TEEB Agriculture & Food - Brazil

REPORT

IMPACTS OF THE RECOVERY GOALS FOR DEGRADED PASTURES OF THE ABC+ PLAN IN BRAZIL

TEEB AGRICULTURE AND FOOD - BRAZIL

Luiz de Queiroz Foundation for Agrarian Studies – FEALQ

ESALQ

"IMPACTS OF THE RECOVERY GOALS FOR DEGRADED PASTURES OF THE ABC+ PLAN IN BRAZIL"

Report 4: Technical document presenting the final results of the economic, social, and environmental contributions of recovering degraded pastures in Brazil, including recommendations for the ABC+ Plan.

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PRESENTATION

This is the fourth report of the TEEB for Agriculture and Food (TEEBAgriFood) Brazil project, reporting the consolidated results of the socio-economic and environmental impacts of the recovery of 30 million hectares of degraded pastures in Brazil (RDP goals of the ABC+ Plan). Two scenarios are considered (SCE1: in conventional ways - RDP and SCE2: RDP with the use of Crop-Livestock Integration - RDP+CLI), which are compared to a baseline in 2030. The study employs four complementary methodological approaches: (i) economic modeling, (ii) spatial modeling, (iii) biophysical modeling and landscape analysis, and (iv) territorial analysis with a multi-criteria approach.

The introductory Chapter recovers the context for the study, summarizing its background and defining its objectives. Chapter 2 brings a note on the organization of the results, including a Summary Table of the evaluated elements and a list of questions that guided the study, divided into three dimensions of impact: economic, social, and environmental. Chapter 3 provides the results in these three dimensions, starting with the results of the Computable General Equilibrium Model - CGE (section 3.1) regarding the effects of policy on macroeconomic aggregates (changes in real GDP, real investment, trade balance, among others) and in the production of economic activity sectors, followed by the effects on income, employment, product prices, and household consumption (section 3.2).

Section 3.3 focuses on presenting the environmental dimension results, with section 3.3.1 showing the effects of pasture recovery on land use transition rates obtained through both the CGE (3.3.1.1) and spatial modeling (3.3.1.2). Section 3.3.2 gives the effects of RDP on Greenhouse Gas (GHG) emissions, obtained through the CGE model. Section 3.3.3 presents the results of landscape analysis, which shows the effects of the two scenarios on habitat maintenance services. Section 3.3.4 addresses where the policy should possibly focus, based on territorial analysis with a multi-criteria approach. These results serve as the basis for the next section (3.3.5), which shows the effects on soil erosion rates obtained through biophysical modeling.

Chapter 4 contains recommendations for improving the ABC+ Plan, based on contributions gathered both from the Committees and from other sources, such as field immersions - carried out between late July and early August 2023 (in Mato Grosso and Pará), which added to a better understanding of regional specificities in terms of the recovery of pastures (RDP and CLI) and for understanding the initiatives of state governments – and for the knowledge of recommendations gathered in bilateral meetings with key stakeholders, such as members of academia, civil society, public officials, and the private sector.

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1. INTRODUCTION

1.1 TEEBAgriFood Initiative

TEEB Agriculture & Food (TEEBAgriFood) is an initiative of the United Nations Environment Programme (UNEP) aimed at developing integrated analyses of eco-agri-food systems. These analyses are based on the identification and measurement of impacts and dependencies between natural, human, produced, and social capitals in agricultural and food systems to generate relevant information for decision-making in public policies. The initiative arose from the perception that many current assessments of agricultural and food systems are partial and overlook important relationships with the economy, society, the environment, and health, leaving out broader issues of sustainability and equity (externalities)[1].

In terms of the TEEBAgriFood Project, it is not possible to reflect on a governance process that leads to the common well-being of society without recognizing its interdependence with the environment, biodiversity and the services it provides to society. Likewise, we must aspire to a development model that recognizes these interactions between society, the economy and nature. In addition, the main issues that require consensus-building to guide decision-making on a given public policy are closely related to how biodiversity and ecosystem services, which underpin all productive, economic and well-being processes, are accessed, used, and managed.

TEEBAgriFood has been financed by the European Union Partnership Instrument (EU PI) and has been implemented in several countries, such as China, India, Indonesia, Mexico, Malaysia, and Thailand. In Brazil, two major themes are being prioritized by TEEBAgriFood:

[1] On certain occasions, the consumption or production of a particular good or service can generate side effects, either positive or negative, known as externalities or external economies. (...) The price system loses the ability to guide society in allocating the scarce resources because private benefits and costs start to differ from social benefits and costs, which are the 'true' ones from the collective perspective. It is precisely this difference that is no longer taken into account or internalized by market prices, hence the name externality. In this case, society will experience a loss, a deadweight, as the social costs associated with the quantity transacted in the market will exceed the social benefits derived from the consumption of that quantity (Vasconcellos, p. 101, 2015)

urban and peri-urban agriculture and low-carbon agriculture. The latter is the focus of this study, along with the Ministry of Agriculture and Livestock and Food Supply (MAPA) as the partner, and the policy to be evaluated is the Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low-Carbon Economy in Agriculture (ABC+), specifically the technology for the recovery of degraded pastures (RDP).

1.2 Objectives

The general objective of the study is to analyze the socioeconomic and environmental impacts of the goals for the recovery of degraded pastures (RDP) outlined in the ABC+ Plan in Brazil.

Specific objectives:

- Using the TEEBAgriFood approach (Evaluation Framework) as a basis, build an integrated method involving economic, spatial, and biophysical modeling that indicates how the recovery of degraded pastures results in economic, social, and environmental impacts and alters flows (e.g., ecosystem services and waste);
- Evaluate the socioeconomic and environmental impacts and flows generated by the adoption of RDP technology, considering conventional pasture recovery, and the adoption of Crop-Livestock Integration (CLI);
- Compare the results of different scenarios of adopting the recovery of degraded pastures (as outlined in the ABC+ Plan goals) with the business-as-usual (BAU) scenario in Brazil;
- Consult, discuss, and incorporate suggestions from the Technical and Directive Committees on methods, data, scenarios, and results obtained throughout the study development process;
- Disseminate partial and final results to key stakeholders involved in the implementation of the ABC+ Plan to generate recommendations and help the improvement of the policy and the promotion of sustainability in agricultural production and environmental conservation.

The study is structured into four Reports, with the first two dedicated to the development, discussion, improvement, and consolidation of the methodology to be used to achieve the objectives. It is important to emphasize that, being a complex study involving various fronts, limitations, contours, and methodological solutions were extensively discussed within the Technical and Directive Committees, either through regular meetings or through the bilateral discussions with different experts. Report 3 presented the preliminary results, and this document (Report 4) is the consolidated version of the results.

Box 1: RDP and CLI Technologies

RDP involves a direct process of pasture recovery through the application of agronomic practices with varying levels of intervention. This ranges from improving soil cover and the vigor of existing forage plants through management techniques and fertilization to the complete restoration of an area through soil turning, chemical amendment, and sowing where more conservative interventions are insufficient. The CLI is an indirect form of pasture recovery that involves the use of temporary crops in intercropping or rotation with forages (Zimmer *et al*., 2012). The implementation of RDP or CLI depends on a series of edaphoclimatic, biophysical, social, and economic factors. The context of RDP presents a system with fewer components and processes, focused exclusively on livestock activity. However, under favorable physical conditions and in regions with better access to infrastructure, local agricultural production, and fewer technology access restrictions, the integration of elements into these production systems (such as annual crops) may be feasible. The crop-livestock integration can occur in a way that emphasizes agriculture (cropping), using pastures as a crop rotation and technique to improve soil quality. Alternatively, pastures can be the main component, using agricultural planting as a means of recovery or silage production for animals, also improving the soil quality (Kichel *et al*., 2014). In this study, the second situation was considered, meaning CLI as a technique for the recovery of degraded pastures.

2. NOTE ON THE ORGANIZATION OF RESULTS AND POLICY RECOMMENDATIONS

This chapter is organized into two sections. In the first (Section 2.1), a review of the TEEBAgriFood Evaluation Framework is provided, which serves as the conceptual and methodological framework for assessing the effects of initiatives (in this case, the recovery of degraded pastures from the ABC+ Plan). Following that, a Summary Framework is presented, outlining the elements of the Evaluation Framework selected for discussion in this study (Section 2.1.1). Section 2.1.2 explains how the study results are organized in Chapter 3. Section 2.2 details the sources of contributions that will form part of the recommendations for the improvement of the ABC+ Plan.

2.1 Presentation of Economic, Social, and Environmental Impacts

2.1.1 TEEBAgriFood Evaluation Framework

To generate and visualize the interrelationships among components of eco-agri-food systems that are generally invisible, TEEBAgriFood developed a structured assessment approach, the Evaluation Framework, based on a conceptual and methodological framework that allows for the recognition and measurement of positive and negative impacts across value chains on social, environmental, and economic spheres. With it, TEEBAgriFood seeks to compare current food systems with other promising ones and assess the impacts of scenarios representing the implementation of actions, policies, or other initiatives against a scenario of non-implementation (business-as-usual - BAU).

Much of the effort in applying the TEEBAgriFood Evaluation Framework in this study focused on understanding the results and impacts of the scenarios aimed at achieving the goals assumed by ABC+ for the RDP technology (30 million hectares of pasture recovered by 2030 in Brazil). The study also examined to what extent the goals and geographical focus of the Plan can be refined to produce synergy effects and positive effects for people and nature. It is essential to note that any methodology chosen for evaluating results and impacts has limitations. This is also the case of this study, which, for the application of the TEEBAgriFood Evaluation Framework, relies heavily on modeling (economic, spatial, biophysical, and landscape analysis), which in themselves are simplifications of the reality and have their own contours in terms of applicability. It is crucial to emphasize that the application of the TEEBAgriFood Evaluation Framework in the context of this study has the virtue of allowing comparison with other studies being conducted under this approach in other countries, strengthening its adoption by sector managers and stakeholders as a powerful tool for decision-making.

Structurally, the Evaluation Framework (Image 1) is divided into four fundamental components:

(i) Identification and characterization of <u>**capital stocks**</u> (produced capital, natural capital, human capital, and social capital): **The natural capital** represents "the limited stocks of physical and biological resources found on Earth and the limited capacity of ecosystems to provide ecosystem services" (TEEB 2010, p. 33)[2]. In the case of this study, natural capitals include, for instance, soil, native vegetation cover, and the pastures (the object of intervention in the ABC+ Plan). **Human capital** refers to "the knowledge, skills, competencies, and attributes embodied in individuals that facilitate the creation of personal, social, and economic well-being". In this study, the used methods made it possible to analyze of the effect of the policy on the wage bill of workers. **Produced capital** or manufactured capital comprises man-made goods and financial assets used in production and services. Here these capitals will be analyzed in terms of change caused by the policy on real investment and the intensity of capital factor use by economic sectors, especially livestock (beef and dairy). Finally, the **social capital** is made up of networks formed between individuals, as well as shared norms, values and understandings, which make it easier the cooperation within or between groups, and enable the production and allocation of other capitals (UNU-IHDP and UNEP 2014)[3]. The social capital is addressed here through the analysis of the territorial incidence of the policy, i.e., the profiles of rural producers who are likely to adopt the technology and where they are located.

(ii) **Flows** resulting from the change of these stocks: the types of flows are: (a) **Inputs purchased in production** that include labor, intermediate goods used in production, and labor inputs. In this study, the computable general equilibrium model general used (TERM-BR) allows evaluating the variance in the quantity produced and the use of inputs by all economic sectors by comparing the result in the policy application scenario in relation to the baseline or BAU; (b) **Agricultural and food production**: this type of flow is economically visible as it encompasses the results of farms

[2] The Economics of Ecosystems and Biodiversity (TEEB). A economia dos ecossistemas e da Biodiversidade: Integrando a economia da natureza: uma síntese da abordagem, conclusões e recomendações do TEEB. (2010)

[3] United Nations University - International Human Dimensions Programme and United Nations Environment Programme (UNU-IHDP and UNEP) (2014). Inclusive Wealth Report 2014: Measuring progress toward sustainability: Summary for Decision-Makers. Delhi.

in agricultural production and the added value of food processing and distribution. In this study, these are flows related to agricultural and food production, the differential productivity between non-degraded and degraded pastures[4] (TERM-BR model input), agricultural production, GDP, real income, and changes in the trade balance (outputs of the TERM-BR model). Note that other research which assessed the impacts of RDP has already contributed to evaluate this flow. However, the present study brings assessments at the landscape level as differences, such as analyzes regarding ecosystem services; (c) **Ecosystem services**: contributions of ecosystems to human well-being, such as carbon sequestration, maintenance of habitats and services related to water and soil. According to The Common International Classification of Ecosystem Services (CICES)[6] they are divided into provisioning, regulation and maintenance, and cultural services[7]. The ecosystem services considered in this study refer to the agricultural production phase, i.e., they do not extend to other links in the value chain. Among them are the maintenance of habitats, carbon fixation (with consequent mitigation of net GHG emissions) and the control of critical erosion processes (erosion avoided). It is noteworthy that metrics of landscape, such as area of native vegetation, size of fragments and functional connectivity[8] between fragments are indicative (proxies) of habitat maintenance,

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[4] Non degraded pastures have a higher animal support capacity than degraded ones, allowing a higher level of productivity to be achieved, represented by the gross production value per hectare in livestock farming.

[5] CICES (Common International Classification of Ecosystem Services) webpage (2018). The Common International Classification of Ecosystem Services (CI-CES). https://cices.eu/.

[6] In Portuguese "Common International Classification of Ecosystem Services (CICES)" was developed based on environmental accounting work carried out by the European Environment Agency (EEA). Please access it at: https://cices.eu/

[7] The CICES classification differs slightly from the classification of ecosystem services described in Law No. 14,119, of 13th January, 2021 (Law on Payment for Environmental Services). This Law classifies services into the following modalities: a) **provision**: those that provide environmental goods or products used by humans for consumption or commercialization (e.g.: water, food, wood, fibers and extracts, among others); b) **support**: those that maintain the perpetuity of life on Earth (e.g.: nutrient cycling, waste decomposition, production, maintenance or renewal of soil fertility, pollination, seed dispersal, control of populations of potential pests and potential vectors of human diseases, protection against ultraviolet solar radiation and the maintenance of biodiversity and genetic heritage); c) **regulation**: those that contribute to maintaining the stability of ecosystem processes (carbon sequestration, air purification, moderation of extreme weather events, balance maintenance in the hydrological cycle, minimization of floods and droughts, and control of critical processes of erosion and slope sliding); d) **cultural**: those that constitute the non-material benefits provided by ecosystems, through recreation, tourism, cultural identity, spiritual and aesthetic experiences, and intellectual development, among others.

[8] Connectivity that incorporates information about the observed or potential movement properties of an organism (Fletcher and Fortin, 2018).

which is an indicative of biodiversity maintenance. It is worth mentioning that biodiversity, in itself, is not considered an ecosystem service in the TEEBAgriFood[9] approach, but the maintenance of habitats is, as it generates benefits to human well-being by providing the necessary conditions to sustain populations of species that people use or enjoy them; (d) **Waste flows**: according to the System of Environmental Economic Accounting - Experimental Ecosystem Accounting (SEEA-EEA[10]), waste is “flows of solid, liquid and gaseous materials and energy, which are discarded, discharged or emitted by establishments and families through processes of production, consumption or accumulation”. In the case of this study, the residual flows evaluated are GHG emissions[11].

(iii) **Results** or changes (qualitative or quantitative) in the extent of capital stocks – produced, social, human, and natural - due to value chain activities;

(iv) **Impacts** (positive or negative) on one or more dimensions of human well-being (environmental, economic, social, and individual health).

Summarizing the Evaluation Framework (Image 1) in the context of this study, in which the main guiding question is "What are the socio-economic and environmental impacts of recovering degraded pastures in Brazil?", we can take Brazilian livestock farming as a basis on pasture. Within the scope of the Evaluation Framework, it is understood that pasture-based livestock farming depends, for example, on natural capital (soil, water) to be viable (pasture production) and to generate food production flows (meat and milk) that benefit in multiple ways the actors involved in the different stages of the value chain.

Depending on how the chain expands (occupies new areas) and how pastures are managed, positive impacts can be observed on ecosystem services (greater soil conservation under well-managed pastures, for example), or otherwise, losses in natural capital (loss of native vegetation, loss of soil and its fertility) can be generated, with negative consequences for the ecosystem services of food provision, erosion regulation, habitat maintenance and climate regulation, resulting in adverse impacts on human well-being. These impacts, in turn, can be considered from an environmental (e.g. global warming), economic (e.g. increase or decrease in GDP), social and human point of view (e.g. increase or decrease in household wages, income, and consumption).

