# Fiscal Policy and Environmental Goals: Impacts of Rural Land Tax Reform in Brazil

## *Política Fiscal e Metas Ambientais: Impactos do Imposto sobre a Propriedade Territorial Rural no Brasil*

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**Abstract**
This study evaluates the socioeconomic and environmental impacts of proposed reforms to Brazil's Rural Land Tax (ITR) to reduce deforestation and align fiscal policy with sustainability goals. Using the TERM-BR computable general equilibrium (CGE) model, two reform scenarios are assessed for the 2022-2030 period: (1) strict enforcement of existing legislation and (2) a new tax structure that incentivizes native vegetation conservation. Both reforms would reduce deforestation, with Scenario 1 preventing 1.96 million hectares (Mha) and Scenario 2 preventing 3.35 Mha by 2030, resulting in a 2.9% to 5.1% decrease in land use change emissions. These environmental gains cost R$ 2.2 billion to R$ 3.7 billion in GDP losses by 2030. The economic cost is approximately R$ 1,100 per hectare of avoided deforestation. Regional impacts vary, with the Mid-West region bearing the largest share of tax revenue increases and deforestation reductions, making the reforms more effective in the Cerrado biome than in the Amazon. While higher ITR taxes reduce land-use expansion and emissions, their uneven economic impacts highlight the need for targeted land taxation policies to balance environmental, economic, and social sustainability.
**Keywords**: land use change, tax reform, Imposto sobre a Propriedade Territorial Rural

***Resumo***
*Este estudo avalia os impactos socioeconômicos e ambientais de reformas propostas para o Imposto sobre a Propriedade Territorial Rural (ITR) do Brasil, com o objetivo de reduzir o desmatamento e alinhar a política fiscal com as metas de sustentabilidade. Usando o modelo de equilíbrio geral computável (CGE) TERM-BR, dois cenários de reforma são avaliados para o período de 2022 a 2030: (1) efetiva aplicação da legislação existente e (2) uma nova estrutura tributária que incentiva a conservação da vegetação nativa. Ambas as reformas reduziriam o desmatamento, com o Cenário 1 evitando 1,96 milhão de hectares (Mha) e o Cenário 2 evitando 3,35 Mha até 2030, resultando em uma redução de 2,9% a 5,1% nas emissões provenientes da mudança no uso da terra, respectivamente. Esses ganhos ambientais têm um custo de redução no PIB de R$ 2,2 bilhões a R$ 3,7 bilhões até 2030. O custo econômico é aproximadamente R$ 1.100 por hectare de desmatamento evitado. Os impactos regionais variam, com a região Centro-Oeste registrando a maior parte do aumento na receita tributária e da redução do desmatamento, tornando as reformas mais eficazes no bioma Cerrado do que na Amazônia. Embora os impostos mais altos do ITR reduzam o desmatamento e as emissões, seus impactos econômicos regionais desiguais destacam a necessidade de políticas tributárias específicas para equilibrar a sustentabilidade ambiental, econômica e social.*
***Palavras-chave****: mudança de uso da terra, reforma tributária, Imposto sobre a Propriedade Territorial Rural*

## 1. Introduction

From 1990 to 2020, land use, land-use change, and forestry (LULUCF) were Brazil's main sources of greenhouse gas (GHG) emissions (Brazil, 2024b). Although emissions from LULUCF declined, they still accounted for an average of 28% of Brazil's total emissions between 2016 and 2020 (Brazil, 2024b). During this period, approximately 2 million hectares (Mha) of native vegetation were deforested annually (Instituto Nacional de Pesquisas Espaciais, 2024).

Deforestation contributes to GHG emissions, threatens biodiversity, degrades soil and water cycles, and disrupts environmental processes (Portela & Rademacher, 2001). Addressing its underlying causes is essential for sustainability and meeting national climate commitments. Multiple factors drive this complex issue, including land characteristics, agricultural expansion, market demand, transportation infrastructure, socioeconomic and cultural dynamics, and profit maximization (Amsberg, 1998; Fearnside, 2007; Ferreira et al., 2013; Levy et al., 2004; Münier et al., 2004; Nepstad et al., 2001; Thomas et al., 2004; Verburg et al., 2014; Von Thünen, 1826). Large-scale commodity agriculture, such as soybean production and cattle ranching, has also been linked to deforestation (Barona et al., 2010; Laurance, 2007; Laurance et al., 2004; Morton et al., 2006; Verburg et al., 2014).

Policies to curb deforestation include legislation, conservation efforts, and market-based mechanisms that either reduce the profitability of deforestation or enhance the economic value of forests (Angelsen, 2010). In Brazil, most policies follow a command-and-control model, such as the Brazilian Forest Code (Diniz & Ferreira Filho, 2015). Specific measures include embargos, sanctions against illegal deforestation, and initiatives like the Plano de Ação para Prevenção e Controle do Desmatamento, targeting the Amazon and Cerrado biomes.

Market-based mechanisms remain underutilized. Existing taxes, such as Brazil's Rural Land Tax (Imposto sobre a Propriedade Territorial Rural – ITR), inadvertently encourage deforestation. The ITR reduces tax rates as land use intensifies (e.g., increased productivity), particularly in cattle ranching. Furthermore, inaccurate land valuation and weak enforcement limit its effectiveness as a fiscal instrument.

Brazil is undergoing Tax Reform, introducing a value-added tax (VAT) system at all government levels. The reform includes a Selective Tax (Imposto Seletivo), targeting harmful products like tobacco and alcohol. Aligning tax policies with sustainability goals could strengthen Brazil's climate commitments. However, the current reform focuses on consumption taxes rather than wealth or land taxation, which may distort capital and labor markets (Kalkuhl et al., 2018; The Organization for Economic Cooperation and Development, 2010). While it does not alter the government budget, shifting tax burdens across sectors could disrupt market equilibrium. Nevertheless, this reform presents an opportunity to incorporate environmental taxation, such as a revised land tax, to discourage deforestation.

Land taxes are among the least distortionary tax systems under fixed supply assumption, promoting efficiency by taxing land based on optimal use rather than productivity (Oates & Schwab, 2009). The current ITR, however, considers bare land value rather than its optimal use. Given annual deforestation of 2 Mha of land, Brazil's land supply may be elastic, making the ITR non-neutral and potentially shifting tax burdens from landowners to consumers and disrupting market equilibrium.

Fendrich et al. (2022) identified inefficiencies in the ITR, revealing that tax revenues were nearly four times lower than they should be under strict legislation enforcement. They suggested that raising the minimum tax charge from BRL 10 to BRL 50 and incorporating native vegetation conservation parameters could increase revenue tenfold while enhancing environmental and economic outcomes.

This study evaluates the socioeconomic and environmental impacts of proposed reforms to Brazil's Rural Land Tax (ITR) to reduce deforestation and align fiscal policy with sustainability goals. Using the TERM-BR computable general equilibrium (CGE) model, two reform scenarios from Fendrich et al. (2022) are analyzed for 2022-2030: (1) strict enforcement of existing legislation and (2) a new tax structure that incentivizes conservation of native vegetation. The assessment projects impact LULUCF, GHG emissions, sectoral outputs, household consumption, trade balance, and regional socioeconomic variables.

## 2. Rural Land Tax in Brazil (Imposto sobre a Propriedade Territorial Rural – ITR)

The ITR is established in the Federal Constitution and governed by Law 9.393/1996, Executive Order 4.382/2002, and IRS Normative Instruction 256/2002 (Brazil, 1988, 1996, 2002a, 2002b). Article 153 of the Constitution grants the government authority to tax rural properties, aiming to discourage unproductive land use while exempting small areas from taxation (Brazil, 1988). Though a federal tax, ITR revenue is partially allocated to municipalities, which can assume full responsibility for its collection and enforcement under Law 11.250/2005, subject to federal oversight (Brazil, 2005).

