yet been incorporated into economic modeling, and is at the frontier of development from both a theoretical and empirical point of view.

And finally, attention is also drawn to the fact that the accumulation of carbon in the soil, included in the alternative method, does not happen indefinitely. The specific literature on the subject shows that this stock would grow for approximately 30 years, stabilizing thereafter in areas where there is recovery. In any case, this period is not reached in the simulation period employed here, which does not invalidate our results.

5. Final remarks

This paper analyzed the economic and environmental impacts of pasture recuperation in Brazil. The results show a positive impact on the economy as a whole, with an increase in GDP and real aggregate household consumption. In terms of regional economies, there was an increase in GDP in all regions, including those where estimated productivity did not grow, as is the case of the state of São Paulo.

It should be noted, however, that the regional results draw attention to the impacts of investments in some particular occupational categories of labor. When the data is analyzed in more disaggregated terms, it can be seen that despite the fall in the prices of the consumption basket for all the 10 categories of families considered, the real consumption of the poorest families showed a drop. This is associated with specific regions of Brazil (some states in the North and Northeast regions), where the labor composition in cattle ranching is particularly intensive in low-skilled labor. In this way, the increase in productivity tends to reduce the demand for labor in the activity, which is not offset, in these regions, by the increase in the GDP, which raises the production of the other sectors. This fact is not enough to determine a drop in real consumption at the aggregate level (Brazil), but it is important for the design of regional economic policy.

The estimated gains also show that the ABC Program investments in pasture recovery had a high rate of return, with GDP returning R$0.56 (at 2015 values) for each real invested in pasture recovery by the program. This is a high social rate of return, and shows the importance of policies that allow the increase of productivity in the Brazilian economy.

From the point of view of total emissions in the economy, the increase in productivity of cattle ranching, by raising its production, also raises total emissions, which was to be expected. Total production, however, rises in greater proportion than emissions, reducing the intensity of emissions in the activity. This shows that this is the pattern to be followed, i.e., that Brazilian cattle raising has developed with increasing sustainability, which is made possible by the recovery of pastures. In this particular, attention is also drawn to the fact that the reduction in emissions intensity calculated here is probably a lower limit for that parameter, since the reduction in herd emissions due to improved forage quality was not considered in this study.

Another aspect relevant to the discussion is the accounting of soil carbon accumulation included in the alternative emissions measure. This mechanism proved to be extremely important in terms of capturing emissions, significantly improving Brazil's sustainability indicators when included in the calculation. This may be an important measure to include in discussions about sustainability, since soil carbon accumulation is not yet included in standard calculations of emissions by international organizations. This is an important factor to consider, and of crucial importance to current discussions about sustainability.

6. References

ASSUNÇÃO, J; SOUZA, P. 2019. The impact of rural credit on Brazilian agriculture and the environment. Policy Brief. Climate Policy Initiative. Rio de Janeiro.

BORGES, M.J; PARRÉ, J.L. 2022. O impacto do crédito rural no produto agropecuário brasileiro. Revista de Economia e Sociologia Rural, 60(2). e230521. https://doi.org/10.1590/1806-9479.2021.230521.

Brasil. (2016). Terceira Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima – Volume I.

COCHRANE, W.W. 1958. Farm prices: Mith and Reality. St. Pau: University of Minnesota Press.

IPCC. **Climate Change 2014**: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, p. 1-151, 2014.

MCT – Ministry of Science and Technology. 2015. Terceiro Inventário Brasileiro de Emissões e Remoções Antrópicas de Gases de Efeito Estufa. Relatórios de Referência. Setor Uso da Terra, Mudanças do Uso de Terra e Florestas. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/publicacoes/relatorios-de-referencia-setorial/pdf/invetario3/rr_lulucf_mudanca_de_uso_e_floresta.pdf.

Rocha Junior, A. B., Gianetti, G. W., & Ferreira Filho, J. B. de S. (2022). Economic and environmental impacts of pastures recovery in Brazil. *2022 WESTERN AGRICULTURAL ECONOMICS ASSOCIATION*. https://waeaonline.org/wp-content/uploads/2022/06/WAEA-2022-Program-6.15.22.pdf

SANTOS, J.A; FERREIRA FILHO, J.B.S. 2017. Substituição de combustíveis fósseis por etanol e biodiesel no Brasil e seus impactos econômicos: uma avaliação do Plano Nacional de Energia 2030. Pesquisa e Planejamento Econômico. V47, no.3.

SILVA, D.I; FERREIRA FILHO, J.B.S. 2018. Impactos dos programas de transferência de renda Benefício de Prestação Continuada e Bolsa Família sobre a economia brasileira: uma análise de equilíbrio geral. Pesquisa e Planejamento Econômico. V.48, no.1.

STOCCO, L; FERREIRA Fo, J.B.S; HORRIDGE, M. 2020. Closing the Yield Gap in Livestock Production in Brazil: New Results and Emissions Insights. In: Madden, J.R;

Shibusawa, H; Higano, Y. (eds). Environmentao Economics and Computable General Equilibrium Analysis. Essays in Memory of Yuzuru Miyata. Springer. 414 p.