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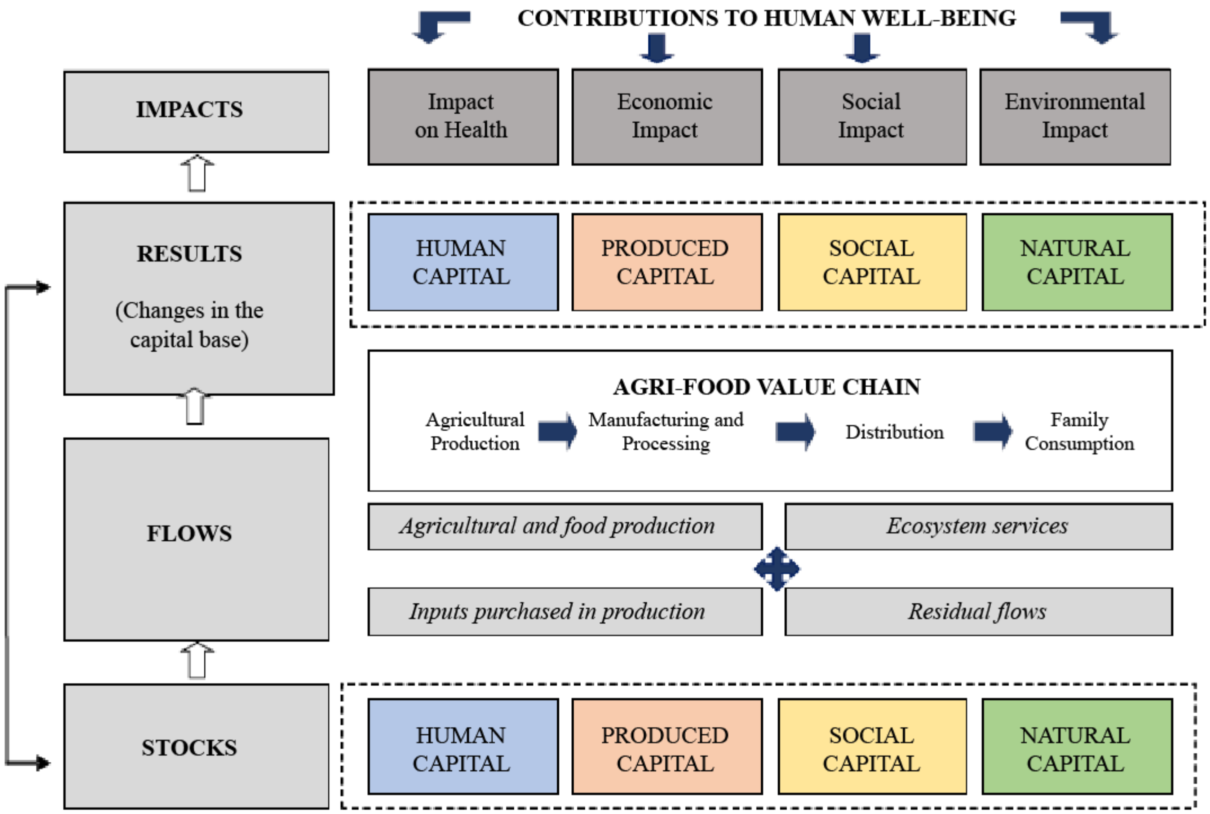
[9] In TeebAgrifood's conception, biodiversity at all levels (ecosystem, species, genetics), both in terms of quantity and variability, is considered a key characteristic of natural capital. It supports the functioning of the ecosystem.

[10] https://ec.europa.eu/eurostat/documents/3859598/6925551/KS-05-14-103-EN-N.pdf/b340ff65-4d00-417b977f2dd9a0220717?t=1437481884000

[11] The model incorporates all sources of emissions related to cattle herds presented in Brazil's emissions inventory.

Image 1 – Capital stocks, flows, outcomes and impacts that make up the TEEBAgriFood Assessment Framework



Source: adapted from TEEB, 2018.

Depending on the public policy/action/initiative to be analyzed, not all the elements that make up the Evaluation Framework are considered. On the contrary, part of the evaluation process is to select the most relevant ones to answer certain guiding questions. The choice of which elements would be covered in this study was based on the following assumptions:

(i) As one of the main and most comprehensive policies of the Brazilian government to tackle climate change, the **ABC+ Plan advocates important changes in land use** due to the intensification of agriculture, **with results and impacts that go beyond the geographical limits** of its application**. The greater the number of impacts forecast for the next policy cycle (2020-2030), the greater the subsidies provided for redirection, adjustments, and prioritization of actions by the policy manager**. These results or impacts can be of an economic, social, and environmental nature. Thus, **methodologies and databases that provide these types of information and can be applied on a national and state scale** (given that decision-making for the Plan is made at this scale) **were considered when choosing the elements of the Evaluation Framework** to be addressed;

(ii) **It is extremely important to analyze the spatiotemporal dimension of policies of this nature**, i.e., policies that operate by clearly altering the rural space and have a differentiated impact on the territory. **This type of approach is still a gap** to be filled in policy impact assessment studies. However, there are currently tabular and geo-referenced databases, combined with multidisciplinary methodologies, which make it possible to advance in this type of analysis. Therefore, the choice of the elements of the **Evaluation Framework also took into account the availability of data on a scale compatible with the objectives of the study and which could be treated, whenever possible, in a spatially explicit way**, using modeling, geotechnologies and data science.

(iii) Therefore, **the choice of the elements of the addressed Assessment Framework** was, on the one hand, **anchored in the perspective of encompassing as broadly as possible the stocks, flows, results and impacts of the ABC+ Plan (RDP)** and, on the other hand, very strongly **related to the possibilities and limitations imposed by the available databases and methodologies**.

(iv) Finally, it should be emphasized that, as the implementation of the ABC+ Plan (RDP) has a direct impact on the "Agricultural Production" link in the eco-agri-food chain**, a large part of the elements of the Framework addressed in the study are related to this link or reflect possible changes in the initial conditions of rural space as a result of the policy**. This is important, as it provides managers with more promising locational alternatives for implementing the policy.

Table 1 summarizes the elements selected within the TEEBAgriFood Evaluation Framework that will be analyzed in the study.

Table 1. Summary table of the elements to be assessed in the study, their relationship to the TEEBAgriFood Assessment Framework and the guiding questions for the study

Components of the TEEBAgriFood Assessment	Subdivision of the components	Elements that make up the TEEBAgriFood Evaluation Framework	Elements to be evaluated in the study	Guiding questions
	Natural Capital	Soil	Relative analysis of soil loss in the BAU and policy application	How will the policy affect soil loss through erosion?
		Vegetation cover and habitat quality	Native vegetation cover, pasture, agriculture and planted forests (land use transition)	Does the RDP decrease or increase the pressure to open up new areas (deforestation)? Does it free up areas for other uses, such as agriculture? Is there a land-saving effect or a rebound effect? Where do these effects occur?
	Produced Capital	Other	Real investment and demand for capital (model provides information in aggregate form, so it is included under "other")	Does RDP lead to changes in investment and in the intensity of the use of capital by economic sectors, especially livestock?
	Human Capital	Other	Wage bill	What effect will the policy have on the wage bill of workers?
	Social Capital	Access to technology/productive concentration	Profile of producers adopting the technology	Where is the RDP policy likely to affect? (producer profile)

Components of the TEEBAgriFood Assessment	Subdivision of the components	Elements that make up the TEEBAgriFood Evaluation Framework	Elements to be evaluated in the study	Guiding questions
Flows		Food security	Household consumption,food prices	What effect does the DPO have on the food security of Brazilian families? Do families have access to more food at better prices?
		Agricultural and food production	Differential productivity, Livestock production	What is the differential productivity achieved by producers when they improve the quality of their pastures after adopting RDP? How much does RDP increase or decrease livestock production (meat and milk)?
	Output from agricultural production	Income	GDP, real income, trade balance (treat as separate boxes)	What effect does the RDP have on macroeconomic variables (GDP, real income, exports, imports)?
		Labor income	Real household wages	Does the application of the RDP change the real wages of families in the economy as a whole? And only in the agricultural sector?
	Inputs needed for production	Intermediate consumption (inputs needed for agricultural production, such as water, energy, fertilizers, pesticides, animal health and veterinary inputs)	Inputs for agricultural production (quantity) Inputs for agricultural production (costs)	Does the application of the RDP change the quantity and costs associated with the inputs needed for production?
	Ecosystem services	Provision	Agricultural production, production of renewable resources	How much does the RDP increase or decrease the production of agricultural and renewable products (meat, grains, fiber, wood, etc.)?

Components of the TEEBAgriFood Assessment	Subdivision of the components	Elements that make up the TEEBAgriFood Evaluation Framework	Elements to be evaluated in the study	Guiding questions
		Regulation and Maintenance	Control of erosion rates, climate regulation (C fixation in the soil), maintenance of habitats (landscape metrics - area of native vegetation, size of fragments and functional connectivity)	Does the recovery of degraded pastures via RDP and CLI result in less soil erosion? Does the adoption of the technology contribute to C fixation in the soil? Does the adoption of the technology contribute to the maintenance (quantity and quality) of habitats?
		GHG emissions	GHG emissions for 38 products and emissions intensity (emissions per unit of product)	What is the effect of RDP on GHG emissions between the different sectors of the economy, especially in the livestock sector (beef and dairy)? Are there changes in the intensity of emissions (GHG per product)?

Captions	(green)	Descriptive (qualitative) information
	(yellow)	Quantitative information
	(blue)	Monetizable" information

2.1.2 Presentation of impacts

It is important to mention that tackling the study's central methodological problem - generating information to show how the four capitals covered by the TEEBAgriFood Evaluation Framework[12] (natural, human, social and productive) are transformed by the introduction of the policy - was extremely challenging and required a multidisciplinary approach, since there is no pre-established method that allows for a comprehensive and spatially explicit analysis of the complex relationships between the capitals and flows generated by the application of a policy such as ABC+. It was therefore necessary to generate, make compatible and integrate different sets of data, based on an integrated methodology that would shed light on the possible trade-offs and synergies between them in the face of the adoption of RDP and CLI.

This challenge imposed certain methodological choices, all presented and discussed with the Technical and Steering Committees and detailed in Report 2 of this study, which sought to provide a wide range of guiding answers for refining the policy, but within a space-time and thematic cut-off. In summary, it can be said that the solution envisaged for the project was to develop it on 4 fronts: (i) economic modeling, (ii) spatial modeling, (iii) biophysical modeling and landscape analysis and (iv) territorial analysis with a multi-criteria approach, integrated based on an analysis of 2 future scenarios (up to 2030) for applying the policy (SCE1: RDP via conventional systems and SCE 2: RDP partially recovered via iLP) which are compared to a baseline (trend to be followed if the policy were not implemented, also in 2030, or Business as Usual - BAU). The simulation methodologies for scenarios 1 and 2 were detailed in Product 2, items 3.2.1 to 3.2.3. These 4 methodological fronts provide answers to guiding questions that cover the impacts of the policy in three dimensions: Economic, Social and Human and Environmental. It must be stressed that the same methodological front can provide answers to questions from different dimensions. As a didactic solution that is more in line with the conceptual and methodological framework of TEEBAgriFood, we decided to present the results organized by dimension rather than by methodological front. Image 2 shows a schematic summary of the way the study's findings were presented.

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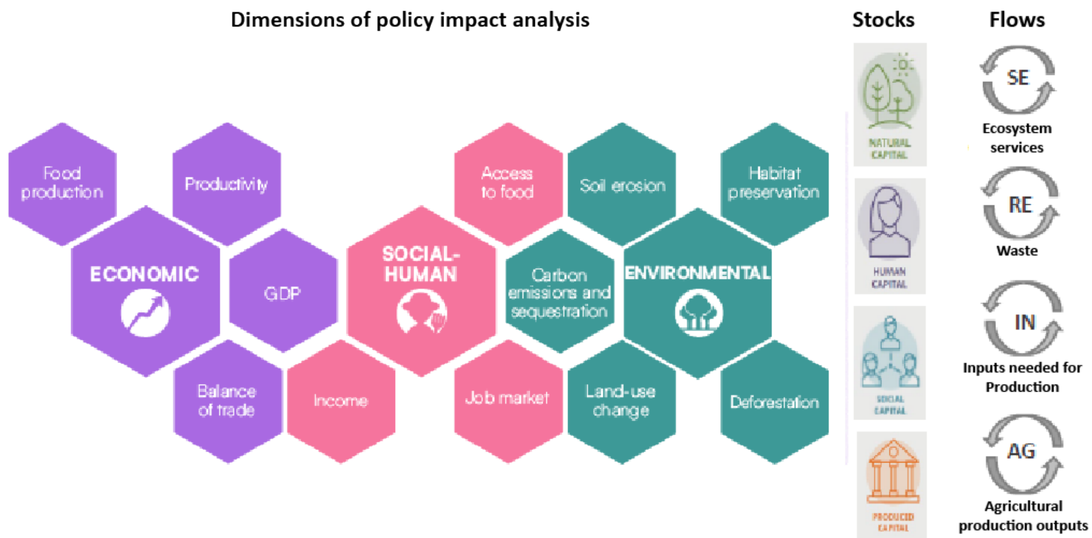
[12] Please see "Synthesis Report - TEEB Agriculture & Food".

Image 2 - Schematic summary of how the results of the study were presented: 3 dimensions of analysis, icons for representing stocks and flows and guiding questions



Source: Own elaboration

Chapter 3 is structured as follows: (i) presentation of the guiding questions for each dimension (Economic, Social and Human, and Environmental), relating them to the components of the assessment framework (Stocks and Flows); (ii) presentation of the expanded analysis of the modeling results; and (iii) review of the questions and conclusion with the answers, presented in a brief and objective way.

2.2 Recommendations for the ABC+ Plan

The study's recommendations are currently being drawn up and are based both on the results of the 4 methodological fronts and the literature review as well as on contributions from various key players gathered at different times throughout the study: field immersions carried out in the states of Pará and Mato Grosso, meetings with the Technical and Steering Committees, bilateral meetings with members of academia, civil society, public authorities and the private sector, and other events. These recommendations will be included in Chapter 4 of this report and the ultimate proposal is to organize them into two blocks.

The first block will be thematic and will provide information and recommendations on the gaps identified in the implementation of the ABC+ Plan's goal of recovering 30 million hectares of degraded pastures. The topics covered include Technical Assistance and Rural Extension (access to assistance for producers, especially family farmers; training for technicians so that they can encourage producers to adopt and apply the technology; among others), Credit/Financing (access to credit, mechanisms and means of credit, methods for credit accounting dedicated to the ABC+ Plan, among others), Research, Land Regularization, etc.

The second block will present structural points so that the Plan can be implemented effectively and efficiently: integrating the Plan with other government sectoral projects such as the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) and Action Plan for the Prevention and Control of Deforestation and Wildfires in the Cerrado (PPCerrado), for example, the importance of an integrated approach to different plans and policies (climate agendas and the fight against poverty and inequalities, for instance), building and/or improving institutional and governance arrangements to make this integrated approach possible, and more.

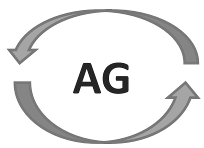
3. IMPACTS OF RECOVERY OF DEGRADED PASTURES IN ABC+ PLAN

3.1 Economic Impacts

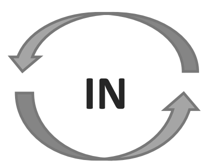
This section contains the simulation results of the TERM-BR Computable General Equilibrium model for the proposed scenarios, considering the achievement of the ABC+ Plan targets: Scenario 1) recovery of 30 Mha of degraded pastures using conventional systems; Scenario 2) recovery of 30 Mha of degraded pastures, of which 24 Mha using conventional systems and 6 Mha using crop-livestock integration (CLI)[13].

The results seek to answer the following guiding questions, which relate to capital stocks and flows in the TEEBAgriFood Assessment Framework

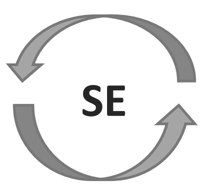
(Image 1):



- What is the differential productivity achieved by producers when they improve the quality of their pastures after adopting RDP?
- How much does RDP increase or reduce livestock production? (Meat and milk)
- What effect does RDP have on macroeconomic variables?



- Does the application of RDP change the quantity and costs associated with the inputs required for production?



- How much does the RDP increase or reduce agricultural production and renewable products?

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[13] The assumption that the ABC+ Plan's targets will be met was made without distinguishing between subsidies or public/private funding. The simulation strategy aims to reproduce average investments and costs, as well as average impacts on productivity, based on the current economic structure. More information on the calibration of these average parameters can be found in item 3.2 of Report 2 of this study.

Scenario 1 (SCE1) highlights the effects of recovering degraded pastures on expanding cattle productivity, as well as the corresponding investments. Scenario 2 (SCE 2), by including CLI systems, has additional impacts to SCE 1. Therefore, in order to obtain the full effect of the policy in SCE2, it is necessary to include the results already obtained in SCE1[14].

This section comprises two main subsections, according to the groups of variables worked on: effects upon macroeconomic aggregates, and the effects upon the production of economic activity sectors. For both subsections, the results are given at national and regional level (including the 14 regions analyzed by TERM-BR).

3.1.1 Effects on macroeconomic aggregates

3.1.1.1 National level

Increased productivity in cattle ranching and the corresponding investments would provide economic growth and increased household consumption in all the analyzed scenarios (Table 1). The results of SCE2 show the additionality of using integration systems to recover pastures, making it possible to simultaneously obtain the economic benefits of livestock and agricultural production, which would provide higher macroeconomic effects than those observed in SCE1 alone (Table 1).

Table 2. Model results. Macroeconomic impact, SCE1 and SCE2. Cumulative % variance in 2030

Macroeconomic Aggregates (Brazil)	SCE1	SCE2	
	(var. in relation to baseline)	(var. in relation to SCE1)	(var. in relation to baseline)
Real GDP	1.3	0.31	1.62
Household consumption	1.82	0.38	2.21
Real investment	3.78	0.8	4.61
Exports (volume)	-3.01	0.14	-2.87
Imports (volume)	3.76	1.32	5.12
Real Wages	2.2	0.55	2.77
Food Price Index (real)	-2.35	-0.21	-2.56

Source: own elaboration

[14] The methodological details of these scenarios were presented in sections 3.1 to 3.3 of Report 2.

If using conventional systems (SCE1) the RDP would have an impact of 1.30% on the accumulated real GDP in 2030 in relation to the baseline (Table 1), or BRL 164.1 billion at 2023 prices[15]. Increased productivity in cattle ranching would increase production in this activity, stimulating the other sectors related to production, in terms of inputs, processing and distribution, with general equilibrium effects on the level of economic activity. The greater availability of cattle products would also lead to a reduction in product prices, implying gains in the other downstream chains. It would also free up production factors such as land and labor for other activities, which could expand more easily. Tanure *et al*. (2021) also highlighted how investment and capital accumulation in sectors impacted by climate change adaptation and mitigation policies frees up primary factors for other sectors of activity. These phenomena will be discussed throughout this chapter.

By including CLI as an RDP system in 20% (6 Mha) of the ABC+ Program's targets (30 Mha), in addition to the effects on livestock, there will be an increase in corn and soybean production, providing an incremental increase of 0.31% in accumulated real GDP in 2030 in relation to SCE1, totaling an effect of 1.62% in relation to the baseline (Table 1), i.e., BRL 202.4 billion at 2023 prices. The dynamic triggered by the increase in agricultural production is similar to that of cattle productivity. However, as these are crops with a high share of production destined for export (over 70% in 2020), it can be seen that, despite the increase in domestic absorption, exports of these commodities would increase. The specifics of these impacts will be detailed below.