ITR is calculated based on bare land value, excluding improvements or buildings, as self-reported by landowners. The government can revise these valuations if discrepancies are detected. Tax rates vary based on land use, property size, and livestock productivity, all self-declared (Appy, 2015; Brazil, 1996). A detailed breakdown of the tax formulas is provided in **4.2.2.2** and **4.2.2.3**.

While the ITR aims to discourage land speculation and low-productivity farming, it has failed to meet these objectives due to weak enforcement. The reliance on self-reported data enables landowners to underreport land value to reduce tax liability, overstate non-taxable areas (e.g., environmental reserves), and inflate land utilization rates to qualify for lower tax rates (Appy, 2015; Reydon et al., 2015). Due to low fiscal revenue potential, authorities have not prioritized strict enforcement. For instance, livestock productivity reference levels, established in the 1980s, remain unchanged, and no crop productivity thresholds are defined, further limiting the tax's effectiveness (Appy, 2015).

Historically, the ITR encouraged agricultural expansion, but current national priorities focus on sustainable land use. However, the tax structure does not penalize non-compliance with environmental laws. Worse, landowners conserving native vegetation beyond legal requirements may face higher tax burdens, creating a perverse incentive (Fendrich et al., 2022).

The ITR can be reformed to support environmental goals, such as tax abatements for landowners preserving native vegetation beyond legal requirements, as proposed by Fendrich et al. (2022). However, increasing the land tax in a non-neutral framework, particularly in elastic land supply scenarios, could shift the tax burden from landowners to consumers, disrupting market equilibrium. We analyzed this economic impact in this study.

### 2.1. Historic ITR revenue

Adjusted to 2015 constant prices, the 2023 ITR revenue reached R$ 1,892 million, marking an increase of R$ 698 million compared to 2015 (Table 1), representing a 59% cumulative real growth. Following the COVID-19 pandemic, the average annual increase surpassed 7.9%, largely influenced by rising commodity prices, which impact land values, one of the key determinants of ITR assessments.

Historically, ITR revenue has played a minor role in Brazil's overall tax system. Between 2019 and 2023, it accounted for only 0.07% to 0.09% of total government tax revenue, while its contribution to Gross Domestic Product (GDP) ranged from 0.02% to 0.03% during the same period (Brazil, 2023). Despite the previously mentioned revenue increase, ITR remains insignificant in the broader fiscal context, with no substantial impact on total tax revenue or its share of GDP.

Municipal data on bare land value per hectare and total ITR revenue are publicly available. Still, key variables such as total bare land value, land area, and average tax rate remain inaccessible. However, Appy (2015) estimated that the average ITR tax rate in 2012 was 0.18% of total land value, providing a historical reference for its relative burden.

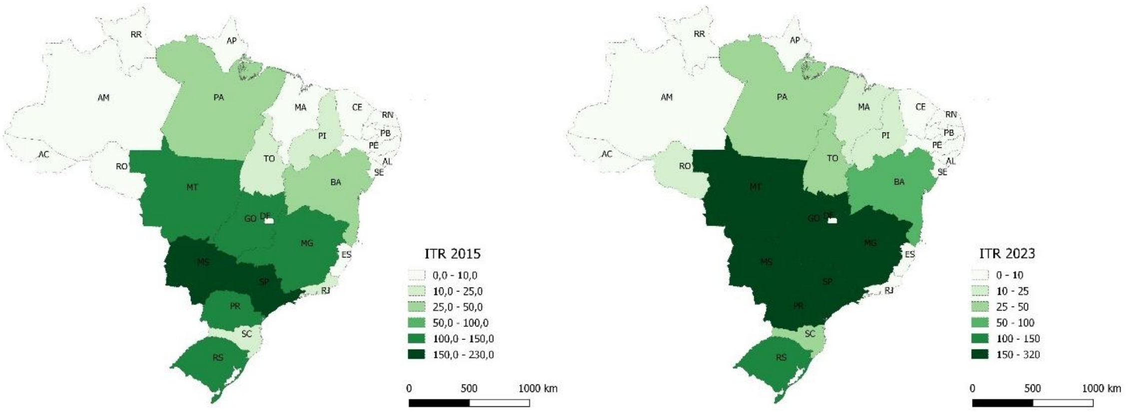
Table 1. ITR revenue 2015-2023 (in 2015 prices)

| Year | 2015 prices | | | | |
|---|---|---|---|---|---|
| | **ITR (R$ millions)** | **Annual % change** | **Accumulated % change** | **Annual absolute change** | **Accumulated absolute change** |
| 2015 | 1,193.3 | - | - | - | - |
| 2016 | 1,146.5 | -3.9 | -3.9 | -46.8 | -46.8 |
| 2017 | 1,220.5 | 6.5 | 2.3 | 74.0 | 27.1 |
| 2018 | 1,282.4 | 5.1 | 7.5 | 61.9 | 89.0 |
| 2019 | 1,450.5 | 13.1 | 21.5 | 168.1 | 257.2 |
| 2020 | 1,468.2 | 1.2 | 23.0 | 17.7 | 274.9 |
| 2021 | 1,599.5 | 8.9 | 34.0 | 131.3 | 406.2 |
| 2022 | 1,726.1 | 7.9 | 44.6 | 126.6 | 532.8 |
| 2023 | 1,891.6 | 9.6 | 58.5 | 165.5 | 698.3 |

Source: authors. Data from (Brazil, 2025).

The regional distribution of ITR revenue is concentrated in Brazil's center-south region, where agricultural production is most prominent. In 2015, Minas Gerais (MG), São Paulo (SP), Paraná (PR), Rio Grande do Sul (RS), Mato Grosso do Sul (MS), Mato Grosso (MT), and Goiás (GO) each collected over R$ 100 million in ITR revenue. By 2023, most of these states had surpassed R$ 150 million, except for Rio Grande do Sul (RS), as shown in Figure 1.

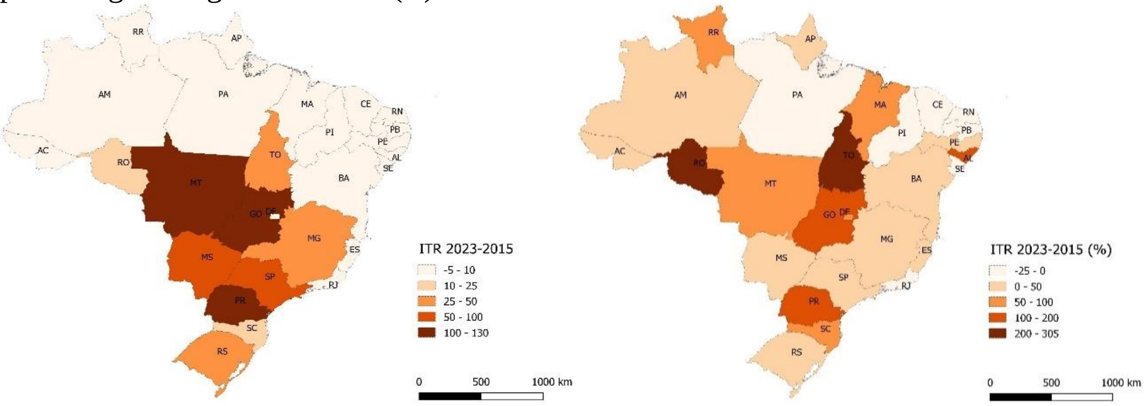
Figure 1. State ITR revenue 2015 (A) and 2023 (B), R$ million of 2015




Source: authors. Data from (Brazil, 2025).

Several states, including Pará (PA), Piauí (PI), Ceará (CE), Rio Grande do Norte (RN), Paraíba (PB), Sergipe (SE), and Rio de Janeiro (RJ), experienced declines in ITR real revenue, despite nominal increases. In contrast, Goiás (GO), Paraná (PR), and Mato Grosso (MT) recorded growth exceeding R$ 100 million between 2015 and 2023. In percentage terms, Rondônia (RO) and Tocantins (TO) more than doubled their ITR revenue. At the same time, Alagoas (AL), Goiás (GO), and Paraná (PR) also achieved at least a 100% increase, reflecting significant regional disparities in tax collection trends Figure 2.