Investments (acquisition of machinery, equipment, warehouses, silos, sheds, greenhouses, tractors, harvesters and other similar goods) for the RDP would total BRL 13 billion in 2030 at 2023 prices. Comparing the investments with the increases in real GDP in SCE1 and SCE2, the policy would present a social return of between 11.6 and 13.9 times for each real invested, respectively.

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[15] Adjusted by the IGPM for 06/2023.

[16] Costs of goods and services used for pasture recovery constitute intermediate consumption for production, a component that reduces GDP. Thus, the gains presented refer to the pure return on used investment in goods and services and on technological progress.

With the increase in economic activity, there would be an increase in real household wages of 2.20% in SCE1 and 2.77% in SCE2, accumulated in 2030 and compared to the baseline (Table 1). There would also be a reduction in food prices, which in 2030 would see a cumulative decrease of 2.35% and 2.56% in SCE1 and SCE2, respectively, compared to the baseline. Thus, with an increase in purchasing power (real wages) and a decrease in the relative price of products, families would increase their real consumption by 1.82% and 2.21% in SCE1 and SCE2, respectively, compared to the baseline in 2030, i.e., between BRL 104.7 billion and BRL 128.9 billion in 2023. The effects of increased wages and real household consumption resulting from a policy to increase agricultural productivity are in line with those presented by Ferrarini and Ferreira Filho (2020).

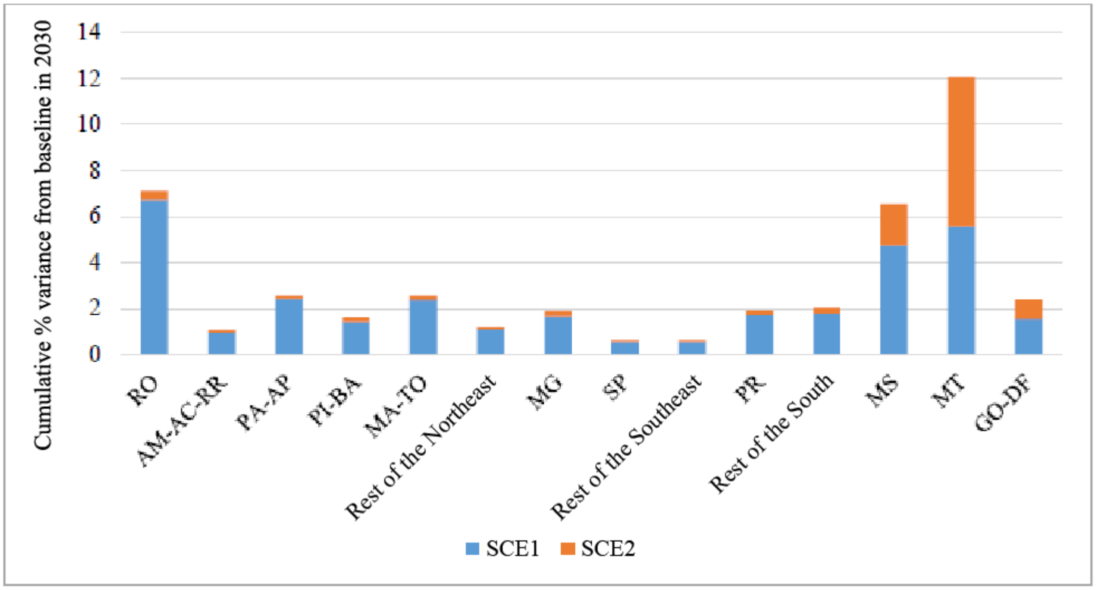
Finally, the increase in consumption, determined by the growth in domestic income, would lead to a reduction in the country's aggregate exports (Table 1), as well as an increase in imports. As will be shown below, however, exports of livestock and its by-products, as well as other agricultural products, would likely grow.

3.1.1.2 Regional level

Analyzing the regional results, the 14 simulation regions would show an increase in real GDP and real household consumption (Image 3 and Image 4). However, the recovery of degraded pastures showed the ability to provide income convergence between regions, since the less developed economies, such as RO, PA-AP, MA-TO, MS, MT and GO-DF, would show greater growth in real GDP than the more developed economies, located in the Southeast and South (Image 3).

In SCE1, the highest regional growth in real GDP would occur in RO, MT and MS (Image 3) and would be related both to the size of the productivity shock (Table 1 of Product 2, presented here in the Annex) and to the share of cattle ranching in the value of total production in these economies, which is also high (Table 2).

Image 3: Model results. Impact on regional real GDP, SCE1 and SCE2. Cumulative % variance from baseline in 2030



Source: own elaboration.

In SCE2, the benefits would be more concentrated in the Central-West, such as MT and MS. This would be due to the representativeness of these regions in Brazil's soybean area, a criterion for allocating the CLI system, as well as the greater dependence of regional economies on soybean cultivation (the two largest in Brazil) (Table 2).

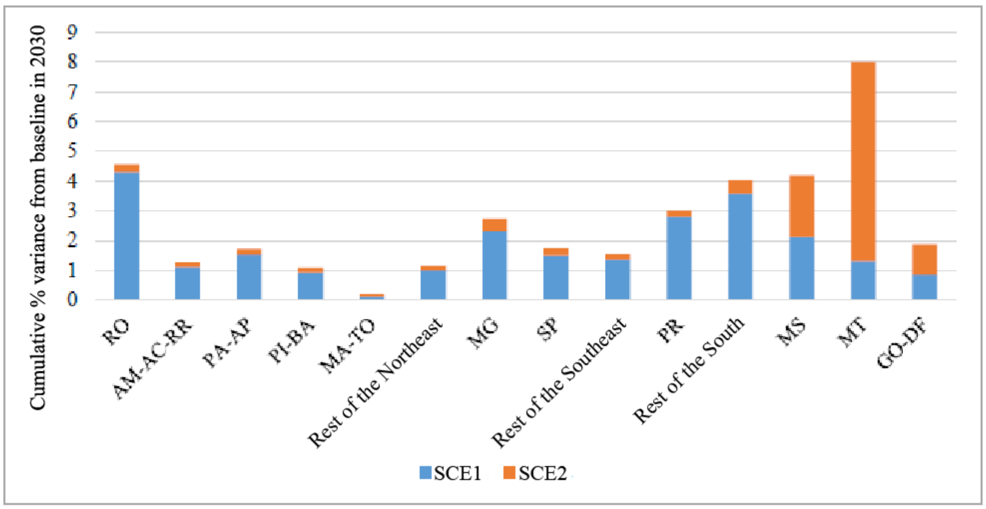
Table 3. Regional shares of agricultural production and meat industrialization in 2015

Regional Production Plots	Corn	Soybeans	Beef	Milk	Other Activities
RO	0.5	1.1	6.0	0.7	91.7
AM-AC-RR	0.1	0.1	1.1	0.1	98.6
PA-AP	0.2	0.5	2.6	0.2	96.5
PI-BA	0.3	1.5	1.2	0.2	96.8
MA-TO	0.6	3.0	3.1	0.3	93.0
Rest of the Northeast	0.1	0.0	0.8	0.3	98.8
MG	0.3	0.4	0.7	0.7	97.9
SP	0.1	0.1	0.1	0.0	99.7
Rest of the Southeast	0.0	0.0	0.1	0.1	99.8
PR	0.7	2.7	0.4	0.4	95.8
Rest of the South	0.3	1.8	0.6	0.5	96.8
MS	2.0	5.3	4.1	0.2	88.4
MT	3.0	15.4	4.5	0.2	76.9
GO-DF	0.7	1.9	1.2	0.5	95.7

Source: own elaboration

Real household consumption shows a similar regional distribution to real GDP, but with smaller percentage variations. In the North and Northeast regions, which are more dependent on less skilled labor, consumption growth would be lower than in the South, for example. This is a result of the joint variation in income and relative prices mentioned above. The behavior of regional consumption will be explained in greater detail in section 3.2.1.2.

Image 4: Model results. Impact on real consumption of regional families, SCE1 and SCE2. Cumulative % variance in relation to the baseline in 2030



Source: own elaboration

It can be observed that despite the potential to contribute towards equalizing real GDP between Brazilian regions, the extent of the benefits on real household consumption would not occur in the same way, especially in the North and Northeast regions of Brazil. Tanure *et al*. (2021), Diniz (2019) and Santos and Ferreira Filho (2017) show how policy scenarios can bring heterogeneous results for different classes of households, depending on the characteristics of the shocks (e.g., productivity or investment), sectors and regions affected.

Subsections 3.2.1.1 and 3.2.1.2 answer the following guiding question:

- What effect would the RDP have on macroeconomic variables?

The RDP would lead to economic growth and real household consumption. The increase in domestic absorption would generate an increase in imports and a decrease in exports.

3.1.2 Effects on the production of sectors of economic activity

3.1.2.1 National level

In SCE1, with an increase in the productivity of cattle farming, the production of beef cattle (BeefOtherAnim) and milk (MilkCattleOtherAnim) would grow by 38.9% and 15.2%, respectively, compared to the baseline in 2030 (Table 3). An increase in the availability of raw materials and a decrease in their relative prices[17] for the animal slaughter and meat processing industry (Meat) would result in growth in this sector by 18.2% compared to the baseline in 2030. The gains in competitiveness are also reflected in the other animal protein production chains, with an increase in swine production (10.2%) and poultry (PoultryEggs, 6.7%).

Table 4. Impact on production, SCE1 and SCE2. Cumulative % variance in 2030

Activity Types	Activities Sectors	SCE1	SCE2	
		(var. in relation to baseline)	(var. in relation to baseline SCE1)	(var. in relation to baseline)
Agriculture	RiceTrigOther	0.4	-1.9	-1.5
	CornGrain	0.0	0.1	0.1
	CottonHerb	-0.5	-5.9	-6.4
	Sugarcane	0.9	-0.2	0.7
	SoybeanGrain	0.9	22.2	23.3
	OtherPrCropTemp	-0.5	-0.7	-1.1
	Orange	-0.4	-0.7	-1.1
	CoffeeGrain	1.8	-2.2	-0.4
	OtherPrCropPerm	0.2	-0.9	-0.8
Livestock	CattleOtherAnim	38.9	0.0	38.9
	MilkBeefOtherAni	15.2	0.0	15.2
	Pigs	10.2	-1.4	8.7
	PoultryEggs	6.7	-0.9	5.7
	FishingAcq	-0.1	-0.5	-0.6
Extractive	ExplForestSilv	0.2	-1.2	-1.0
	Mining	-1.9	-0.5	-2.5
Industry	Meat	1.,2	-1.0	17.1
	OtherFood	-0.7	-0.4	-1.1
	OtherAgrobusiness	-5.7	-1.7	-7.3
	Ethanol	1.6	0.1	1.7

Source: own elaboration.

[17] The effects on prices will be discussed in the section Effects on household income, prices, and consumption.

With regard to agricultural activities, in SCE1 the impacts in relation to the baseline in 2030 are generally less than 1% (Table 3). These are the result of the reorganization of production, given the impacts on relative prices and on product profitability (which are analyzed regionally in section 3.1.2.2 Regional Level). However, in SCE2, soybean and corn production[18] (which are directly involved in the CLI process) grow by 22.2% and 0.1%, respectively, compared to SCE1, with their production gains having a negative impact on other agricultural activities, due to competition for productive resources between activities.

As highlighted above, growth in domestic income and exchange rate appreciation would lead to a lower aggregate volume of exports. However, in SCE1 there would be an increase in beef cattle and meat exports of 572.4% and 38.2%, respectively, compared to the baseline in 2030 (Table 4). Despite the significant increase in live cattle exports, this represented only 1% of the sector's production in 2020, while the meat sector exported 30.8% of its production.

The gains in the slaughtering and meat processing industry would also result in an increase in its intermediate consumption (use of raw materials), which together with the increase in domestic consumption, would result in lower exports of swine (-19.5%) and live poultry (-17.4%) (Table 4). In agricultural activities, variations in exports are the result of a balance of impacts on production and domestic consumption. In SCE1, for example, the other agro-industrial products sector (OtherAgrobusiness), that includes textile products, showed a production reduction in the simulation, which would lead to a drop in domestic demand for cotton. This led to a 4.4% increase in exports of this product (Table 4). In SCE2, however, strong competition for land with soybean cultivation reduces cotton production, resulting in a net reduction in cotton exports.

Table 5: Model results. Impact on exports, SCE1 and SCE2. Cumulative % variance in 2030

Type of Activity	Activities Sectors	SCE1	SCE2	
		(var. in relation to baseline)	(var. in relation to baseline SCE1)	(var. in relation to baseline)
Agriculture	RiceWheatOther	0.1	-3.9	-3.8
	MaizeGrain	0.9	0.7	1.6
	CottonHerb	4.4	-9.9	-5.9
	SoybeanGrain	1.3	29.7	31.5

[18] National corn production shows little growth compared to soybean production, as the regions simulated with corn iLP are less representative of Brazilian grain production, as will also be discussed in section 3.1.2.2 Regional Level.

Activity Type	Activities Sectors	SCE1	SCE2	
		(var. in relation to baseline)	(var. in relation to baseline SCE1)	(var. in relation to baseline)
	OtherCropTemp	0.7	-3.7	-3.0
	CoffeeGrain	2.2	-2.4	-0.2
	OthertPrCropPerm	-0.6	-3.2	-3.8
Livestock	CattleOtherAnim	572.4	5.2	607.4
	Swine	-19.5	-5.3	-23.8
	PoultryEggs	-17.4	-5.4	-21.9
Extractive	FishingAcq	-14.7	-5.0	-18.9
	ExplForestSilv	5.4	-3.3	2.0
	Mining	-10.7	-3.5	-13.8
Industry	Meat	38.2	-2.1	35.3
	OtherFood	-8.2	-3.3	-11.2
	OtherAgrobrusiness	-14.6	-4.5	-18.4

Source: own elaboration.

In SCE2, the drop in agricultural production, with the exception of soybeans and corn, combined with the increase in income and domestic consumption, would reduce agricultural exports (Table 4), compared to what would be observed in SCE1. The increase in soybean production discussed above would allow exports of this product to grow by 29.8% compared to SEC1, representing a total variation of 31.5% compared to the baseline in 2030. As soy would have more than 70% of its production exported in 2030 and represents an important product on Brazil's export agenda, it can be seen that the result of this sector supported the increase in aggregate exports in SCE2 (Table 1).

3.1.2.2 Regional level

As observed in SCE1, the regional effects on beef cattle production (Table 5) are similar to the magnitudes of the productivity shocks applied in the simulation, seen in Table 1 of Report 2 (in Annex). The production impacts in dairy farming, on the other hand, are smaller than the shocks. A greater price reduction was observed in dairy farming than in beef farming in relation to production growth, so that the profitability of dairy farming would be more affected, causing it to free up pasture areas for beef farming in all regions (variations in land use will be presented in section 3.3.1). However, the only drop in milk production would occur in AM-AC-RR, where productivity gains would be the lowest in Brazil.

Table 6. Model results. Impact on regional production, SCE1 and SCE2. Selected products. Cumulative % change from baseline in 2030

Regions	SCE1				
	CornGrain	**SoyGrain**	**CattleOtherAnim**	**MilkBeefOtherAni**	**Meat**
RO	-0.1	0.8	46.2	17.5	20.8
AM-AC-RR	5.6	5.9	11	-7	-5.2
PA-AP	0.4	1.2	29.2	5	4.3
PI-BA	-0.3	0.9	33.6	13.5	-4.6
MA-TO	0	0.7	31.2	7.2	0.6
Rest of the Northeast	-0.2	0.7	49	16	-4.2
MG	1.1	2.4	27.3	14.4	8.9
SP	-0.2	0.4	54	28.5	21.9
Rest of the Southeast	-0.5	0.2	45.5	24.2	17.9
PR	-0.4	0.6	27.3	11.9	21.4
Rest of the South	0.1	1	41.8	16.6	24.1
MS	-0.7	0.1	60.8	38.5	19.1
MT	-0.1	0.9	42.1	16.1	23.8
GO-DF	0.8	1.7	35.6	12.8	-9
Regions	**SCE2**				
	CornGrain	**SoyGrain**	**CattleOtherAnim**	**MilkBeefOtherAni**	**Meat**
RO	39.1	-5.5	46.2	17.5	21.8
AM-AC-RR	76.8	3	11	-7	-4.9
PA-AP	40.5	-3.6	29.2	5	4
PI-BA	35.7	-4.1	33.6	13.5	-4.3
MA-TO	35.7	-4.7	31.2	7.2	0.5
Rest of the Northeast	36.3	-11.2	49	16	-4
MG	-1	37.2	27.3	14.4	8.8
SP	-2.4	40.2	54	28.5	21.6
Rest of the Southeast	-2.5	35.8	45.5	24.2	18.3
PR	-2.1	8.1	27.3	11.9	20.6
Rest of the South	-2.1	19.8	41.8	16.6	22.8
MS	-5.8	35.9	60.8	38.5	16.7
MT	-11.6	37.4	42.1	16.1	15.9
GO-DF	-3.3	37.2	35.6	12.8	-11.6

Source: own elaboration.

The impacts on agricultural activities, such as corn and soybeans, would also be relatively small in SCE1 (Table 5), since regions with the highest percentage variation in these activities, such as AM-AC-RR, have small production in absolute terms. These effects on agriculture are the result of the systematic effects of the RDP on relative prices in agriculture and on the availability of factors of production.

In SCE2, variations in regional production of corn in the North and Northeast, and soybeans in the rest of Brazil, were determined by the CLI area implemented in the simulations (exogenous shocks). An increase in these productions in the selected regions would lead to a reduction in the relative prices of soybeans and corn, impacting the regions that did not have CLI in the respective activity, resulting in a reduction in soybean production in the North and Northeast, and corn production in the rest of Brazil.

Regarding SCE1 exports, as highlighted in the national result, the gain in competitiveness in the meat chain would result in a significant increase in exports of live animals (despite the low representativeness in the volume exported as mentioned above) and of processed meats (Table 6). For meat exports, the regional impacts have a strong correlation (0.85) with the variations in production discussed above (Table 6).

Table 7. Model results. Impact on regional exports of selected products, SCE1 and SCE2. Cumulative % variance in relation to the baseline in 2030

Region	**SCE1**			
	CornGrain	**SoyGrain**	**CattleOtherAnim**	**Meat**
RO	0.2	0.9	736.6	60.8
AM-AC-RR	6.2	6	542.7	26.8
PA-AP	1	1.5	413.8	23.4
PI-BA	1.4	1.2	728.4	19.2
MA-TO	0.8	1	638.2	24.2
Rest of the Northeast	0.6	1.1	788	18.9
MG	3.5	3.4	746.2	42.8
SP	0.4	1	819.2	45.9
Rest of the Southeast	0.2	0.8	795.3	50.1
PR	0.2	1	640.4	37.1
Rest of the South	0.3	1.1	712.4	37.2
MS	0	0.7	943.2	54.7
MT	0.7	1.4	796.7	58.7
GO-DF	2.2	2.5	755.3	8.1
Region	**SCE2**			
	CornGrain	**SoyGrain**	**CattleOtherAnim**	**Meat**
RO	64.8	-1.1	785.9	57.7
AM-AC-RR	80	7.6	581.9	23.6
PA-AP	45.9	0.2	432.1	20.2
PI-BA	61.2	-1	777	15.9
MA-TO	41.3	-0.6	680.3	20.9
Rest of the Northeast	58	2.5	835.9	15.8

MG	-0.1	73.7	793.4	39.7
SP	-2.4	52	874.6	43.4
Rest of the Southeast	-1.8	48.1	844.6	47.7
PR	-2.4	13.3	686.7	35.1
Rest of the South	-2.8	24.5	764.3	34.7
MS	-5.4	49.5	1012	46.8
MT	-10.5	49.7	888.8	42.8
GO-DF	-2.3	55.5	808.9	2.1

Source: own elaboration

Still with regard to SCE1, despite the small variations in regional agricultural production, all regions showed growth in exports of corn and soybeans. In particular, the AM-AC-RR, MG and GO-DF regions, which would have the highest production growth, would also show greater increases in exports compared to the other regions (Table 6).

The biggest impacts on SCE2 occur in corn and soybean exports (Table 6). The variations have a strong correlation (greater than 0.96) with the variations in production. The differences in the regional effects are due both to the proportions of the impacts on production as well as to the regional structures of household consumption and intermediate consumption (for instance, for the industrial sectors).

Subsections 3.2.2.1 and 3.2.2.2 provide answers to the following guiding questions:

AG

- What is the differential productivity achieved by producers when they improve the quality of their pastures after adopting RDP?

Recovering degraded pastures would increase the gross value of livestock production in Brazilian regions by between BRL 698 and BRL 3,421 per hectare. The distribution of reclaimed areas to achieve the ABC+ Plan's target would lead to increases in average livestock productivity in the regions of between 1.5% and 4.9% per year.

AG

- How much does RDP increase or decrease livestock production (meat and milk)?

In the traditional RDP system (SCEN1), beef cattle, dairy cattle and meat production would increase by 38.9%, 15.2% and 18.2% compared to the baseline in 2030.

In the Crop-Livestock Integration (CLI) system, livestock production would remain at the SCE1 level, but meat industrialization would grow less, by 17.1% compared to the baseline in 2030. In addition, soybean production would increase by 23.3% compared to the baseline in 2030.

IN

- Does the application of RDP change the quantity and costs associated with the inputs needed for production?

It is possible to say that livestock farming becomes more capital-intensive by increasing investments in pasture recovery. In other words, the activity would replace a portion of the factors of production land and labor with capital. In this context, it is expected that the reclaimed portion will use more inputs.

SE

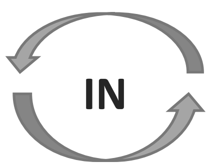
- How much does the RDP increase or decrease agricultural production and renewable products?

In the traditional RDP system (SCE1) there would be deviations of less than 1% in the production of agricultural activities, except for coffee, which would increase by 1.8% compared to the baseline in 2030. Other livestock activities such as pigs and poultry would grow by more than 10% compared to the baseline in 2030. Forestry (planted forests) and the production of ethanol and other biofuels would increase by 0.2% and 1.6%, respectively, compared to the baseline in 2030.

In the Crop-Livestock Integration (CLI) system, the growth of soybean and corn activities would lead to lower prices and, consequently, a drop in production in other agricultural activities, compared to SCE1. Ethanol production would increase by 0.1% due to the growth in economic activity, compared to SCE1. In total, apart from soybeans, corn and cattle, only sugar cane, pigs, poultry and ethanol would continue to show growth in production.

3.2 Social and Human Impacts

The results, presented at national and regional level (considering the 14 regions analyzed by TERM-BR) in this section, seek to answer the following guiding questions (which relate to capital stocks and flows in the TEEBAgriFood Evaluation Framework) (Image 1):

Human Capital	- What effect does the policy have on workers' wages?
Social Capital	- What effect does the RDP have on the food security of Brazilian families? Do families have access to more food at better prices?
Produced Capital	- Does the RDP lead to changes in investment and in the intensity of the use of the capital factor by economic sectors, especially livestock?
	- Does the application of the RDP change real household wages in the economy as a whole? And only in the agricultural sector?

3.2.1 Effects on household income, prices and consumption

3.2.1.1 National level

In the two scenarios analyzed (SCE1 and SCE2), the recovery of degraded pastures would lead to an increase in real household consumption. This is true for all classes of households, except for the poorest (POF1), which would see a small reduction (Table 7). Thus, despite the positive effects for the population as a whole, this result draws attention to the need to develop complementary policies to provide gains for the poorest families. Furthermore, spatial analysis will provide more information on the profile of land and rural producers involved in the pasture recovery process, which can complement the notions of social impact in Brazilian agriculture.

Table 8. Model results. Impact on real household consumption, SCE1 and SCE2. Accumulated % variance in 2030

Families	SCE1		SCE2			
	(var. in relation to baseline)		(var. in relation to baseline SCE1)		(var. in relation to baseline)	
	Total	**Food**	**Total**	**Food**	**Total**	**Food**
POF1	-0.04	0.58	-0.03	0.02	-0.08	0.60
POF2	1.07	1.30	0.03	0.07	1.10	1.37
POF3	1.29	1.49	0.25	0.20	1.55	1.69
POF4	1.50	1.74	0.32	0.24	1.82	1.98
POF5	1.70	1.94	0.42	0.31	2.13	2.25
POF6	1.65	1.64	0.44	0.32	2.09	1.97
POF7	1.84	1.80	0.49	0.35	2.34	2.16
POF8	2.02	2.06	0.50	0.36	2.53	2.42
POF9	2.02	1.83	0.51	0.38	2.54	2.22
POF10	2.26	2.17	0.44	0.34	2.70	2.52

Source: own elaboration

This impact derives from two main components: the variation in the price of the consumer basket and the change in household income. The combination of these factors generates different results depending on the family income group. The average prices of the consumption baskets of the family social class showed greater reductions for the poorest families (POF1, Table 8), compared to the richest families (POF10). This result is related to the increase in agricultural production, which increases the supply of these products and reduces their relative prices, especially milk and meat in SCE1 (Table 9). As food has a greater weight in the consumption basket of poorer families, this explains the greater price drop mentioned above. Therefore, despite the decrease in aggregate consumption, there was still a 0.6% increase in food consumption by the poorest families (POF1, Table 7).

Table 9. Model results. Impact on the price of the household consumption basket, SCE1 and SCE2. Cumulative % variance in 2030

Families	SCE1	SCE2	
	(var. in relation to baseline)	(var. in relation to baseline SCE1)	(var. in relation to baseline)
POF1	-1.17	-0.13	-1.29
POF2	-1.05	-0.12	-1.17
POF3	-0.94	-0.10	-1.04
POF4	-0.86	-0.10	-0.95
POF5	-0.81	-0.09	-0.90
POF6	-0.51	-0.08	-0.59
POF7	-0.50	-0.08	-0.58
POF8	-0.55	-0.07	-0.62
POF9	-0.31	-0.06	-0.36
POF10	-0.18	-0.03	-0.21

Source: own elaboration

Table 10. Model results. Impact on product prices, CEN1 and CEN2. Cumulative % variance in relation to 2030

Activity Type	Activity Sectors	CEN1	CEN2	
		(var. in relation to baseline)	(var. in relation to baseline SCE1)	(var. in relation to baseline)
Agriculture	RiceWheOther	-3.6	-0.1	-3.7
	CornGrain	-4.1	-1.7	-5.7
	CottonHerb	-4.3	1.3	-3.0
	Sugarcane	-3.3	0.1	-3.2
	SoybeanGrain	-3.4	-7.3	-10.5
	OtherCropsTemp	-4.5	-0.2	-4.7
	Orange	-4.1	-0.2	-4.3
	CoffeeGrain	-3.6	-0.5	-4.2
	OtherCropPerm	-3.8	-0.4	-4.2
Livestock	BeefOtherAnim	-35.4	-2.4	-37.0
	MilkBeefOtherAni	-40.7	-0.4	-41.0
	Swine	0.4	0.1	0.5
	PoultryEggs	0.4	0.0	0.4
	FishAcq	0.1	-0.2	-0.1
Extractive	ExplForSilv	-5.0	-0.2	-5.2
	Mining	-0.9	-0.4	-1.3
Industry	Meat	-11.7	-0.6	-12.2
	OtherFood	-1.7	-0.4	-2.1
	OtherAgrobusiness	-0.3	-0.2	-0.5

Source: own elaboration.

Income, therefore, is the factor that explains the small reduction in real consumption by the poorest families. These families would show lower gains in real wages (Table 10), because since cattle ranching (SCE1) and agriculture (SCE2) have a higher demand for less qualified labor (Table 11), normally provided by the poorest families, the growth in land productivity and investment makes cattle ranching more "capital intensive", replacing labor (Table 12). The Appendix shows the effects on labor demand and real wages by groups of sectors of activity in agriculture, livestock and agribusiness. In SCE1, for example, beef and dairy farming would reduce the demand for labor by 6.9% and 30.0%, respectively, compared to the baseline in 2030. Thus, even with the reduction in prices, the lower income growth explains the negative or very low impacts on the real consumption of the poorest families (Table 7).

Table 11. Model results. Impact on real wages, SCE1 and SCE2. Accumulated % variance in 2030

Labor	SCE1	SCE2	
	(var. in relation to baseline)	(var. in relation to baseline SCE1)	(var. in relation to baseline)
OCC1	0.49	0.04	0.54
OCC2	1.47	0.10	1.58
OCC3	1.74	0.91	2.66
OCC4	2.16	1.12	3.30
OCC5	2.77	0.94	3.74
OCC6	3.15	0.79	3.96
OCC7	3.14	0.73	3.89
OCC8	3.22	0.65	3.89
OCC9	3.25	0.63	3.90
OCC10	2.93	0.56	3.51

Source: own elaboration.

Table 12. Sectoral composition of labor demand, by labor qualification classes in 2020

Labor	Agriculture	Livestock	Cattle	Other activities
OCC1	4.2	8.9	10.3	2.4
OCC2	41.6	55.0	54.6	28.6
OCC3	24.7	20.1	20.3	14.7
OCC4	11.7	5.9	5.6	8.8

Labor	Agriculture	Livestock	Cattle	Other activities
OCC5	5.3	2.5	2.3	6.2
OCC6	3.0	1.7	1.5	4.7
OCC7	1.8	1.3	1.1	3.8
OCC8	1.1	0.7	0.6	3.1
OCC9	1.6	1.1	1.0	5.0
OCC10	4.8	2.9	2.7	22.6
Total	100	100	100	100

Source: own elaboration.

Table 13. Model results. Impact on the use of capital, SCE1 and SCE2. Cumulative % variance in 2030

Activities Types	Activities Sectors	SCE1 (var. in relation to baseline)	SCE2 (var. in relation to baseline SCE1)	SCE2 (var. in relation to baseline)
Agriculture	RiceWheaOther	-3.2	-2.0	-5.1
	CornGrain	-3.0	-0.7	-3.8
	CottonHerb	-2.8	-4.4	-7.1
	Sugarcane	-1.8	-0.1	-1.9
	SoyGrain	-1.9	13.0	10.9
	OthePrCropTemp	-4.2	-0.5	-4.7
	Orange	-3.7	-0.6	-4.3
	CoffeeGrain	-1.5	-2.6	-4.0
	OthePrCropPerm	-3.2	-1.0	-4.2
Livestock	CattOthAni	10.6	0.0	10.6
	MilkCattOthAni	9.5	0.0	9.5
	Swine	10.3	-0.4	9.9
	PoultryEggs	6.8	-0.2	6.6
	FishingAcq	-2.9	-1.1	-3.9
Extractive	ExtrForSilv	0.8	-0.2	0.6
	Mining	-1.7	-0.4	-2.1
Industry	Meat	18.0	-0.3	17.6

Source: own elaboration

This is a common feature of policies to increase land productivity in agriculture. Evaluations such as those by Otsuki (2013), Spolador and Roe (2018) and Queiroz *et al*. (2018) also showed how technological progress in agriculture can distort the production function towards the use of one primary factor, at the expense of others. In this context, ancillary policies to the ABC+ for retraining and reallocating rural workers to other sectors of the economy, such as agribusiness, could extend the benefits to the poorest families.

3.2.1.2 Regional level

As shown above, with the recovery of pastures, real household consumption would increase. However, disaggregating the results by class of household regionally, in some cases the poorest families (POF1) would see reductions in consumption (Table 13). This would occur in SCE1 in AM-AC-RR, PA-AP, PI-BA, MA-TO, the Rest of the Northeast, MG and GO-DF, and in SCE2 in RO, AM-AC-RR, PA-AP, PI-BA, MG and the Rest of the Southeast.

To analyze these dynamics, we return to the two factors that determine household consumption: income and prices. In general, prices fell in all regions, both in SCE1 and SCE2. Thus, it can be seen that families' income was once again a determining factor in regional variations in consumption.

Table 14. Model results. Regional impact on real household consumption, SCE1 and SCE2. Cumulative % variance in relation to 2030

Regions	SCE1									
	POF1	**POF2**	**POF3**	**POF4**	**POF5**	**POF6**	**POF7**	**POF8**	**POF9**	**POF10**
RO	0.9	3.5	3.3	3.4	3.7	3.5	3.9	4.1	4.7	6.1
AM-AC-RR	-2.3	1.1	1	1.1	1.2	1.2	1.4	1.4	1.7	1.8
PA-AP	-0.4	1.3	1.3	1.3	1.4	1.4	1.7	1.8	2	2.1
PI-BA	-1.3	0.4	0.6	0.7	0.9	1	1.2	1.2	1.7	1.7
MA-TO	-2.4	-0.1	0	0.1	0.2	0.2	0.7	0.6	0.6	1
Rest of the Northeast	-0.2	0.6	0.8	0.8	0.8	1	1.3	1.2	1.5	1.8
MG	-0.6	1.6	1.4	1.5	2.8	1.9	2.1	2.4	2.4	3
SP	2.1	1.6	1.7	1.9	1.6	1.5	1.5	1.6	1.5	1.4
Rest of the Southeast	0.8	1	1.7	1.5	1.6	1.7	1.8	2.1	1.9	1
PR	2.8	2.9	2.4	2.5	2.4	2.2	2.5	2.7	2.8	3.3
Rest of the South	2.4	1.4	1.7	1.9	2.3	2.5	3.1	3.4	3.6	5.1
MS	2.9	1.8	1.9	1.8	1.6	1.6	1.8	2.8	1.8	2.5
MT	1.1	3	1.5	1.1	0.9	0.5	0.5	0.6	0.8	1.5
GO-DF	-0.5	0	-0.2	0	0	0.2	0.8	0.6	1	1.8
Regions	**SCE2**									
	POF1	**POF2**	**POF3**	**POF4**	**POF5**	**POF6**	**POF7**	**POF8**	**POF9**	**POF10**
RO	0.3	3.4	3.4	3.5	3.9	3.6	4.2	4.3	5.1	6.7

AM-AC-RR	-2.5	1.2	1.2	1.3	1.4	1.5	1.7	1.6	2	1.9
PA-AP	-0.6	1.3	1.4	1.5	1.7	1.7	2.1	2.2	2.4	2.3
PI-BA	-1.5	0.4	0.6	0.8	1	1.1	1.4	1.4	1.9	2
MA-TO	-2.2	-0.1	0.1	0.2	0.2	0.3	0.8	0.6	0.7	1
Rest of the Northeast	-0.2	0.6	0.8	0.9	0.9	1.2	1.5	1.5	1.8	2.2
MG	-1	1.6	1.7	1.8	3.2	2.4	2.6	2.9	3	3.5
SP	2.3	1.6	1.9	2.1	1.8	1.8	1.7	1.9	1.8	1.7
Rest of the Southeast	0.6	0.9	1.8	1.7	1.9	2	2.1	2.5	2.2	1.2
PR	2.8	2.8	2.4	2.6	2.6	2.4	2.7	3	3	3.6
Rest of the South	2.3	1.4	1.8	2.1	2.6	2.8	3.5	3.7	4	5.8
MS	3.2	2.5	3.4	3.6	3.8	4	4.5	5.4	4.3	4.7
MT	2.2	3.7	5.5	6.9	8.2	8.7	10	10.3	10.5	10.5
GO-DF	0.3	0.3	0.9	1.2	1.5	2	2.6	2.5	2.8	2.4

Source: own elaboration

In SCE1, it can be noted that the regions that have reduced consumption have a high share of lower-skilled labor (OCC1) in beef and dairy farming (Table 14). These regions also have the largest reductions in labor demand from livestock activities. In SCE2, the reduction in consumption by the poorest families is more easily explained by the dynamics of the shock to agricultural production. As explained above, the most representative production gains occur in the Central-West region, reducing livestock prices for all regions. Thus, adjustments in the agricultural production labor market would result in lower purchasing power for the poorest families.