Figure 2. State-level ITR revenue absolute change 2015-2023 in R$ million of 2015 (A) and percentage change 2015-2023 (B)




Source: authors. Data from (Brazil, 2025).

## 3. Methods

This analysis is divided into two components: a spatial component to model the application of the rural land tax (ITR) on different tax reforms and its distribution across Brazilian regions, and an economic modeling component to simulate the impacts of the ITR reform scenarios on the Brazilian economy and LULUCF. Data from the spatial analysis will serve as inputs for a computable general equilibrium (CGE) model, specifically the Enormous Regional Model for Brazilian Economy (TERM-BR). This dynamic, inter-regional (bottom-up) model includes a module for analyzing LULUCF and GHG emissions.

The ITR tax rate and value depend on rural property characteristics, requiring spatially explicit modeling to estimate and project outcomes under different reform scenarios. We updated the database for 2022 using the scenarios proposed by Fendrich et al. (2022): i) The first scenario enforces existing legislation, using secondary data for land use and prices to avoid bias from self-reported data; ii) The second scenario introduces a tax reform, modifying land uses in the tax base and offering a deduction for conserving native vegetation beyond legal requirements.

## 4. Computable General Equilibrium (CGE)

CGE models typically operate within a competitive economy framework, using a system of equations to represent the optimal economic behaviors of agents. For instance, households maximize utility subject to budget constraints, while firms minimize costs based on the availability and prices of primary factors. Recently, CGE models have expanded to include variables beyond monetary flows and stocks, such as livestock and crop models, water flows, land use, GHG emissions, and other ecosystem services. They also offer subnational representations of economies. Given Brazil's socioeconomic and biophysical diversity, including variations in native vegetation, subnational representation is essential for accurately assessing policy impacts on the economy and the environment.

The TERM-BR model provides a thorough representation of agricultural and agroindustrial production in Brazil, incorporating land use transitions across the 27 Brazilian states, six biomes (Amazonia, Cerrado-Savanah, Atlantic Forest, Pampa, Pantanal-Wetlands, and Caatinga-Scrublands), and four land use types (crops, pasture, planted forest, and unused land), linked to 15 agricultural products (Table 2).

The land use transition matrix estimates the probability of land use changes over time, incorporating GHG emission coefficients for each transition, model region, and biome. Deforestation rates increase land supply according to the transition matrix, while economic drivers can also influence land use changes endogenously. Land use categories are assigned to specific products and industries based on their relative rate of return, determined by Constant Elasticity of Transformation (CET) functions (Ferreira Filho et al., 2015; Gianetti & Ferreira Filho, 2024). Additionally, the model includes GHG emissions from economic activity, fuel consumption, and other input uses, alongside emissions from land use transitions.

TERM-BR is a dynamic, inter-regional, bottom-up general equilibrium model of the Brazilian economy, recently calibrated by Gianetti & Ferreira Filho (2024) using 2015 as the base year. A key feature of dynamic models is their ability to evaluate the economy's trajectory over time, with capital accumulation and investment determined endogenously.

As an inter-regional model, Brazil's 27 states are aggregated into 16 regions (Figure 3) based on agricultural production characteristics and land prices. The regions are interconnected through trade flows and the factor market. As a bottom-up model, the aggregated regional results reflect national-level outcomes. Household consumption is driven by regional income, and changes affect labor mobility and relative real wages.

Table 2. TERM-BR products and industries

| Sector | Product/industry | Sector | Product/industry |
| --- | --- | --- | --- |
| Agriculture | Rice, wheat, and other cereals | Industry | Fuel except for gasoline C and ethanol |
| Agriculture | Maize | Industry | Gasoline C |
| Agriculture | Cotton | Industry | Other manufacture |
| Agriculture | Sugarcane | Industry | Ethanol |
| Agriculture | Soybeans | Industry | Chemistry |
| Agriculture | Other annual crops | Industry | Metallurgy |
| Agriculture | Orange | Industry | Electric and electronics |
| Agriculture | Coffee | Industry | Automobiles |
| Agriculture | Other perennial crops | Industry | Electricity and gas |
| Agriculture | Cattle and other livestock | Industry | Water and sewage |
| Agriculture | Milk | Industry | Construction |
| Agriculture | Swine | Service | Trade |
| Agriculture | Poultry and eggs | Service | Transportation |
| Agriculture | Planted forest | Service | Accommodation and food |
| Agriculture | Fishery | Service | Communication and finance |
| Mining | Mining and oil extraction | Service | Public services |
| Agroindustry | Meat house | Service | Education and health care |
| Agroindustry | Other food | Service | Domestic services |
| Agroindustry | Other agroindustry | Service | Other services |

Source: authors.

The model's production technology specifies that 38 industries each produce a single good or service (Table 2). The production combines intermediate inputs, primary factors, and other costs like taxes in fixed proportions, defined by the Leontief function. A nested production function optimizes agent behavior. Constant Elasticity of Substitution (CES) functions determined the allocation of primary factors, the choice between domestic and imported inputs, and subnational input selection.

Figure 3. Spatial location of the TERM-BR15 regions


Source: authors.

Households and labor supply are grouped into 10 wage-based categories. The first group earning half the minimum wage (MW), the second earning one MW, and the subsequent groups increasing by one MW each. Households maximize their utility within budget constraints using the Klein-Rubin function. This optimization leads to a linear expenditure system for each representative household. A CES function also determines labor utilization, enabling substitution between different labor qualifications (Aguiar et al., 2019; T. B. Diniz, 2019).

These features allow for a detailed assessment of potential ITR tax reform impacts on agricultural activities, linking land use and GHG emissions at a subnational level, reinforcing the suitability of TERM-BR for this analysis.

### 4.1. TERM-BR Adaptation for ITR Reform Assessment

Changes in rural land taxation are expected to affect land prices by reducing expected land rents. In a scenario with a perfectly inelastic land supply, an increase in land taxes would lead to a proportional decrease in land prices and expected rents, meaning current landowners would bear the tax burden. However, considering Brazil's history of expanding agricultural land by an average of 2 Mha annually, part of the tax burden may shift to consumers. Therefore, since the TERM-BR model does not explicitly account for ITR taxes, it must be adapted to include both pre- and post-tax land rents, enabling the evaluation of changes in general market equilibrium resulting from ITR reforms.

The TERM-BR model captures industry demand for primary factors (capital, labor, and land) using a Constant Elasticity of Substitution (CES) function. This function shows how industries in different regions adjust land use based on changes in output and relative land costs compared to other primary factors. Additionally, land-augmenting technological changes influence land efficiency, mitigating or amplifying land use impacts.

Land rental payments depend on land demand and rents, which vary by industry and region. As rural land taxation affects land rents, it also influences land demand. Model equations calculate post-tax land rentals, accounting for region-specific changes in land use and taxation policies.

The model also allocates cropland and pastureland to different uses, such as various crop types or beef and dairy production. These allocations are driven by shifts in land demand across industries and regions, with new equations adjusting for post-tax land rents. The model considers how attractive different land uses are after taxes.

The new model equations also track changes in land tax rates and total land tax revenue for each industry and region. Tax rate adjustments influence land costs for industries in different regions. Changes in revenue reflect pre-tax land rents, demand shifts, and tax rate changes. As pre-tax land values exceed post-tax values by tax amount, the model captures how taxation affects land rents, land demand, and regional and industry decisions.

The model adaptation thus establishes a clear relationship between pre-tax and post-tax land values and rents for each industry and region, enabling a detailed analysis of how increased rural land taxation impacts various economic sectors, especially agricultural industries. By simulating these dynamics across regions and industries, the model helps assess the broader economic effects of land taxation policies.

## 4.2. Simulation Strategy

The TERM-BR model is dynamic, incorporating factors like capital accumulation and population growth annually. To assess policy impacts, we first simulate a business-as-usual (BAU) scenario, adjusting macroeconomic aggregates (e.g., household consumption, GDP) to reflect the baseline. Policy scenarios are then modeled as shocks relative to BAU, with results expressed as percentage differences, which can later be converted into absolute values for key variables like ITR revenue.

The BAU simulation covers two periods: a historical simulation from 2015 to 2023, updating the model with observed data on ITR revenue, deforestation, and population growth, where ITR revenue changes are treated as exogenous. The tax rate is solved endogenously to meet revenue targets. The second period, 2024-2030, applies shocks to GDP and population growth, adjusting ITR revenue endogenously based on changes in land value while keeping the tax rate constant. This allows for an examination of how land use, land-use change, and GHG emissions respond to current ITR revenue.

For policy simulations, we apply ITR tax revenue changes for 2022, calculating tax rate deviations endogenously. From 2023 to 2030, it was used with an exogenous tax rate but endogenously determined tax revenue. The policy shocks for both proposed scenarios will be analyzed and presented in 5.1.1 ITR Scenarios.

### 4.2.1. Business-as-Usual simulation

We used macroeconomic variables, population growth, land use changes, and ITR revenue data for the BAU simulation to replicate the economy's behavior from 2015 to 2023. Except for ITR revenue, BAU data was based on Gianetti & Ferreira Filho (2024). From 2015 to 2023, ITR revenue increased by R$ 533 million (44.6%), rising from R$ 1,193 million to R$ 1,726 million in 2015 prices, as shown in **2.1 Historic ITR revenue**. The center-south region accounted for most of the revenue, while northern states like Amazonas, Pará, and Amapá saw a real-term decline, though their contribution remained minimal.

Land use changes were driven by observed deforestation, averaging 2.2 Mha per year from 2015 to 2022, peaking at 2.75 Mha in 2022, mainly in the Amazon (1.2 Mha) and Cerrado (1.0 Mha). Over the period, deforestation totaled 6.5 Mha in the Amazon, 5.4 Mha in the Cerrado, and smaller amounts in the Caatinga, Atlantic Forest, Pampa, and Pantanal biomes.

The only fixed macroeconomic variables for the 2024-2030 projection were 2.5% GDP growth and population growth estimates. ITR revenue and land use transitions were endogenously determined, with the ITR tax rate treated as exogenous and the tax collection adjusting only based on changes in land rents and land use dynamics.

### 4.2.2. Policy Scenarios

#### 4.2.2.1. Spatial modeling database

To update the Fendrich et al. (2022) scenarios to the 2022 base year, data on land registry, land type, and land prices were used. The Brazilian land registry, based on Sparovek et al. (2019) and Freitas et al. (2018), defines the boundaries of rural properties for spatial modeling, including property size, land use, and factors needed for ITR calculations. The latest registry, from 2021, covers 82.6% of Brazil's territory, with 4,519,223 rural properties, ensuring no overlaps after cleaning.

The Mapbiomas (2024) database on land use and land-use change was integrated with the registry to create land-use maps for 2015-2022. Land-use classifications were categorized into crops, pasture, and native vegetation (Table 3). The land use data was also combined with agricultural suitability information from Bolfe et al. (2024) and reclassified[1] into three categories: low, medium, and high suitability.

Table 3. Mapbiomas land use types aggregation

| Mapbioma Land Type | New Land Type |
|---|---|
| 3, 4, 5, 6, 11, 12, 32, 49 and 50 | Native vegetation |
| 9, 20, 21, 35, 39, 40, 41, 46, 47, 48 and 62 | Crop |
| 15 | Pasture |

Source: authors.

Land price information is crucial for ITR estimation, though it is complex due to factors like land quality, infrastructure, and speculation. The Brazilian Internal Revenue Service (Brazil, 2024a) provides the data for rural land taxes. Still, its updates may be influenced by its role in taxation, as previously mentioned. Alternatively, we used the IHS Markit (2024) database, which offers detailed land price surveys, representing 570 municipalities extrapolated across Brazil's 5,570 municipalities.

This land price database covers 32 land types (e.g., native vegetation or pasture) and varying levels of agricultural suitability. The data was processed to create annual averages and categorized into high, medium, and low suitability. Prices for pasture and native vegetation were averaged, while cropland prices were weighted by product area using data from the Municipal Agricultural Survey (PAM) (Instituto Brasileiro de Geografia e Estatística, 2024).

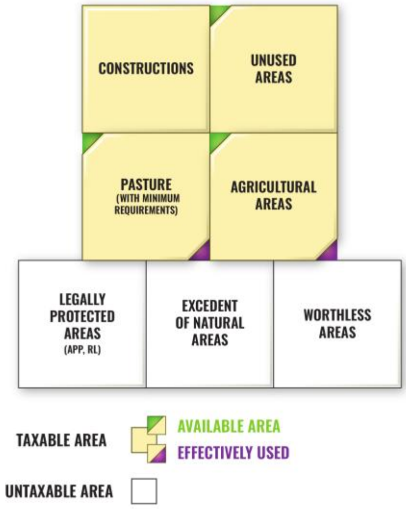
The resulting bare land price database represents three land uses (crops, pastures, native vegetation) and three suitability levels (high, medium, low), resulting in nine combinations. For missing data in some municipalities, values were extrapolated from mesoregion or state-level averages, used to determine the bare land value for ITR scenarios.

#### 4.2.2.2. Methods for Scenario 1 – enforcement of existing legislation

The first scenario simulates the effects of strict enforcement of existing legislation by adjusting observed land use and land value rather than relying on self-reported data from landowners. ITR calculation follows the methodology outlined by Fendrich et al. (2022). The tax rate and amount depend on the land use of private rural properties, as shown in Figure 4.

[1] low suitability for areas with strongly restricted or restricted agricultural potential, medium suitability for areas with moderate potential, and high suitability for areas with good or very good potential.

Figure 4. Definition of the components for the ITR calculation




Source: Fendrich et al. (2022).

The tax value is determined by equation 1:

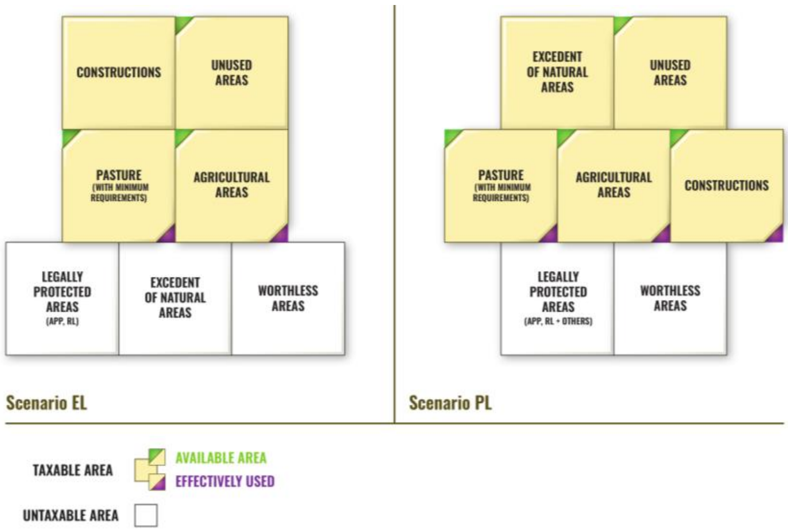
$$\text{ITR} = \text{Land value} \cdot \frac{\text{taxable area}}{\text{total area}} \cdot \text{tax rate} \quad (1)$$

The tax rate is based on the total property area and the degree of utilization (ratio of effectively utilized area to total available area). If the property does not meet the required number of cattle per hectare for pasture areas, only part of the area is considered "effectively utilized," which raises the tax burden by increasing the applicable tax rate.