Table 1. Model results. Impacts on the regional livestock labor market, SCE1. Cumulative % variance in relation to the baseline in 2030

Regions	**CattOtherAnim**		**MilkCattOtherAni**	
	Work share OCC1	**Impact on total labor demand**	**Work share OCC1**	**Impact on total labor demand**
RO	8.8	-1.2	8.8	-28.9
AM-AC-RR	17.8	-15.4	15.1	-35.1
PA-AP	13.5	-4.1	13.6	-29.7
PI-BA	27.5	-10.0	27.5	-29.5
MA-TO	18.9	-7.9	20.0	-31.9
Rest of the Northeast	22.8	-0.5	23.0	-31.6
MG	13.7	-15.0	13.7	-27.5
SP	1.3	-0.1	1.3	-23.9

Regions	CattOtherAnim		MilkCattOtherAni	
	Work share OCC1	Impact on total labor demand	Work share OCC1	Impact on total labor demand
Rest of the Southeast	5.4	-5.2	5.3	-25.2
PR	2.7	-19.4	2.7	-33.6
Rest of the South	1.8	-9.3	2.0	-32.3
MS	2.0	-0.2	2.0	-20.3
MT	3.8	-6.3	3.8	-30.8
GO-DF	6.9	-8.2	6.9	-30.3

Source: own elaboration

As far as food consumption is concerned, the dynamics of lower product prices in SCE1 would lead to an increase in the consumption of these goods by the poorest families in PA-AP, the Rest of the Northeast, MG and GO-DF, which show a decrease in the total consumption basket (Table 15). However, in AM-AC-RR, PI-BA and MA-TO, the results would still be negative, but to a lesser extent than those shown in Table 13. The impacts of SCE2 would not change the direction of the total effects on food consumption, which would continue to be negative for the poorest families in AM-ACC-RR, PI-BA and MA-TO.

Table 2. Model results. Regional impact on real household food consumption, SCE1 e SCE2. Cumulative % variance in relation to 2030

Regions	SCE1									
	POF1	POF2	POF3	POF4	POF5	POF6	POF7	POF8	POF9	POF10
RO	1.4	2.9	3	2.8	3.2	2.8	3	3.1	3.3	3.7
AM-AC-RR	-0.7	1.1	0.9	1	1	0.9	1.1	1	1	1.2
PA-AP	0.6	1.3	1.3	1.3	1.3	1.2	1.5	1.4	1.5	1.4
PI-BA	-0.2	0.8	0.9	1.1	1.1	1.2	1.3	1.2	1.5	1.4
MA-TO	-0.8	0.5	0.6	0.6	0.6	0.5	1.3	0.8	0.8	0.9
Rest of the Northeast	0.5	0.9	1	1.1	0.9	1	1.1	1.1	1.2	1.3
MG	0.5	2.2	1.7	1.9	4	2	2.1	2.6	2.1	2.9
SP	1.9	1.8	1.9	2.3	1.8	1.6	1.5	1.8	1.6	1.8
Rest of the Southeast	1.1	1.2	1.8	1.5	1.4	1.4	1.5	2	1.4	1
PR	3.4	2.7	2.4	2.6	2.3	2.2	2.3	2.5	2.4	3.1
Rest of the South	2.5	1.8	2.1	2.1	2.4	2.4	3.1	3.2	3.1	4.4
MS	3.1	1.9	2.4	2.1	1.8	2	1.9	4.5	2	2.7
MT	1.4	2.8	1.6	1.4	1.2	0.8	0.8	1	1	1.6
GO-DF	0.2	0.6	0.4	0.5	0.4	0.5	0.9	0.7	1	1.3

Regions	SCE2									
	POF1	**POF2**	**POF3**	**POF4**	**POF5**	**POF6**	**POF7**	**POF8**	**POF9**	**POF10**
RO	1.1	2.9	3.1	2.9	3.4	2.9	3.2	3.3	3.6	4.1
AM-AC-RR	-0.8	1.2	1.1	1.1	1.2	1.1	1.2	1.2	1.2	1.3
PA-AP	0.5	1.3	1.4	1.5	1.5	1.5	1.7	1.7	1.8	1.6
PI-BA	-0.3	0.8	1	1.2	1.2	1.4	1.5	1.4	1.7	1.7
MA-TO	-0.6	0.6	0.7	0.7	0.7	0.7	1.4	0.9	0.8	1
Rest of the Northeast	0.6	0.9	1.1	1.2	1.1	1.2	1.3	1.3	1.5	1.6
MG	0.3	2.3	1.9	2.1	4.3	2.3	2.5	3	2.5	3.3
SP	2.1	1.9	2.1	2.6	2	1.8	1.8	2.1	1.8	2
Rest of the Southeast	1.1	1.3	1.9	1.7	1.6	1.6	1.7	2.3	1.6	1.2
PR	3.5	2.7	2.5	2.8	2.5	2.4	2.5	2.7	2.6	3.4
Rest of the South	2.6	1.9	2.2	2.3	2.6	2.7	3.4	3.5	3.4	5
MS	3.3	2.4	3.4	3.3	3.2	3.4	3.5	6.3	3.6	4
MT	2	3.2	4	4.7	5.3	5.5	6	6.4	6.5	6.7
GO-DF	0.7	0.9	1.1	1.2	1.3	1.5	1.9	1.7	2	1.7

Source: own elaboration

Subsections 3.2.1.1 and 3.2.1.2 answer the following guiding questions:

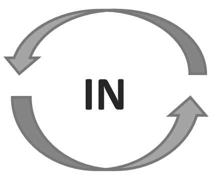
Produced Capital	- Does the RDP lead to changes in investment and in the intensity of the use of the capital factor by economic sectors, especially livestock? Increased investment in beef and dairy farming would increase the use of capital by 10.6% and 9.5%, respectively, compared to the baseline in 2030. At the same time, the use of labor and land would be reduced, highlighting the intensification of the use of capital in cattle farming. The other agricultural crops would increase the use of the productive factors freed up by livestock farming, reducing the intensity of capital use.
Human Capital	- What effect would the policy have on workers' wages? With the application of the policy, the total wage bill rises for all qualifications of workers in Brazil as a whole, but that of low-skilled workers rises.

Social Capital

- What effect does the RDP have on the food security of Brazilian families? Will families have access to more food at better prices?

In all classes of families, there would be growth in food consumption and lower relative prices than those observed in the baseline in 2030, for both simulation scenarios.

It is worth noting that even the poorest families would see food prices between 1.24% and 1.38% lower than in the baseline in 2030, which would increase food consumption by approximately 0.6%.



- Does the application of the RDP change real household wages in the economy as a whole? Only in the agricultural sector?

In the economy as a whole, the real wage would increase for all job qualifications. However, for groups of economic activity such as cattle farming in SCE1 and agriculture in SCE2, the least skilled jobs in the economy would register lower real wages compared to those observed in the baseline in 2030.

3.3 Environmental Impacts

This dimension of the study used several methodological approaches: economic modeling, spatial modeling, biophysical modeling and landscape metrics. The results will therefore be presented with reference to the respective methods adopted.

The results sought to answer the following guiding questions (which relate to capital stocks and flows in the TEEBAgriFood Assessment Framework) (Image 1):

Natural Capital

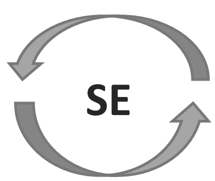
- Does RDP reduce or increase the pressure to open up new areas (deforestation)?

- Does it free up areas for other uses, such as agriculture?

- Is there a land-saving effect or a rebound effect?

- Where do these effects occur?

- How will the policy affect soil loss through erosion?



- Are there changes in the intensity of emissions (GHG per product)?

- Does the adoption of the technology contribute to the C fixation in the soil?

- Does the adoption of RDP technology result in less soil erosion? What part of this service is due to pasture recovery or avoided deforestation?

- Does the adoption of the technology contribute to habitat maintenance?

- What is the effect of RDP on GHG emissions among the different sectors of the economy, especially in the livestock sector (beef and dairy)?

3.3.1 Effects on land use

Box 2: Note on land use change results

This section describes the effects of the degraded pasture recovery scenarios on land use. Some initial considerations are important to clarify the results. For this analysis, it was necessary to integrate the results of two different models: the CGE model, TERM-BR15, which presents results for 14 regions of Brazil; and a spatial land use allocation model, spatially explicit for the entire national territory with a detail of 1 km². These two models are different, both in terms of their application and their database.

TERM-BR15 uses in its database information on planted areas from the Municipal Agricultural Production (PAM) and Vegetable Extraction and Forestry Production (PEVS) surveys (Brazilian Institute of Geography and Statistics) (IBGE, 2018a; 2018b), and for the pasture area, the Pasture Atlas (Image Processing and Geoprocessing Laboratory, 2023). The area of native vegetation is obtained as a residual to the uses for agriculture and pasture. The simulation of land use in the model also relies on a land use transition matrix based on data from the National Emissions Registration System (SIRENE) (Brazil, 2016), which may also suffer endogenous impacts in the simulation due to changes in technology, productivity and remuneration of activities in the different land uses and regions. These databases are, by their nature, aggregated at the state level, which is the appropriate geographical scale for the CGE model.

The spatial allocation model, in turn, uses as its database a union between the land use map from MapBiomas and the pasture map from Image Processing and Geoprocessing Laboratory (LAPIG) in 2020.

In order to integrate the models, it was necessary to use a technique known as "soft link". In this methodological option, the models are solved separately, and the results from one of them are transmitted to the other, which generates more disaggregated results. This technique is widely used in economic modeling, for example when international price adjustments are used in global models to learn about sub-regional effects within a country, through a more detailed inter-regional model. It was used, for example, in Ferreira Filho and Horridge (2006 a, 2006 b), Fachinelli and Ferreira Filho (2020), Ibarra *et al.* (2023) and Hanusch *et al.* (2023). In this type of study, the "boundary conditions" of the more general model are transferred to the more specific model.

The definition of these "boundary conditions" is always a matter of modeling choice, in terms of defining which model is more general and which is more specific. Given the nature of this study, the CGE model was defined as the most general model. Thus, in terms of land use analysis, the boundary conditions are defined from the CGE model and transmitted to the detailed spatial model. In this way, the percentage variations in land use transitions from the TERM-BR15 model, by aggregate use (agricultural crops, pastures, planted forests, and native vegetation) and by region, are transmitted to the spatial model, which makes the detailed territorial allocation.

It should therefore be noted that the results in terms of absolute variations are not the same in both models, given the differences previously described in the databases. Similarly, and as a consequence of the above, the results in terms of percentage variations, once computed from the results of the spatial model, are not identical to those initially observed from the

TERM-BR15 model. This limitation is intrinsic to the methodology used and should be highlighted in order to clarify how the model results are interpreted. In this sense, **the results of the equilibrium model provide the "boundary conditions", but the consolidation of the impacts of the application of the ABC+ policy on variations in land use must be interpreted from the point of view of the spatial allocation model.**

3.3.1.1 Results of the Computable General Equilibrium (CGE) model

This subsection deals with the effects of pasture recovery on land use change and Greenhouse Gas (GHG) emissions estimated by the Computer General Equilibrium model (CGE).

3.3.1.1.1 National Level

Regarding land use, Land Use Change, and Forestry (LUC), growth in the productivity of cattle farming, by increasing production (see item 3.1.2) and consequently reducing the price of products (see item 3.2.1), would have an impact on the sector's profitability. In SCE1, this would lead to an impact of reducing the demand for pasture areas by -1.88% compared to the baseline in 2030 (Table 16). This would prevent the deforestation by 0.5% of native vegetation, which means that the intensification of cattle farming would provide greater preservation of native vegetation than that observed in the baseline (Borlaug effect). The results corroborate the evidence of Villoria *et al*. (2014), in which, in general, local or national technological progress has an avoided deforestation effect. In addition, there would be an expansion of the agricultural area (0.52%) and planted forests (0.2%), i.e., the release of productive resources from cattle farming would make it easier to expand these activities.

Table 17. Model results. Impact on LUC, SCE1 and SCE2. Cumulative % variance in relation to 2030

LUC	**SCE1**	**SCE2**	
	(var. in relation to baseline)	**(var. in relation to baseline SCE1)**	**(var. in relation to baseline)**
Agriculture	0.52	-0.27	0.25
Pastures	-1.88	0.00	-1.88
Planted Forests	0.20	0.00	0.20
Native Vegetation	0.50	0.04	0.54

Source: own elaboration

In SCE2, on the other hand, in which the fixed pasture area was maintained - determined by the conditions of SCE1 - the impacts on agricultural production and its prices would increase the avoided deforestation by 0.04% compared to SCE1, through the release of areas from agriculture (Table 16). Therefore, in the SCE2 total, the agriculture area would increase by 0.25% and the avoided deforestation would be 0.54% compared to the baseline in 2030.

In terms of variations in land use by sector of economic activity, in SCE1 it can be seen that the release of pastures would occur mainly in dairy farming, with a decrease of 16.9% in relation to the baseline in 2030, while in beef farming the decrease would be 0.5% (Table 17). In addition to avoided deforestation, soy, sugarcane and coffee crops would register the largest increases in area, which is related to changes in the profitability of economic activities.

In SCE2, there is a change in livestock areas in order to maintain the level of production estimated in the SCE1, resulting in a small transition from beef cattle pastures to dairy cattle. Agricultural crops would show small variations in area compared to SCE1 (Table 17). For corn and soybeans, as there would be increases in production in selected regions, corn in the North and Northeast, and soybeans in the rest of Brazil, the regions not impacted by the policy would suffer as a result of the drop in the price of goods, reducing their areas for these crops, as will be shown in section 3.3.2. The area of sugarcane grows due to the increase in economic activity and fuel consumption, determined by the increase in income.

Table 18. Model results. Impact on LUC by sector of activity, SCE1 and SCE2. Cumulative % variance in relation to 2030

Activity Sectors	SCE1	SCE2	
	(var. in relation to baseline)	(var. in relation to baseline SCE1)	(var. in relation to baseline)
RiceWheaOther	0.2	-0.2	0.1
CornGrain	0.0	-1.3	-1.3
CottonHerb	-0.4	0.0	-0.4
Sugarcane	0.8	0.6	1.4
SoyGrain	0.9	-0.2	0.7
OtherPrCropTemp	-0.4	0.5	0.1
Orange	-0.5	0.0	-0.5
CoffeeGrain	1.9	-0.7	1.1
OtherPrCropPerm	0.1	0.2	0.3
CattOtherrAnim	-0.5	-0.1	-0.6
MilkBeafOtherAni	-16.9	0.8	-16.2
ExplForesSilv	0.2	0.0	0.2
Native Vegetation	0.5	0.0	0.5

Source: own elaboration.

3.3.1.1.2 Regional Level

In SCE1, it can be verified that pasture areas would be reduced or maintained in all regions, with an increase in avoided deforestation (an increase in the stock of native vegetation compared to the baseline) (Table 18). Areas would also be freed up for agriculture in practically all regions. In SCE2, on the other hand, the area of fixed pastures - determined by the conditions of SCE1 - was maintained so that the release of agricultural areas would generate an increase in avoided deforestation, which would also occur in all regions. The impacts of SCE2 would cause RO, MA-TO, the Rest of the Northeast, the Rest of the Southeast, the Rest of the South and MT to reverse the growth in the area destined for the agricultural sectors of SCE1, resulting in a reduction in relation to the baseline in 2030.

Table 3. Model results. Regional impact on LUC, SCE1 and SCE2. Cumulative % variance in relation to 2030

Regions	SCE1 (var. in relation to baseline)				SCE2 (var. in relation to baseline SCE1)		SCE2 (var. in relation to baseline)	
	Agriculture	**Pasture**	**Planted Forest**	**Native Veg.**	**Agriculture**	**Native Veg.**	**Agriculture**	**Native Veg.**
RO	0.15	-0.63	0.05	0.45	-0.36	0.02	-0.20	0.47
AM-AC-RR	4.74	-4.36	-0.01	0.16	-0.07	0.00	4.67	0.16
PA-AP	0.29	-1.59	-0.51	0.33	-0.16	0.00	0.13	0.34
PI-BA	0.39	-3.48	1.50	1.25	-0.28	0.05	0.11	1.30
MA-TO	0.45	-2.51	0.50	0.88	-0.47	0.05	-0.02	0.93
Rest of the Northeast	0.00	0.00	0.05	0.00	-0.09	0.02	-0.09	0.02
MG	2.38	-4.10	1.43	1.98	-0.21	0.06	2.17	2.04
SP	0.05	0.00	-0.36	0.00	-0.02	0.02	0.03	0.02
Rest of the Southeast	0.11	0.00	-0.37	0.00	-0.19	0.08	-0.08	0.08
PR	0.06	0.00	-0.34	0.00	-0.05	0.11	0.01	0.11
Rest of the South	0.06	0.00	-0.27	0.00	-0.10	0.08	-0.04	0.08
MS	-0.03	-0.24	-0.39	0.35	-0.31	0.13	-0.34	0.48
MT	0.52	-1.54	0.18	0.56	-0.73	0.24	-0.21	0.80
GO-DF	1.46	-2.22	1.00	1.40	-0.17	0.10	1.29	1.50

Source: own elaboration.

As for economic activity sectors, in SCE1 in all regions dairy farming would free up pasture areas for beef farming (Table 19). In addition, in AM-AC-RR, PA-AP, PI-BA, MA-TO, MG, MT and GO-DF, the pasture area for beef cattle would also be reduced, freeing up areas in absolute terms that would be converted to agriculture and generate avoided deforestation.

In SCE2 it was possible to highlight the dynamics mentioned above, in which there would be an increase in the area of corn in the North and Northeast regions, and soy in the rest of Brazil, while the regions not impacted by CLI would reduce the areas for corn and soy crops, compared to what was observed in SCE1 (Table 19). This effect in SCE2 would outweigh the growth in soybean area in SCE1 in the regions of RO, PA-AP, PI-BA, MA-TO, the Rest of the Northeast and the Rest of the Southeast, which would then register a reduction in this area.

Table 4. Model results. Regional impact on LUC by sector of activity, SCE1 and SCE2. Cumulative % variance in relation to 2030. Selected sectors

Regions	SCE1 (var. in relation to baseline)				SCE2 (var. in relation to baseline SCE1)		SCE2 (var. in relation to baseline)	
	Corn Grain	Soy Grain	Cattle OtherAnim	MilkMeat OtherAnim	Corn Grain	Soy Grain	Corn Grain	Soy Grain
RO	-0.32	0.59	1.03	-18.82	0.55	-2.62	0.22	-2.05
AM-AC-RR	5.29	5.61	-2.98	-18.65	0.11	-2.11	5.40	3.38
PA-AP	0.31	1.05	-0.04	-18.74	0.34	-2.49	0.65	-1.46
PI-BA	-0.22	1.01	-2.32	-17.01	-0.01	-2.24	-0.23	-1.25
MA-TO	0.08	0.73	-1.25	-19.25	-0.20	-1.74	-0.12	-1.02
Rest of the Northeast	-0.14	0.72	1.92	-20.68	-0.03	-8.28	-0.17	-7.62
MG	1.46	2.71	-3.30	-13.07	-0.60	-0.28	0.86	2.43
SP	-0.38	0.30	1.49	-15.30	-1.44	-0.11	-1.82	0.19
Rest of the Southeast	-0.47	0.16	0.93	-13.82	-0.96	-0.20	-1.43	-0.03
PR	-0.42	0.51	1.49	-10.76	-0.64	0.10	-1.06	0.61
Rest of the South	-0.40	0.48	2.01	-16.11	-0.76	0.10	-1.15	0.58
MS	-0.57	0.24	0.87	-13.14	-1.44	0.27	-2.00	0.51
MT	-0.12	0.89	-0.09	-18.40	-3.11	0.31	-3.22	1.20
GO-DF	0.75	1.66	-0.67	-17.37	-1.57	0.20	-0.84	1.86

Source: own elaboration

3.3.1.2 Spatial Model Results

This subsection addresses the results of the spatial allocation of land uses obtained through the Spatial Modeling methodological approach. This work stage employed the land use transition rates generated by the EGC model (TERM-BR) for each application scenario of the ABC+ Plan (RDPD and RDP + CLI), namely SCE1 and SCE2, these rates were applied to the land use data in 2020 from MapBiomas with the aim of predicting where in the national territory the estimated transitions by the economic model would occur. The results are presented in an aggregated way (Brazil) and by state (Federation Unit).

Observing the results from Table 20, it is possible to make a comparison between land use in 2030 in the baseline and in the policy application scenarios to quantify its impact on stocks of native vegetation, agriculture, and pasture.

Table 21. Stocks of native vegetation, agriculture and pasture in 2030 in the baseline and in each ABC+ policy application scenario

Land use	Baseline	SCE1	SCE2
		Mha	
Native Vegetation	508.4	514.6	515.6
Agriculture	108.9	107.8	107.9
Pasture	176.9	171.8	170.7

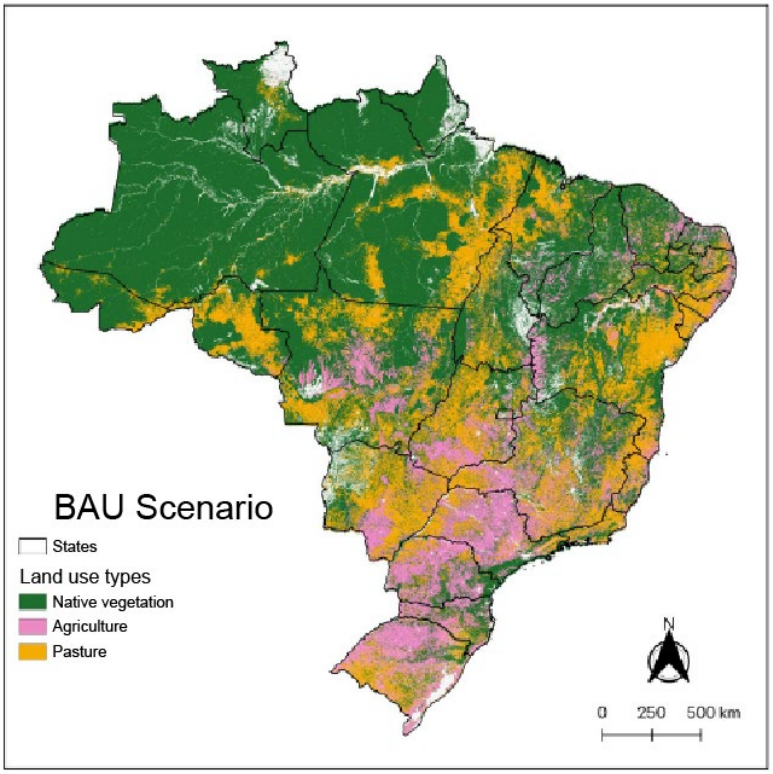
Source: own elaboration

According to the spatial modeling, the recovery of 30 Mha of degraded pastures in Brazil has the potential to promote a "land-saving" effect of about 6.2 Mha at a nationally. Out of those 6.2 Mha, 5.1 Mha would come from the reduction of pasture areas, and 1.1 Mha would come from the reduction of the area of agriculture in relation to the baseline.

By inserting the agricultural component in the recovery of degraded pastures (CLI) in Scenario 2, the "land-saving" effect would be even greater, of 7.2 Mha. Out of this area, 6.2 Mha would come from reducing the pasture area and 1 Mha would come from reducing the agricultural area in relation to the baseline. Images 5, Image 6, and Image 7 show the spatial distribution of these three uses of land in the baseline, SCE1 and SCE2, respectively.

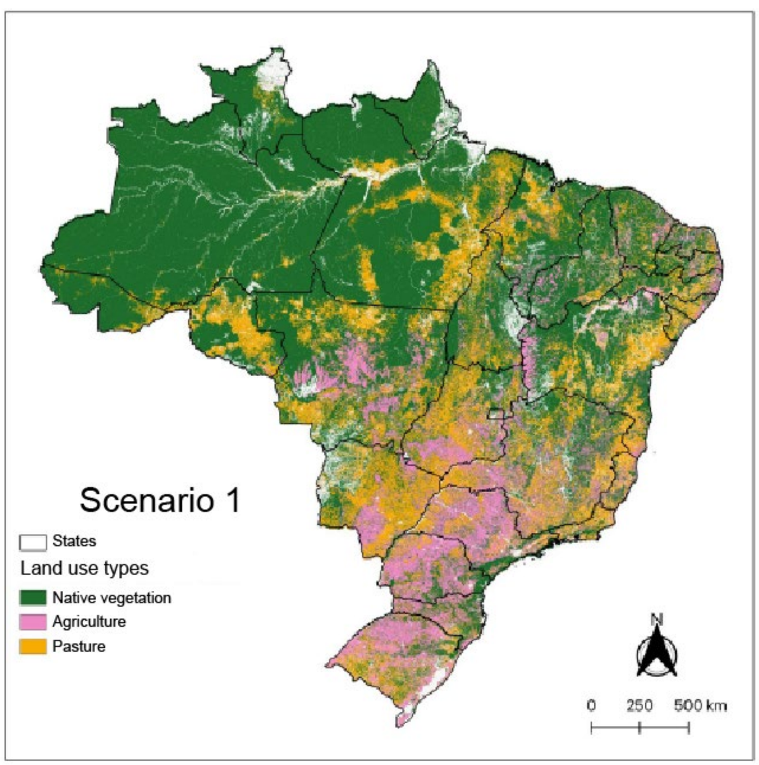
On a national scale, the "land-saving" effect would be 1.2% and 1.4% in scenarios 1 and 2, respectively. However, Table 21 shows that in some states there would be a "rebound effect", where the intensification of cattle ranching would result in an expansion of agricultural production areas over native vegetation. This effect would occur in seven states: Amapá, Ceará, Distrito Federal, Mato Grosso, Piauí, Paraná and Rio de Janeiro. In most of these states, what explains the "rebound effect" is the expansion of the pasture area, with the exception of the states of Mato Grosso and Rio de Janeiro, where the activity that would expand its area over native vegetation is agriculture.

Image 1. Land use in 2030 in the baseline (Business-as-Usual - BAU)



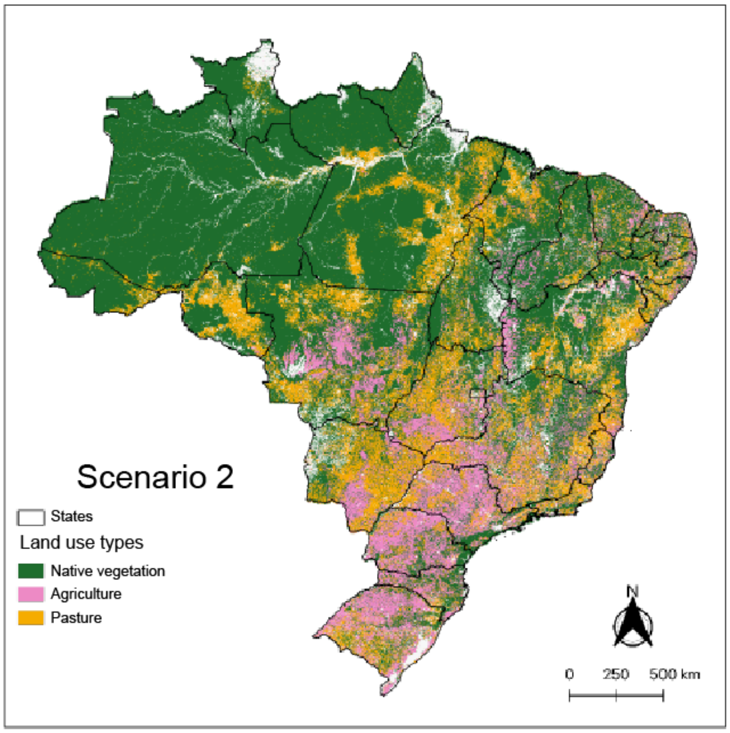
Source: Own elaboration

Image 6. Land use in 2030 in scenario 1 (RDP)



Source: own elaboration

Image 2. Land use in 2030 in scenario 2 (RDP + CLI)



Source: own elaboration

Table 22. The percentage variation of native vegetation, agriculture, and pasture stocks in scenarios 1 and 2 compared to the baseline in 2030

Greater Region	STATE	Native Vegetation		Agriculture		Pasture	
		SCE1	SCE2	SCE1	SCE2	SCE1	SCE2
NORTH	AC	3.6	3.7	1,931.9	1,965.9	-19.9	-20.3
	AM	0.1	0.1	305.9	308.6	-4.7	-5.7
	AP	-3.2	-3.1	2.3	2.2	393.9	383.0
	PA	1.4	1.5	-13.4	-13.2	-4.8	-5.3
	RO	2.0	2.3	-12.6	-12.3	-2.1	-2.5
	RR	2.0	2.0	-27.6	-27.3	-24.5	-24.9
	TO	1.5	1.9	-2.9	-2.9	-2.7	-3.4
NORTHEAST	AL	87.2	87.5	-13.4	-13.4	-22.7	-22.8
	BA	8.0	8.6	6.9	7.1	-13.1	-13.9
	CE	-7.2	-7.2	-1.2	-1.3	47.0	47.0
	MA	1.4	1.7	2.2	2.1	-4.2	-5.0
	PB	6.4	6.4	-5.0	-5.1	-8.8	-8.8
	PE	11.5	11.6	3.2	3.1	-17.2	-17.3
	PI	-7.1	-6.9	-2.5	-2.5	121.8	117.7
	RN	0.3	0.3	-15.0	-15.1	35.1	35.2
	SE	104.1	104.3	9.0	9.0	-26.7	-26.8
SOUTHEAST	ES	1.5	1.6	-6.1	-6.2	3.3	3.2
	MG	3.5	4.0	-0.9	-0.5	-3.0	-3.9

Greater Region	STATE	Native Vegetation		Agriculture		Pasture	
		SCE1	SCE2	SCE1	SCE2	SCE1	SCE2
	RJ	-5.1	-5.0	21.1	20.9	-3.2	-3.2
	SP	8.2	8.2	-4.9	-5.0	4.0	4.0
SOUTH	PR	-7.4	-7.3	3.0	3.0	4.1	4.1
	RS	21.2	21.4	-7.2	-7.2	-2.1	-2.1
	SC	3.7	3.8	-8.1	-8.2	16.1	16.1
CENTRAL-WEST	DF	-4.0	-3.7	-7.0	-6.8	22.1	20.9
	GO	1.9	2.5	1.0	1.3	-2.2	-2.8
	MS	2.1	2.6	0.0	0.4	-1.3	-1.8
	MT	-0.5	-0.1	5.2	4.9	-1.8	-2.4

Source: own elaboration

In Subsection 3.3.1.2, the following guiding questions were answered:

- Does pasture recovery decrease or increase the pressure to open up new areas (deforestation)?

On a national scale, the recovery of 30 Mha of pastures would reduce the pressure to open up new areas, resulting in 6.2 Mha (1.2%) and 7.2 Mha (1.4%) of avoided deforestation in scenarios 1 and 2.

- Does it free up areas for other uses, such as agriculture?

At a national level, there would be a reduction in the agriculture area stock in scenario 1 (-1.1 Mha, or -1%) and in scenario 2 (-1 Mha, or -0.9%) in relation to the baseline.

Natural Capital

At the state level, eleven states would have an increase in agriculture area compared to the baseline in scenario 1 (with the largest percentage increases in AM and AC), and 12 states in scenario 2 (with higher percentage increases in AP, CE, PI and RN).

- Is there a land-saving effect or a rebound effect?

On a national level, there is a land-saving effect in both scenarios, although this effect would not be enough to reverse the deforestation trend that existed in the baseline. However, at state level, a rebound effect was observed in seven states for both scenarios. In five of them there would be an increase in the area of pasture, and in four of them there would be an increase in the area of agriculture. The presence of a rebound effect stands out in the state of Mato Grosso, which is the third in the current deforestation ranking in Brazil (behind Pará and Amazonas).

3.3.2 Effects on GHG emissions

3.3.2.1 National Level

The effects on GHG emissions associated with transitions, as well as the activity level in productive sectors, fuel and input consumption are presented in this section. In SCE1, considering the original method of accounting for GHG emissions[19], the avoided deforestation would reduce the share of LUC emissions in total emissions by 1.4%, related to the baseline in 2030 (Table 22). However, growth in economic activity would imply an 11.2% increase in emissions, which would increase total emissions by 9.9% related to the baseline. This increase in emissions with the pasture recovery was also recorded by Ferreira Filho and Horridge (2016).

Table 23. Model results. Impact on emissions, SCE1 and SCE2. Variation in the contribution of each source of emissions to the total variation. Original and alternative emissions accounting methods. Accumulated % variance from baseline in 2030

Emissions accounting method	Source of emissions	SCE1 (var. related to baseline)	SCE2 (var. related to SCE1)	(var. related to baseline)
Original	LUC	-1.4	-0.2	-1.6
	Production	11.2	0.1	11.3
	Total	9.9	-0.1	9.7
Alternative	LUC	-1.3	-0.3	-1.6
	Production	0.0	0.1	0.1
	Total	-1.3	-0.1	-1.5

Source: own elaboration. *Production: emissions in intermediate consumption + activity level.

If the alternative method of accounting for GHG emissions is considered, which includes the benefits of the Soil Organic Carbon (SOC) setting, in SCE1 the emissions associated with intermediate consumption and the activity level would remain practically constant, different from what is seen in the original method (i.e., an increase of 11.2%) (Table 22). The 1.3% mitigation of emissions related to the baseline estimated by the alternative method is therefore due to the effect of land use change (LUC). Thus, carbon in the soil has the potential to more than offset the environmental implications of increased economic activity.

[19]The original GHG emissions accounting method only considers data provided by the national GHG emissions inventory. The alternative emissions method incorporates the organic carbon fixation in the soil as a benefit of changing the pasture management and recovery system, with parameters presented in Report 2, item 3.3 Elasticity of productivity-GHG emissions in cattle farming.

In SCE2, the emissions accounting method is not relevant, as cattle farming production would remain unchanged. However, as there is an increase in avoided deforestation related to SCE1, a further decrease in LUC emissions would be observed related to SCE1 (Table 22). Even with economic growth, total emissions in SCE2 would reduce by 0.1% related to SCE1.

It is observed that the main impacts on GHG emissions occur in SCE1, given the importance of cattle farming as a source of emissions. In this scenario and with the original emissions accounting method, meat and dairy farming would increase emissions by 38.36% and 14.46%, related to the baseline in 2030 (Table 23). Productivity growth would allow a small reduction in emissions intensity (GHG per unit of product), less than 1% in both sectors of economic activity.

Table 24. Model results. Impact on emissions from cattle farming, SCE1. Original and alternative emissions accounting methods. Cumulative % variance from 2030 baseline

GHG		Meat	Dairy
Original	Emissions	38.36	14.46
	Intensity	-0.42	-0.68
Alternative	Emissions	-1.04	-1.59
	Intensity	-28.78	-14.60

Source: own elaboration.

By including the SOC setting, an inversion of the sign of emissions in cattle farming activities is obtained, which now records reductions of 1.04% and 1.59%, related to the baseline in 2030, for meat and dairy, respectively (Table 23). This would provide reductions in the intensity of GHG emissions in meat and dairy in the order of 28.8% and 14.6%, respectively. Despite this result, it is noteworthy that exclusively the impact of RDP on SOC setting was considered. Additional reductions, however, could still occur due to effects on animal diet, genetics, time to slaughter, among other factors that have the potential to provide greater reductions in the intensity of GHG emissions in cattle farming. These effects were not considered in the model due to the lack of data, but they are aspects to be included in future studies.

3.3.2.2 Regional Level

As small impacts on GHG emissions were presented in SCE2, the regional analysis of emissions is focused only on SCE1. The regional impacts reinforce the national results, showing that, in the original emissions accounting method, the mitigation of emissions with avoided deforestation would not be sufficient to overcome the increase in emissions due to the level of economic activity and intermediate consumption (Table 24). The only exception would occur in the AM-AC-RR region, where the native vegetation of the Amazon biome has a high carbon coefficient. In this way, the avoided deforestation makes an important contribution to regional mitigation. It is also observed that, despite the growth in total emissions in all regions, the magnitudes show regional heterogeneity in GHG emissions. The differences are the result of a combination of factors, such as the size of the productivity impact on livestock, the share of livestock in the value of regional production, growth in the level of activity (GDP), among others.