#### 4.2.2.3. Methods for Scenario 2 – Fendrich et al. (2022)

The second scenario follows the tax reform proposed by Fendrich et al. (2022), which modifies the land uses included in the tax base and introduces a deduction for conserving native vegetation beyond legal requirements, as shown in Figure 5.

Figure 5. Difference between Scenario 1 (left) and Scenario 2 (right) for ITR calculation




Source: Fendrich et al. (2022). Scenario EL: Scenario 1; Scenario PL: Scenario 2.

The new proposed equation for the ITR tax rate is represented in equation 2:

$$\text{tax rate} = \alpha_1 + \left(\frac{\text{available area}}{\text{taxable area}}\right) * \left(\alpha_2 * f(available\ area)\ +\ \alpha_3 * (1 - \text{GU})\right) \quad (2)$$

Where $\alpha_1$,$\alpha_2$ and $\alpha_3$ represent the minimum tax rate on natural area surpluses, the progressiveness of productive areas, and penalties for unproductive farms, respectively. The function is positive, continuous, and monotonically increasing. Fendrich et al. (2022) used the alpha parameters as $\alpha_1 = 0.2\%$, $\alpha_2 = 0.025\%$, $\alpha_3 = 3.00\%$ and $f(available\ area) = \frac{\min(1000;\ available\ area)}{50}$.

The $\alpha_1$ applies to the entire taxable area. For properties with a native vegetation deficit, reforestation reduces the taxable area, while surplus vegetation incentivizes permanent conservation, lowering the tax by reducing the taxable area.

The $\alpha_2$ influences the available area up to a maximum limit. It is calculated by multiplying the ratio of taxable area to total area and the minimum value between 20 and the available area divided by 50. This coefficient penalizes properties with larger available areas, increasing the ITR tax amount.

The $\alpha_3$ affects the Utilization Rate (GU), which is the ratio between the effectively used area and available area, including buildings, agricultural areas, and pastures. For pastures, minimum stocking rates are applied. $\alpha_3$ penalizes lower productivity by multiplying the taxable-to-total area ratio with (1 - GU).

The minimum productivity requirement for cattle per hectare on pastureland was updated using municipality-level data, with a threshold at the 40th percentile. A t-distribution was applied to adjust for potential biases in regions with fewer municipalities. Lastly, minor updates were made for Forest Code compliance, and the minimum tax charge was increased from BRL 10 to BRL 50.

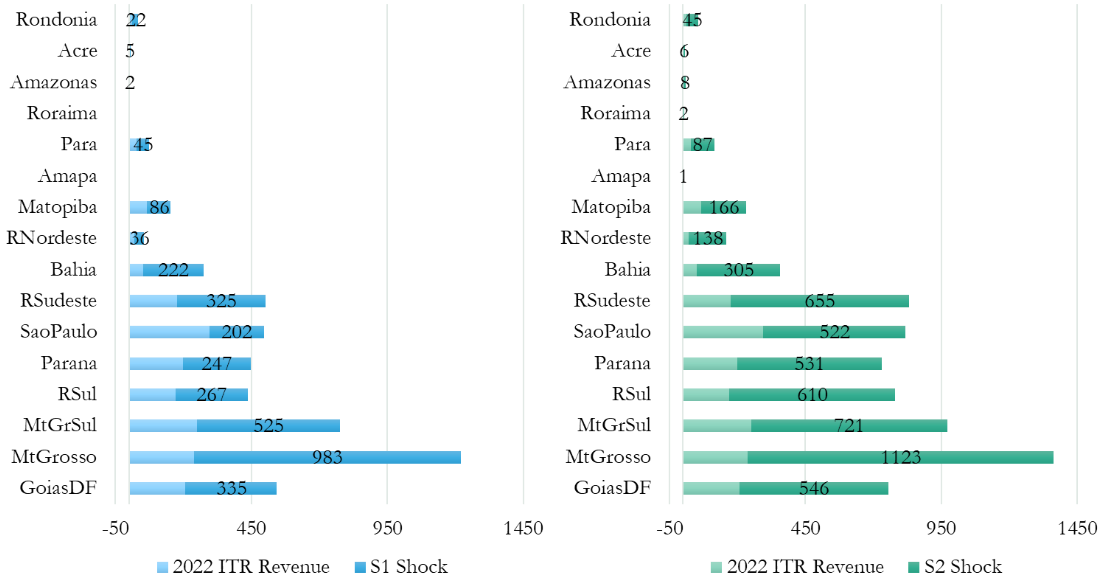
#### 4.2.2.4. ITR Scenarios for the TERM-BR policy shocks

The spatial modeling generated ITR revenue estimates at the property level, which were aggregated into the 16 regions of the TERM-BR model. Using the implicit GDP deflator, the data were then adjusted to 2015 constant prices, the model's base year. We calculated the difference between observed ITR revenue and simulated revenue under Scenarios 1 and 2, identifying these differences as policy shocks for 2022, as shown in Figure 6[2] and **Erro! Fonte de referência não encontrada.**.

In 2022, the BAU scenario recorded R$ 1.7 billion in ITR revenue (2015 prices). Under Scenario 1, revenue reached R$ 5.0 billion, a 191.3% increase of R$ 3.3 billion. Scenario 2 projected R$ 15.4 billion in revenue, a R$ 13.7 billion increase. However, the nearly 800% change caused convergence issues in the model, making it unfeasible. To resolve this, a 40% adjustment was applied to the difference from the BAU scenario (R$ 13.7 billion), resulting in a total revenue of R$ 7.2 billion, a 316.7% increase (Figure *8*).

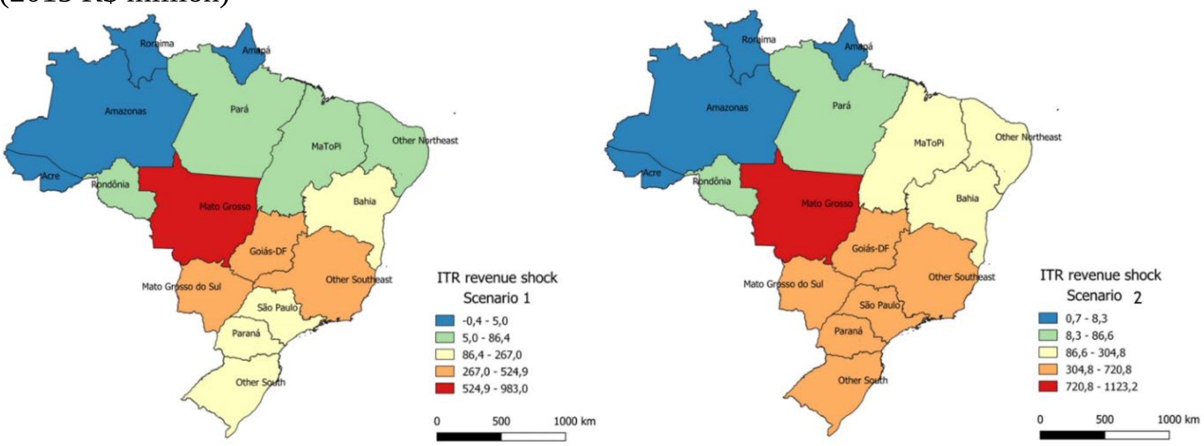
[2] It is important to note that the real price declines in tax revenue observed under Scenario 1 for Roraima and Amapá are treated as zero.

Figure 6. ITR revenue policy shocks in 2022, Scenario 1 and 2 (2015 R$ million)




Source: authors.