Table 25. Model results. Impact on emissions, SCE1. Original and alternative emissions accounting methods. Accumulated % variance from baseline in 2030

Regions	Original (w/o SOC) *	Alternative (w/ SOC)
RO	22.2	-0.3
AM-AC-RR	-9.6	-15.4
PA-AP	7.4	-2.0
PI-BA	9.0	-2.4
MA-TO	11.0	-3.1
Rest of the Northeast	16.1	-0.4
MG	5.2	-2.9
SP	4.0	-0.1
Rest of the Southeast	2.9	-0.8
PR	6.4	0.9
Rest of the South	10.7	0.5
MS	35.0	-0.2
MT	18.2	-2.0
GO-DF	14.5	-0.9

* Soil Organic Carbon setting - SOC

Source: own elaboration.

With the alternative emissions accounting method, there would be an inversion of emissions in the activity level due to mitigations in 12 of the 14 regions of the model. In regions where increases in emissions would still occur (PR and rest South), the values would be reduced to less than 1% related to the baseline (Table 24). The permanence of the emissions level would be related both to the shock size to productivity and economic growth, to productivity-mitigation elasticities and to the intensity of GHG emissions originally observed in the regions.

Regarding emissions from cattle farming, it is observed that in the original emission accounting method, variations in emissions occur proportional to increases in productivity (Table 25). This occurs because efficiency gains, without changing emission parameters, generate negligible changes in emission intensity, which grow proportionally to production. When the SOC setting is incorporated, meat and dairy farming begins to mitigate GHG emissions in all regions of Brazil.

Table 26. Model results. Impact on emissions from cattle farming, SCE1. Original and alternative emissions accounting methods. Accumulated % variance from baseline in 2030

Regions	Emissions				Emissions Intensity			
	MeatOtherAni		MilkCattleOtherAni		MeatOtherAni		MilkCattOtherAni	
	Orig	Altern	Orig	Altern.	Orig	Altern.	Origin	Altern.
RO	5.7	0	16.6	-1.0	0.4	-31.6	0.8	-15.7
AM-AC-RR	0.7	0.2	-7.5	-1.4	0.2	-10.1	0.6	6.0
PA-AP	8.8	0.1	4.3	-1.1	0.3	-22.7	0.7	-5.9
PI-BA	3.1	1.0	12.7	-2.2	0.4	-25.9	0.7	-13.8
MA-TO	0.7	1.4	6.5	-3.5	0.3	-24.8	0.7	-10.0
Rest Northeast	8.4	1.4	15.1	-1.7	0.4	-33.8	0.7	-15.2
MG	6.8	2.0	13.6	-1.1	0.4	-23.0	0.7	-13.6
SP	3.3	0.4	27.5	-0.9	0.4	-35.3	0.7	-22.8
Rest Southeast	5.0	3.1	23.3	-1.7	0.4	-33.4	0.8	-20.9
PR	7.0	0.4	11.2	-0.9	0.2	-21.8	0.7	-11.5
Rest South	1.3	2.3	15.8	-2.2	0.3	-31.1	0.7	-16.1
MS	0.1	1.0	37.3	-7.3	0.5	-38.4	0.9	-33.1
MT	1.6	0.7	15.1	-4.3	0.4	-30.2	0.8	-17.5
GO-DF	5.1	0.5	12.0	-1.2	0.4	-26.6	0.7	-12.4

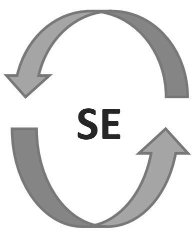
Source: own elaboration.

Subsection 3.3.2 provided answers to the following guiding questions:

- Are there changes in emissions intensity (GHG per product)?

The RDP would result in a reduction in the intensity of cattle farming emissions of less than 1% related to the baseline in 2030. However, incorporating the soil organic carbon setting in the estimate, it could be possible to reduce the intensity by 28.8% and 14.6%, for meat and dairy farming, respectively.

- Does the adoption of technology contribute to the setting of C in the soil?



The RDP in the traditional system could result in sufficient soil organic carbon setting to maintain the volume of emissions resulting from the activity level and input use, related to the baseline in 2030, even with higher production. This means that soil C setting would be capable of reversing the potential 11.2% growth in emissions that would be observed without the inclusion of soil carbon setting parameters in the emissions estimate.

- What is the effect of the RDP on GHG emissions between different sectors of the economy, especially in the cattle farming sector (meat and dairy)?

In the original emissions accounting method, the expansion of meat and dairy farming would result in an increase of 38.4% and 14.5% in GHG emissions, respectively, related to the baseline in 2030, at the national level. However, considering soil carbon setting estimate, there would be mitigation of 1% and 1.6%, respectively.

3.3.3 Effects on habitat maintenance

By measuring indicators of **quantity** (native vegetation coverage area) and **quality** (size of fragments capable of maintaining biodiversity, core area of fragments and functional connectivity) it seeks to evaluate the possible impact of implementing the ABC+ policy in terms of the habitat maintenance service. This analysis was carried out for the Baseline (BAU) and for the two policy application scenarios (SCE1: RDP and SCE2: RDP + CLI) and for each state in Brazil and the Distrito Federal.

3.3.3.1 Quantity indicator: native vegetation coverage area

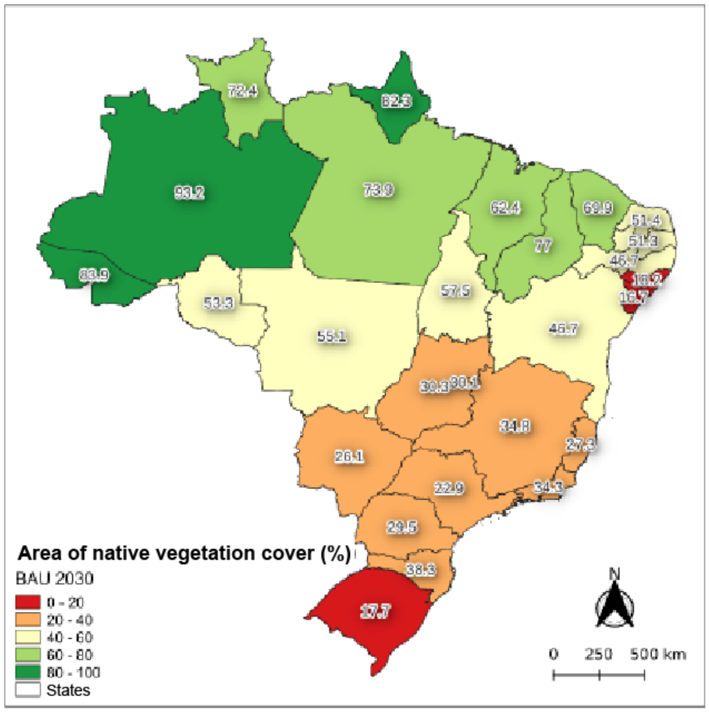
In the BAU scenario (2030), all states in the North region would have a percentage above the coverage threshold of 30% of native vegetation area[20], which according to Banks-Leite and collaborators (2014), can guarantee the species conservation and the ecological integrity maintenance to a level similar to that observed in protected areas. This 30% threshold was also established as a habitat conservation target for several biomes by the UN Biodiversity Conference (COP 15). In the Northeast and Central-West regions, respectively, only the states of Alagoas (18.2%), Sergipe (16.7%) and Mato Grosso do Sul (26.1%) would present values below this threshold. In the Southeast region, these values would be lower for São Paulo (22.9%) and Espírito Santo (27.3%). As for the South region, only Santa Catarina (38.3%) would obtain a native vegetation coverage value above 30% (Image 8).

In general, in both SCE1 and SCE2 there would be an increase in the vegetation percentage (higher in SCE2), with the exception of MT, AP, PI, CE, RJ, PR and DF. This percentage increase would be enough to raise the AL and SE states above the 30% threshold. However, DF would be demoted (Image 9 and Image 10).

In general, in both scenarios evaluated (SCE1 and SCE2) there would be a decrease in the percentage of remnants that come from natural regeneration processes (past suppressions that are recovering), showing that an increase in native vegetation would be a result of the avoided deforestation (Image 11 and Image 12).

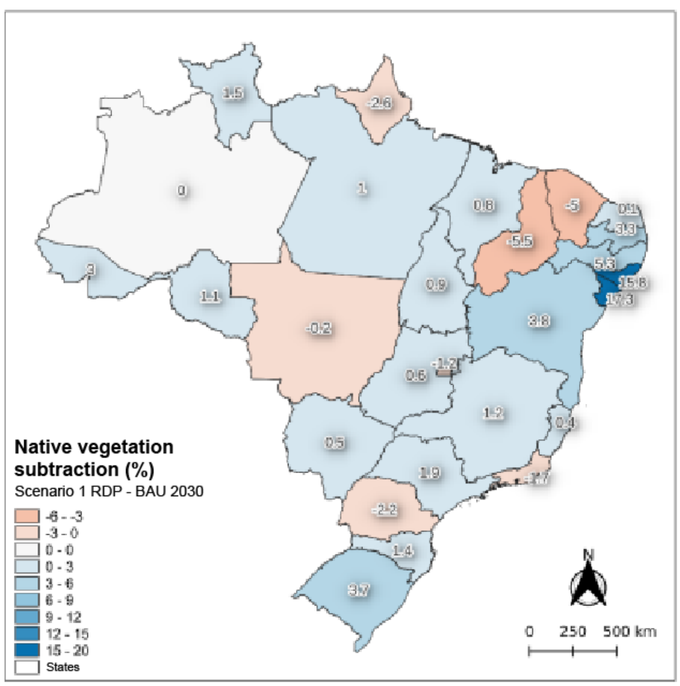
[20] There are references that can support "tipping-point" for specific geographic areas (Amazon, Pantanal, etc.), however the 30% threshold was used in this study because it is a consensus on a global scale and because the present analysis was focused on the state scale, not in the biome sections. However, it is important to highlight that the total native vegetation area metric was calculated independently of the thresholds, followed by extensive discussion and comparison between the values achieved.

Image 8. Native vegetation coverage (%) present in Brazilian states in the baseline (2030)



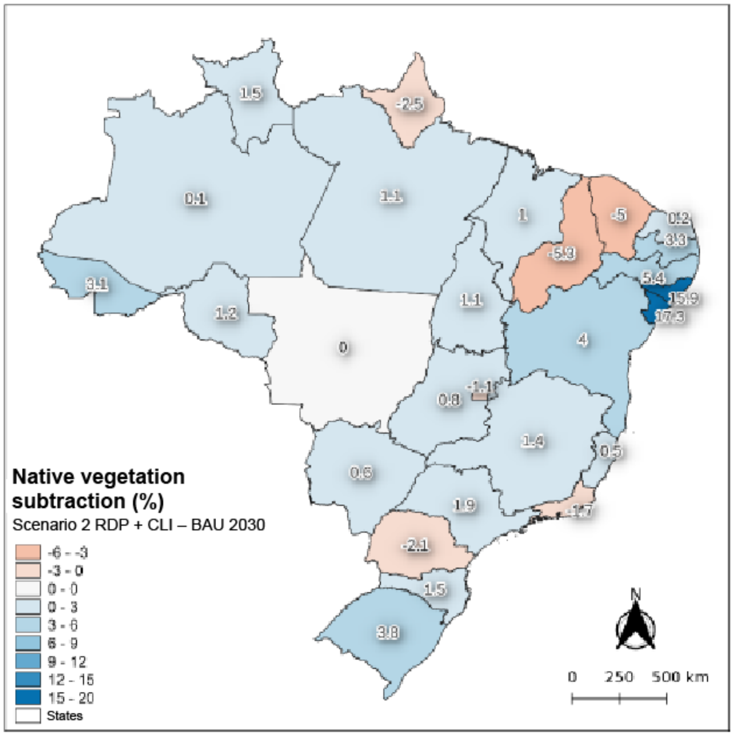
Source: Own elaboration

Image 9. Subtraction of the native vegetation coverage area (%) between the scenarios BAU and SCE1 (RDP)



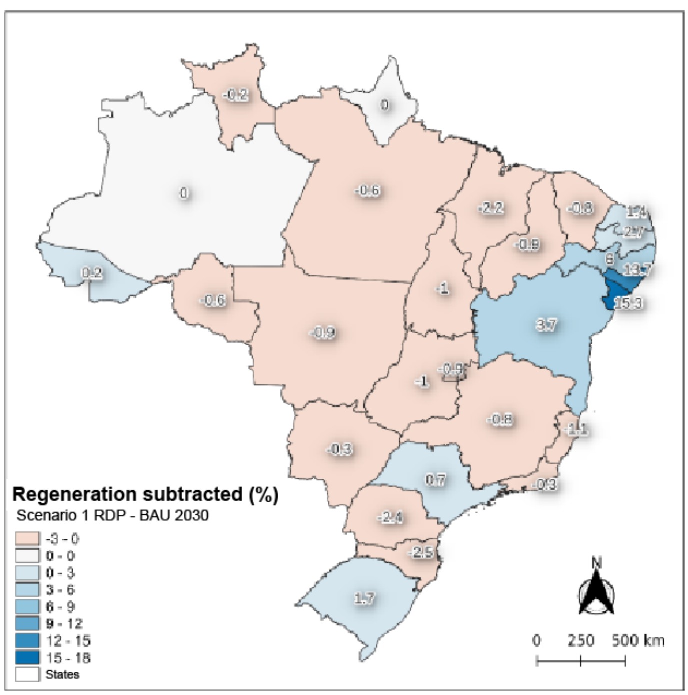
Source: Own elaboration

Image 10. Subtraction of the native vegetation coverage area (%) between the scenarios BAU and SCE2 (RDP + CLI)



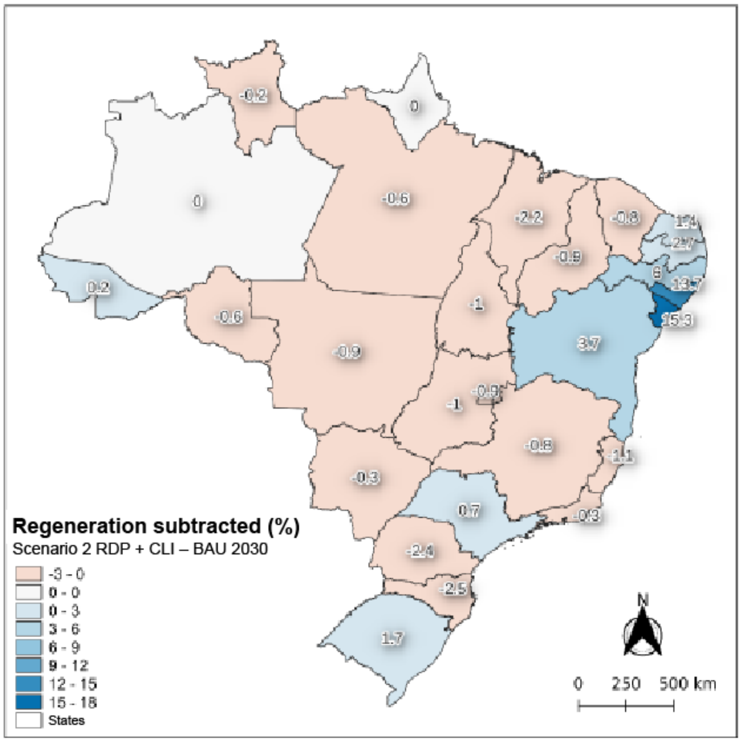
Source: Own elaboration

Image 11. Subtraction of the natural regeneration area (%) between the scenarios BAU and SCE1 (RDP)



Source: Own elaboration

Image 12. Subtraction of the natural regeneration area (%) between the scenarios BAU and SCE2 (RDP + CLI)



Source: Own elaboration

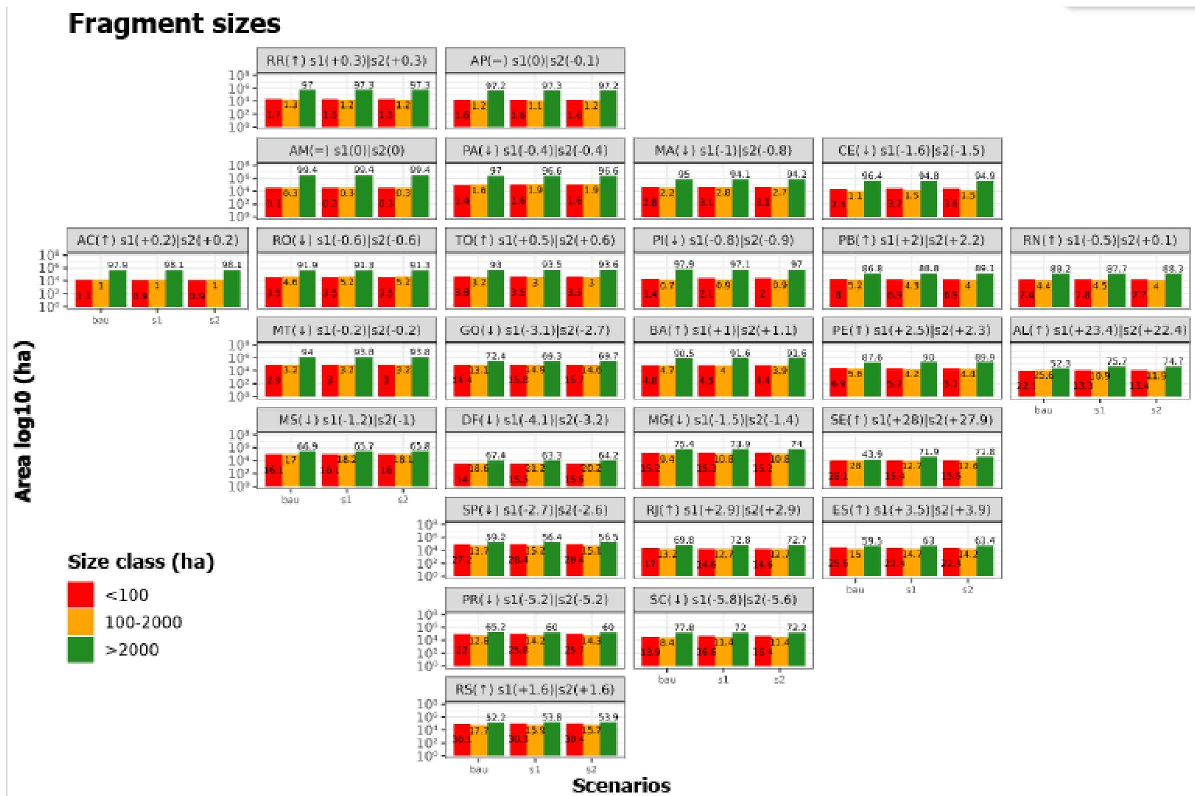
3.3.3.2. Quality indicator: fragment size

The results of comparing scenarios 1 and 2 with the BAU showed that there would be both an increase and a decrease in the proportion of vegetation fragments in the classes of analyzed size. Only the states of Amapá and Amazonas would not have changes in the proportions of fragment size classes. Rio Grande do Norte would be the only state that would obtain different patterns between the scenarios, with a decrease of -0.5% in SCE1 and a slight increase of +0.1 in SCE2. It is important to highlight that in general the effect of SCE1 and SCE2 on the proportion of vegetation fragments in the classes analyzed was practically the same compared to BAU, with no significant differences between them.