Figure 7. Regional representation of the ITR revenue policy shocks in 2022, Scenario 1 and 2 (2015 R$ million)

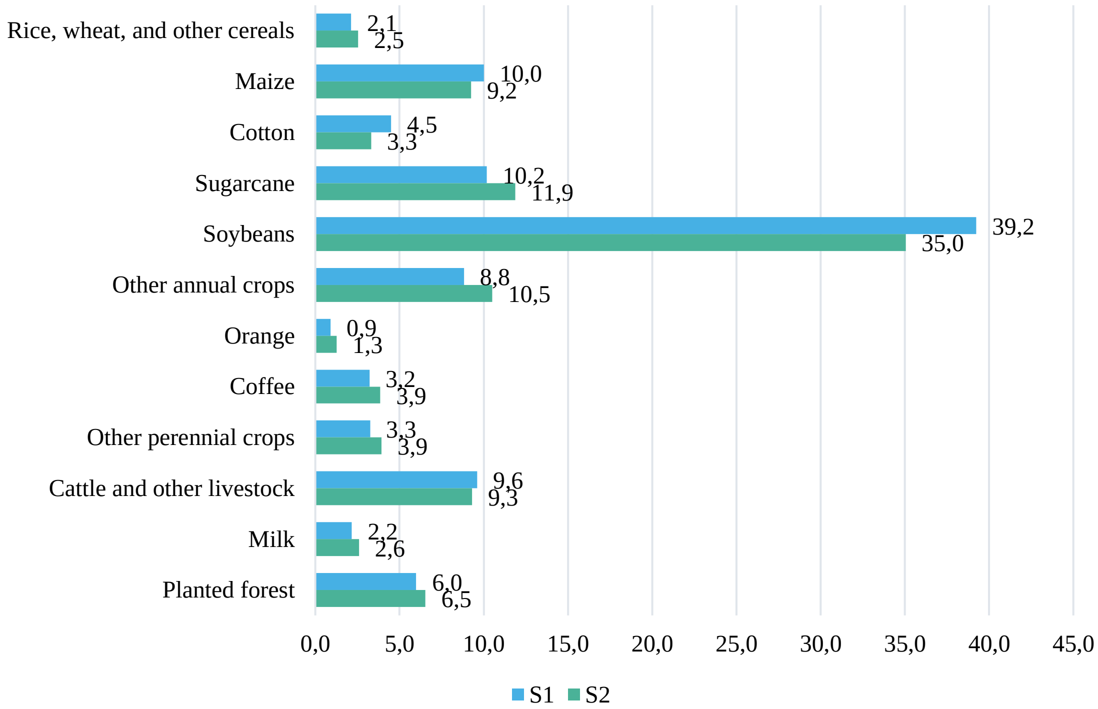



Source: authors.

Under both scenarios, regions such as Rondônia, Acre, Amazonas, Pará, Amapá, MaToPi, and the Other Northeast combined accounted for less than 8.5% of the revenue increases. In Scenario 1, the Mid-West (Mato Grosso, Mato Grosso do Sul, and Goiás-DF) accounted for 55.8% of the revenue growth, with Mato Grosso representing 29.8%. In Scenario 2, the Mid-West's share decreased to 43.8%, with Mato Grosso's contribution dropping to 20.5%.

Regarding the distribution of ITR revenue across agricultural goods (Figure 8), we allocated regional revenue increases proportionally to each industry's share of land rents. Consequently, the differences between Scenarios 1 and 2 stem from variations in regional distribution in agricultural and livestock activities. Most of the tax increase will be borne by soybean farmers, sugarcane, maize, other annual crops, and cattle ranchers. Together, these industries account for over 75% of the tax burden in both scenarios.

Figure 8. Agriculture industries percentage share in ITR revenue policy shocks




Source: authors.

## 5. Results and Discussion

### 5.1. ITR revenue impacts

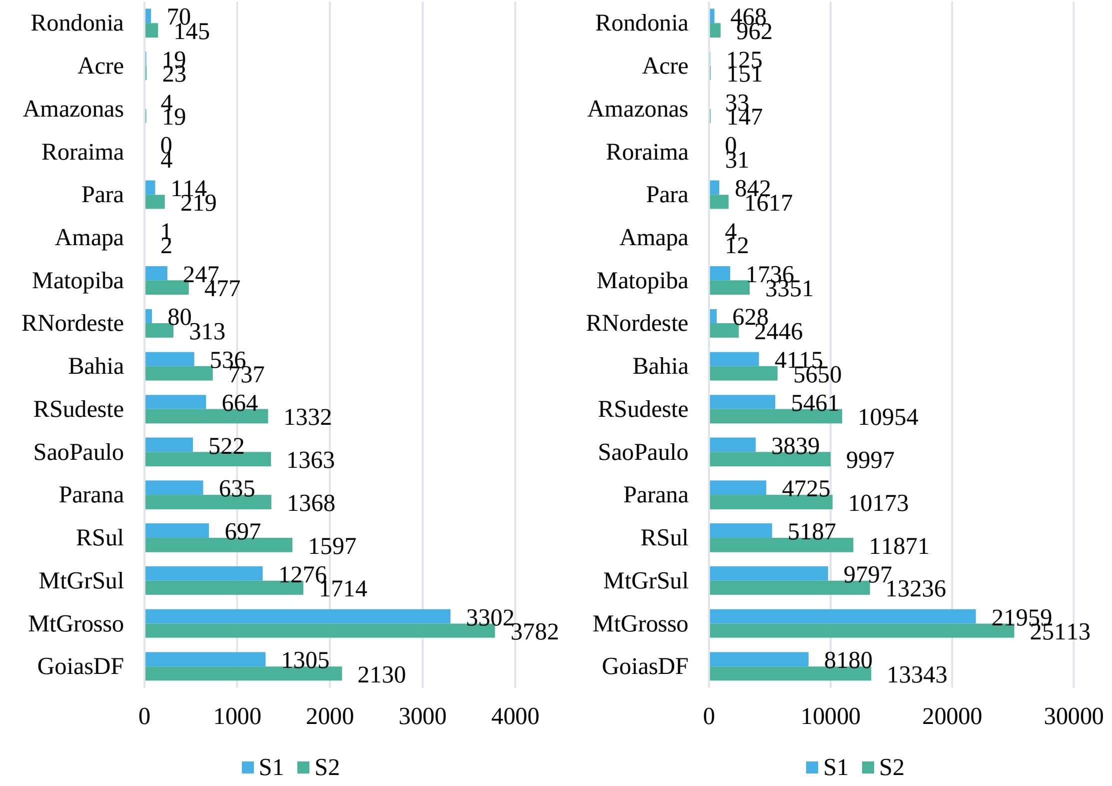
The policy shocks applied in 2022 led to adjustments in the ITR tax rate, influencing tax revenue from 2023 to 2030. As a result, in 2030, Scenario 1 shows a national difference of R$ 9.5 billion from the 2030 BAU scenario (in 2023 prices), while Scenario 2 shows a R$ 15.2 billion increase (also in 2023 prices). The accumulated difference in ITR revenue between Scenarios 1 and 2 and the 2022-2030 BAU is R$ 67.1 billion and R$ 109.0 billion (in 2023 prices), respectively.

The annual ITR revenue increase would surpass the rural credit allocated to low-carbon agriculture under the Safra Plan for 2024/2025, which amounts to R$ 7.7 billion. Note that the equalization subsidies tied to this credit would be lower than the total resources, meaning ITR revenue could be redirected to increase resources for promoting sustainable agricultural practices.

Subnational tax revenue registered proportional increases in line with the policy shock ratios, as shown in

Figure 9. Notably, in 2030, the regions of Mato Grosso, Goiás-DF, and Mato Grosso do Sul would contribute approximately R$ 5.9 billion in Scenario 1 and R$ 7.6 billion in Scenario 2 to the increased revenue, compared to the 2030 BAU.

Figure 9. Simulation results, ITR revenue difference from the 2030 BAU (2023 R$ million) [A], and accumulated difference 2022-2030 (2023 R$ million) [B]




Source: authors.

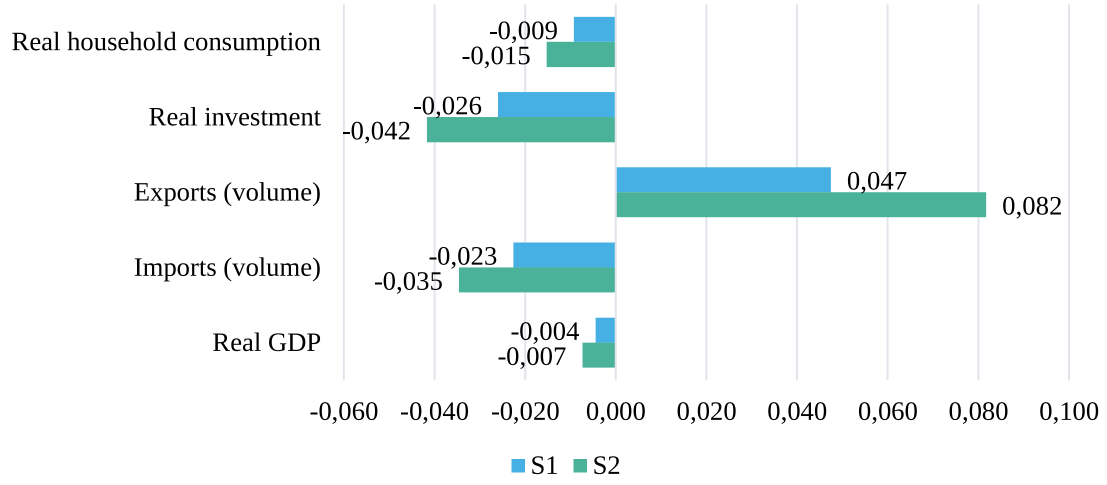
## 5.2. National impacts

The increase in rural land tax leads to a decline in land rents, discouraging land use for agriculture and prompting substitution with capital and labor, competing with other sectors' use of primary factors. This shift reduces agricultural output, triggering a cascading effect on related sectors and ultimately depressing overall economic activity. The accumulated percentage differences in real GDP and household consumption compared to the 2030 BAU scenario are projected to be 0.004% and 0.009% in Scenario 1, and 0.007% and 0.015% in Scenario 2, respectively (Figure 10).

Starting in 2022, these economic impacts result in accumulated reductions in household consumption of R$ 3.4 billion to 5.8 billion (in 2023 prices) and a decrease in GDP of R$ 2.2 billion to 3.7 billion relative to the BAU. Compared to the projected increase in ITR revenue (from R$ 67.1 billion to R$ 109.0 billion), the socioeconomic losses in real GDP represent approximately R$ 0.03 for every R$ 1.00 of ITR revenue in both scenarios.

The trade balance is expected to improve, with exports increasing by 0.047% and 0.082% in Scenarios 1 and 2, respectively, and imports decreasing by 0.023% and 0.035% (Figure 10). This typical outcome of reduced economic activity lowers domestic demand, freeing up goods for export while reducing households' capacity to import. While most agricultural exports decline, the depreciation of the exchange rate (0.02% in Scenario 1 and 0.03% in Scenario 2) will boost exports from other industries.

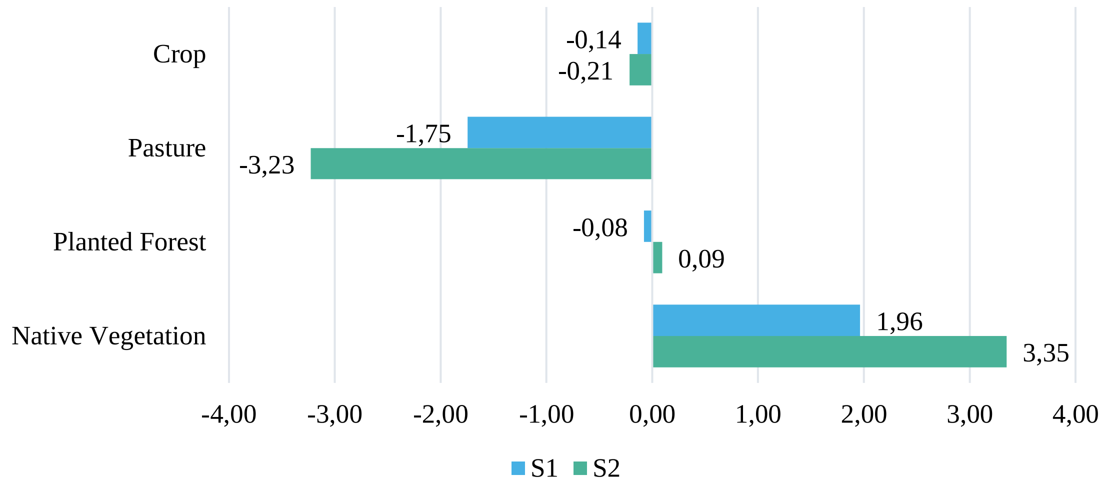
Figure 10. Simulation results, macroeconomic variables accumulated percentage difference from the 2030 BAU




Source: authors.

Decreased land profitability would shift demand towards capital, making agricultural production more capital-intensive. The reduction in agricultural land use, shown in Figure 11, illustrates an accumulated decline in cropland of 0.14 Mha in Scenario 1 and 0.21 Mha in Scenario 2, along with a decrease in the pastureland of 1.75 Mha and 3.23 Mha, respectively, relative to the 2030 BAU. As a result, the changes in ITR policy would prevent deforestation of approximately 1.96 Mha in Scenario 1 and 3.35 Mha in Scenario 2. These figures equate to about R$ 1,100.00 in real GDP losses for each hectare of native vegetation preserved.

Figure 11. Simulation results, land use change accumulated Mha difference from the 2030 BAU

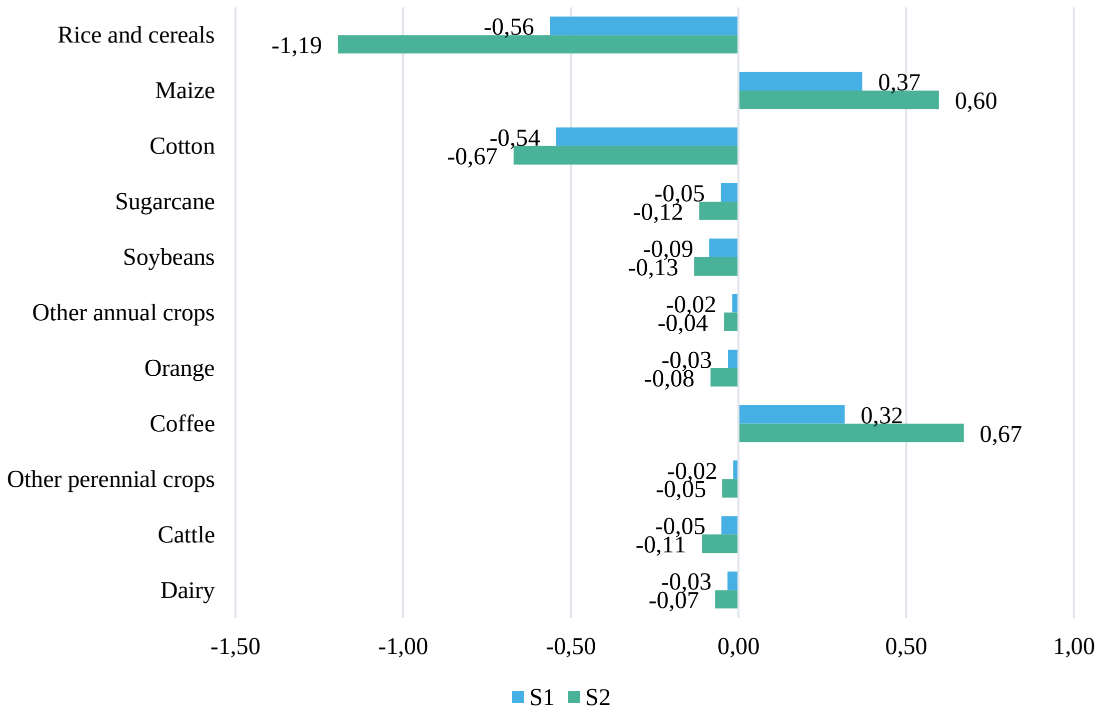



Source: authors.

Avoided deforestation would reduce land-use change GHG emissions by 2.9% in Scenario 1 and 5.1% in Scenario 2, compared to the 2030 BAU scenario. However, total national emissions would decline by 0.64% and 1.12%, respectively. This smaller impact is due to the increasing share of emissions from economic activities and fuel consumption rather than land-use change in recent years.

Despite a greater reduction in pastureland, crop output is more affected by the decline in land use due to their higher land productivity (yield), as shown in Figure 12. Lower agricultural production would raise the food consumer price index by 0.014% in Scenario 1 and 0.024% in Scenario 2.

Figure 12. Simulation results, agricultural output accumulated percentage difference from the 2030 BAU



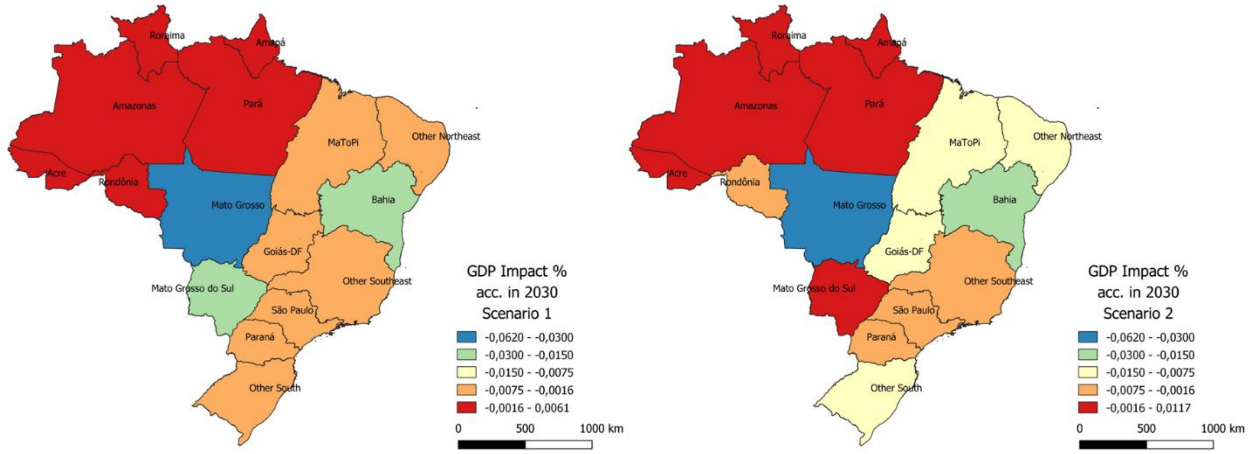

Source: authors.

Maize and coffee benefit from substitution effects, as these crops have some of the highest land productivity. As a result, some of the land freed from pasture is reallocated to these crops, suggesting a shift in land use towards more productive crops under reduced land availability. Additionally, the regional distribution of the shock plays a role. For example, Mato Grosso, experiencing the highest increase in ITR revenue, sees some maize and soybean production shift to Mato Grosso do Sul, which has more available pastureland to transition to crops.

### 5.3. Subnational impacts

Regionally, northern areas, which experienced smaller tax increases, are expected to see a shift in agricultural production, resulting in an increase in real GDP in both scenarios, as shown in Figure 13. The Mato Grosso do Sul region benefits from this shift, particularly through increased soybean production due to reduced cultivated areas in Mato Grosso, leading to positive real GDP growth in Scenario 2. However, there is a concerning decline in economic activity in the Northeast, a region already facing low development and socioeconomic challenges.

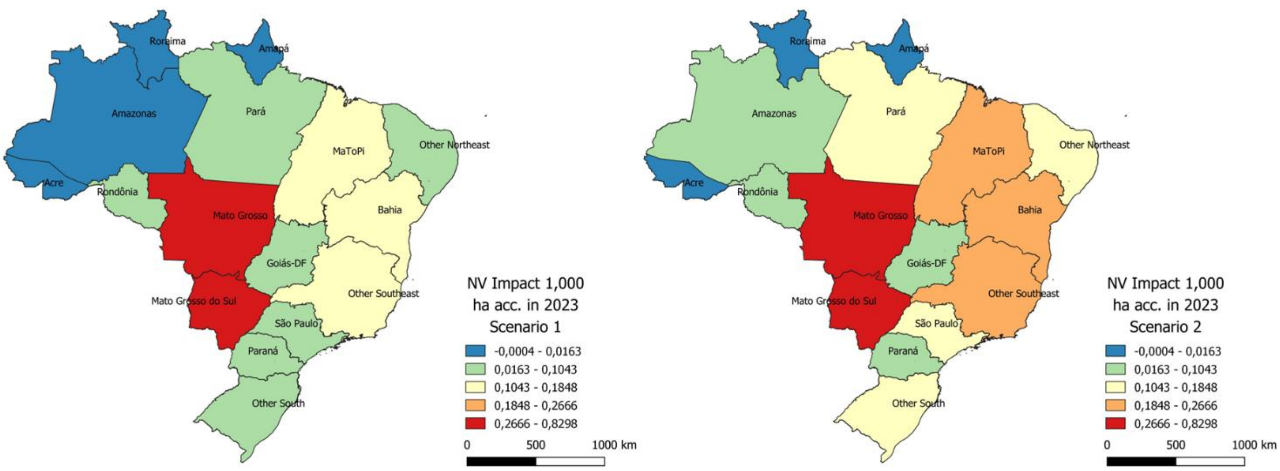
Figure 13. Simulation results, regional real GDP accumulated percentage difference from the 2030 BAU




Source: authors.

Regarding avoided deforestation, most of the impact would occur in regions highly affected by the tax increase, especially in the Mato Grosso region (Figure 14). In contrast, northern regions, which had the lowest tax increases, would experience minimal changes. As a result, the economic instrument designed to curb land-use change would be most effective in biomes like the Cerrado, which hosts a large portion of Brazil's agricultural production. However, its effectiveness would be limited in the Amazon rainforest, where land-use pressures and agricultural production responses differ.

Figure 14. Simulation results, regional native vegetation accumulated Mha difference from the 2030 BAU




Source: authors.

## 6. Final remarks

Using the TERM-BR model, this study assessed the socioeconomic and land-use change impacts of different ITR policy scenarios. The analysis incorporated spatially explicit taxation data, offering a detailed view of regional variations in tax revenue distribution. Our findings show that the tax reform may present distinct regional effects, differing economic losses, and varying levels of policy cost-effectiveness.

Compared to the BAU scenario, the proposed ITR reforms would increase tax revenue, reduce land rents, and lower deforestation incentives, preserving about 2.0 Mha to 3.4 Mha of native vegetation, with estimated GDP economic losses of approximately R$ 1,100.00 per hectare preserved. Additionally, LULUCF emissions would decrease by 2.9% to 5.1%. The reforms would be more effective in curbing deforestation in the Cerrado biome but less so in the Amazon rainforest. The fiscal benefits to economic losses ratio is projected at around R$ 0.03. However, household consumption would decline, and regional income distribution would shift, impacting economically vulnerable regions like the Northeast.

The scenarios highlight the trade-offs between economic activity, land use, and environmental conservation under different ITR policy designs. While higher ITR taxes effectively discourage land-use expansion and reduce emissions, their economic impacts are uneven, disproportionately affecting certain regions and income groups. These findings underscore the importance of designing land taxation policies to meet sustainability goals without exacerbating socioeconomic inequalities.

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