It was observed that there would be an increase in the proportion in the size class of fragments above 2000ha in the North region, in the states of Roraima (+0.3%), Acre (+0.2%) and Tocantins (+0.6%); in the Northeast region, in the states of Paraíba (+2.2%), Bahia (+1.1%), Pernambuco (+2.2%), Alagoas (+23.4%) and Sergipe (+28%); in the Southeast region, in the states of Rio de Janeiro (+2.9%), Espírito Santo (+3.9%); and in the South region only the state of Rio Grande do Sul (+1.6%). In this analysis, the increase in the fragment size class proportion would be greater in the states of Alagoas and Sergipe, increasing the fragments proportion above 2000ha by 23.4% and 28% compared to the BAU situation.

A negative effect of the application of scenarios 1 and 2 for this indicator was also found in the rest of the states. There would be a decrease in the fragment size class proportion above 2000ha in the North region, in the states of Pará (-0.4%) and Rondônia (-0.6%); in the Northeast region, in the states of Maranhão (-1.0%), Ceará (-1.6%), Piauí (-0.9%); in the Central-West region, in the states of Mato Grosso (-0.2%), Goiás (-3.1%), Mato Grosso do Sul (-1.2%) and Distrito Federal (-4.1%); in the Southeast region, in the states of Minas Gerais (-1.5%), São Paulo (-2.7%); and in the South region, in the states of Paraná (-5.2%) and Santa Catarina (-5.8%). The decrease in the fragment size class proportion would be greater in the states of Paraná and Santa Catarina, which would downgrade the fragments proportion above 2000ha by -5.2% and -5.8% compared to the BAU situation (Image 13).

Image 13. Effect of applying the RDP (s1) and RDP+CLI (s2) scenarios related to BAU on the fragment size indicator. Each set of graphs represents the size class in BAU, s1 and s2 for each Brazilian state. The gray bar above each graph indicates the growth (up arrow), decline (down arrow) or stability (=) of the data against the scenarios and their respective proportional gains or losses.



Source: Own elaboration

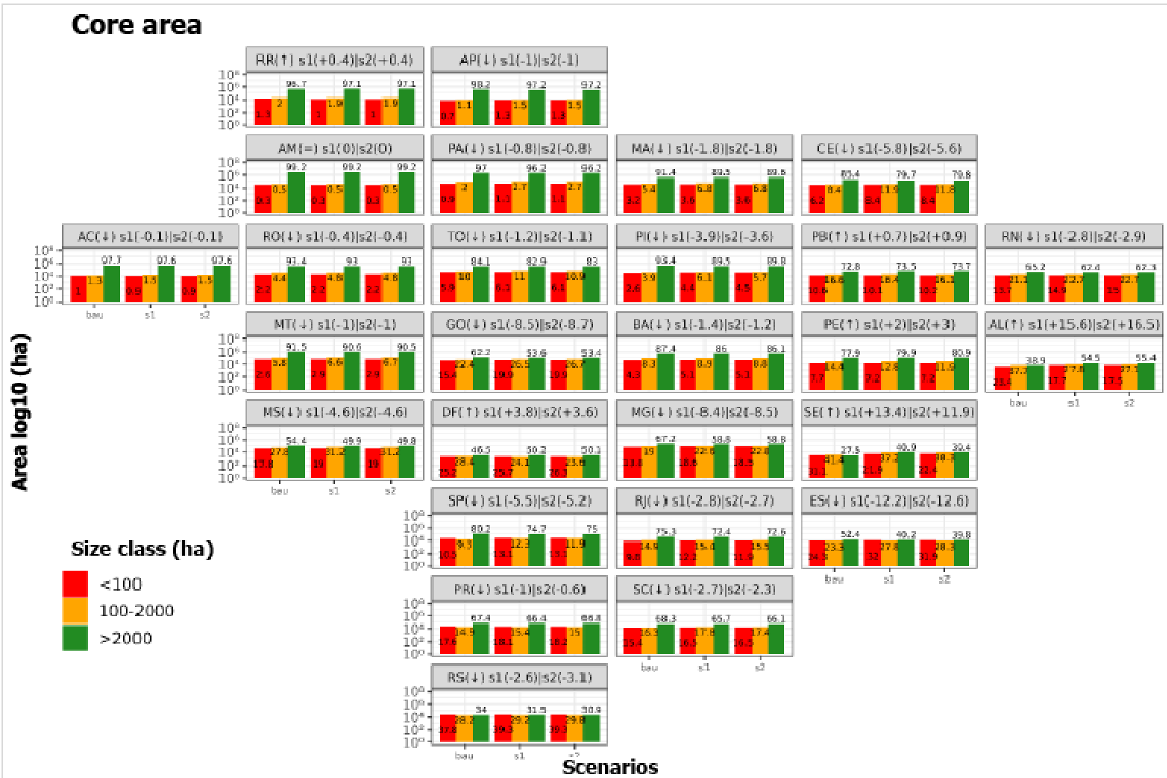
3.3.3.3 Quality indicator: core area

Similar to the previous indicator, the comparison between the scenarios with the BAU resulted in an increase and decrease in the core area proportion analyzed between the states. Furthermore, in the state of Amazonas, no changes in the size class proportions of the core area would be observed due to the large portions of habitat that the scenarios presented. It is important to highlight that the effect of SCE1 (RDP) and SCE2 (RDP+CLI) was practically the same compared to BAU, with no significant differences between them (with exceptions for the states of Sergipe, Paraná and Rio Grande do Sul).

It was observed that there would be an increase in the size class proportion of core areas above 2000ha in the North region, in the state of Roraima (+0.4%); in the Northeast region, in the states of Paraíba (+0.9%), Pernambuco (RDP +2%; RDP+CLI +3%), Alagoas (+16.5%) and Sergipe (RDP +13.4%; RDP +CLI +11.9%); in the Central-West region, in the Distrito Federal (+3.8%). In this analysis, the increase in the fragment size class proportion would be greater in the states of Alagoas and Sergipe, increasing the proportion of core areas above 2000ha by up to 16.5% compared to the BAU situation.

It was also found that there would be a negative effect of applying the scenarios for this indicator in the rest of the states. There would be a decrease in the proportion of the size class of core areas in the North region, in the states of Amapá (-1.0%), Acre (-0.1%), Rondônia (-0.4%), Pará (-0 .8%), Tocantins (-1.2%); in the Northeast region, in the states of Maranhão (-1.8%), Ceará (-5.8%), Piauí (-3.9%), Paraíba (-0.9%), Rio Grande do Norte (-2 .9%), Bahia (-1.4%); in the Central-West region, in the states of Mato Grosso (-1%), Goiás (-8.7%), Mato Grosso do Sul (-4.6%); in the Southeast region, in the states of Minas Gerais (-8.5%), São Paulo (-5.5%), Rio de Janeiro (2.8%), Espírito Santo (-12.6%); and in the South region, in the states of Paraná (RDP -1%; RDP+CLI -0.6%), Santa Catarina (-2.7% and Rio Grande do Sul (RDP -2.6%; RDP+CLI - 3.1%). The decrease in the fragment size class would be significant in the states of Minas Gerais and Espírito Santo, which would downgrade the core area proportion of up to -12.6% compared to the BAU situation (Image 14).

Image 14. Effect of applying the RDP (s1) and RDP+CLI (s2) scenarios related to BAU on the core area indicator. Each set of graphs represents the size class in BAU, s1 and s2 for each Brazilian state. The gray bar above each graph indicates the growth (up arrow), decline (down arrow) or stability (=) of the data against the scenarios and their respective proportional gains or losses.



Source: Own elaboration

3.3.3.4 Quality indicator: functional connectivity

Connectivity is a landscape property that strongly influences the abundance and distribution of species, being a key aspect for understanding interactions between organisms and the ecological processes resulting from such interactions (e.g., Curtin & Tabor, 2016; Fletcher & Fortin, 2018). Furthermore, functional metrics, such as functional connectivity, consider the capacity and response of species to the landscape structure (Riva & Nielsen, 2020). The functionally connected areas considering the ability to cross a distance of 100m between fragments were categorized into three size classes: 0 to 100ha, 100 to 2000ha and above 2000ha.

Again, similar to the previous indicator, the comparison between scenarios 1 (RDP) and 2 (RDP+CLI) with the BAU would result in both an increase and a decrease in the proportion in the size classes analyzed. Furthermore, the states of Amazonas, Amapá, Pará and Mato Grosso would not have changes in the size class proportions of functionally connected areas. It is important to highlight that the effect of scenarios 1 and 2 was practically the same compared to BAU, with no major differences between the scenarios. However, the states of

Roraima (RDP 0%, RDP+CLI +0.1%), Maranhão (RDP -0.1%, RDP+CLI 0%), Ceará (RDP -0.1%, RDP+CLI 0%) obtained different patterns between the scenarios.

It was observed that there would be an increase in the proportion in the size class of core areas above 2000ha in the North region, in the states of Acre (+0.4%) and Tocantins (+0.3%); in the Northeast region, in the states of Alagoas (+14.7%), Bahia (+0.7%), Paraíba (+0.7%), Pernambuco (+2.0%) and Sergipe (+20.5%); in the southeast region in the states of Minas Gerais (+1.1%), São Paulo (+2.5%), Rio de Janeiro (+1.4%), Espírito Santo (+3.4%; +2.4 %); and in the South region in the states of Rio Grande do Sul (+2.8%) and Santa Catarina (+0.9%). In this analysis, the increase in the fragment size class proportion would be significant in the states of Alagoas and Sergipe, increasing the proportion of functionally connected areas above 2000ha by up to 20.5% compared to the BAU situation.

A negative effect of applying the scenarios for this indicator was also found in the rest of the states. It was observed that there would be a decrease in the size class proportion of core areas in the North region, only in the state of Rondônia (-0.4%); in the Northeast region, Piauí (-0.1%); in the Central-West region in the states of Goiás (-0.9%), Mato Grosso do Sul (-1.0%) and Distrito Federal (-1.3%); in the South region, only in Paraná (-2.4%) (Image 15). Table 26 summarizes the main results of the work.

Table 27. Summary of main percentage results[21] achieved with indicators of quantity and quality of habitat maintenance in the baseline (BAU) and in SCE1 (RDP) and SCE2 (RDP+CLI)*

States	**Native vegetation cover area**			**Fragment size**		**Core Area**		**Functional connectivity**	
	BAU	*SCE (RDP)*	*SCE2 (RDP+CLI)*	*SCE1*	*SCE (RDP+CLI)*	*SCE1 (RDP)*	*SCE2 (RDP+CLI)*	*SCE1 (RDP)*	*SCE2 (RDP+CLI)*
Acre	83.9	+3.0	+3.1	+0.2	+0.2	-0.1	-0.1	+0.4	+0.4
Amapá	82.3	-2.6	-2.5	0.0	0.1	-1.0	-1.0	0.0	0.0
Amazon	93.2	0.0	+0.1	0.0	.0	0.0	0.0	0.0	0.0
Pará	73.9	+1.0	+1.1	-0.4	-0.4	-0.8	-0.8	0.0	0.0
Rondônia	53.3	+1.1	+1.2	-0.6	-0.6	-0.4	-0.4	-0.4	-0.4
Roraima	72.4	+1.5	+1.5	+0.3	+0.3	+0.4	+0.4	0.0	+0.1
Tocantins	57.5	+0.9	+1.1	+0.5	+0.6	-1.2	-1.1	+0.3	+0.3
Alagoas	18.2	+15.8	+15.9	+23.4	+22.4	+15.6	+16.5	+14.7	+14.7
Bahia	46.7	+3.8	+4.0	+1.0	+1.1	-1.4	-1.2	+0.6	+0.7
Ceará	69.9	-5.0	-5.0	-1.6	-1.5	-5.8	-5.6	-0.1	0.0
Maranhão	62.4	+0.8	+1.0	-1.0	-0.8	-1.8	-1.8	-0.1	0.0
Paraíba	51.3	+3.3	+3.3	+2.0	+2.2	+0.7	+0.9	+0.7	+0.6
Pernambuco	46.7	+5.3	+5.4	+2.5	+2.3	+2.0	+3.0	+2.0	+2.0
Piauí	77.0	-5.5	-5.3	-0.8	-0.9	-3.9	-3.6	-0.1	-0.1

Rio Grande do Norte	51.4	+0.1	+0.2	-0.5	+0.1	-2.8	-2.9	+0.2	+0.2
Sergipe	16.7	+17.3	+17.3	+28.0	+27.9	+13.4	+11.9	+20.5	+20.5
Distrito Federal	30.1	-1.2	-1.1	-4.1	-3.2	+3.8	+3.6	-0.5	-1.3
Goiás	30.3	+0.6	+0.8	-3.1	-2.7	-8.5	-8.7	-0.9	-0.6
Mato Grosso	55.1	-0.2	0.0	-0.2	-0.2	-1.0	-1.0	0.0	0.0
Mato Grosso do Sul	26.1	+0.5	+0.6	-1.2	-1.0	-4.6	-4.6	-1.0	-0.9
Espírito Santo	27.3	+0.4	+0.5	+3.5	+3.9	-12.6	-12.6	+3.4	+2.4
Minas Gerais	34.8	+1.2	+1.4	-1.5	-1.4	-8.4	-8.5	+1.0	+1.1
Rio de Janeiro	34.3	-1.7	-1.7	+2.9	+2.9	-2.8	-2.7	+1.4	+1.2
São Paulo	22.9	+1.9	+1.9	-2.7	-2.6	-5.5	-5.2	+2.3	+2.5
Paraná	29.5	-2.2	-2.1	-5.2	-5.2	-1.0	-0.6	-2.4	-2.3
Rio Grande do Sul	17.7	+3.7	+3.8	+1.6	+1.6	-2.6	-3.1	+2.7	+2.8
Santa Catarina	38.3	-2.2	+1.5	-5.8	-5.6	-2.7	-2.3	+0.9	+0.8

Source: Own elaboration.

**For BAU, the green color indicates values above the 30% threshold (Banks-Leite et al., 2014) and red indicates values below this threshold. For SCE1 and SCE2, the green color indicates a percentage increase, red a decrease and blue the stability of the evaluated habitat maintenance indicators.*

[21]The percentage variations expressed in the table and throughout the text are always related to the baseline (BAU).

Image 15. Effect of applying the RDP (s1) and RDP+CLI (s2) scenarios related to BAU on the functional connectivity indicator. Each set of graphs represents the size class in BAU, s1 and s2 for each Brazilian state. The gray bar above each graph indicates the growth (up arrow), decline (down arrow) or stability (=) of the data against the scenarios and their respective proportional gains or losses

Source: Own elaboration

Subsection 3.3.2 answered the following guiding question:

- Does the adoption of technology contribute to the habitat maintenance?

After applying the policy, in general, in both scenarios (RDP and RDP+CLI), there would be, related to the baseline, an increase in the native vegetation cover area, including in the states with the largest cattle herds. However, there would be no improvement in habitat quality indicators (fragment size, core area and functional connectivity).

The pasture recovery in both scenarios would contribute to the increase of all indicators related to the quantity and quality of habitats in the states of Roraima, Alagoas, Paraíba, Pernambuco and Sergipe. However, it would decrease all indicators related to the quantity and quality of habitats in the states of Ceará, Piauí and Paraná.

In the BAU scenario, only the states of Alagoas, Sergipe, Mato Grosso do Sul, Espírito Santo, São Paulo, Paraná, Rio Grande do Sul would not reach the threshold of 30% native vegetation coverage. After applying the policy (in both scenarios: CEN1 and CEN2), there would be an increase in the vegetation percentage, with the exception of MT, AP, PI, CE, RJ, PR and DF. This increase was enough to raise the AL and SE states above the 30% threshold. However, DF would be downgraded.

Overall, there would be a decrease in the percentage of remnants that come from natural regeneration processes, showing an increase in native vegetation due to the avoided deforestation.

In the North region, in the states of Pará and Rondônia, despite there being an increase in the amount of native vegetation cover, a worsening in habitat quality indicators would be observed, in both scenarios of the policy application. The state of Amazonas was the least influenced by the policy application.

In the Northeast region, for the states of Sergipe and Alagoas, the increase in vegetation would be large for all indicators related to habitat maintenance.

In the Southeast and South regions, with the exception of Paraná, in all states there would be an increase in functional connectivity after the application of the RDP.

3.3.4 Spatial allocation of RDP and RDP+CLI

This section deals with the spatial allocation of the pasture that would be recovered in the two policy application scenarios evaluated in this study. As this allocation must occur in degraded pasture areas, it was necessary to identify them. This identification for both scenarios was made based on the pasture area obtained in spatial modeling (section 3.3.1.2) and the location of the degraded pasture area in 2020 defined by LAPIG[22].

According to the simulation, the area of degraded pastures in Brazil, in 2030, would be 79.3 Mha in BAU, 80.7 Mha in SCE1 and 80.5 in SCE2. And the states with the largest area would be Mato Grosso, Minas Gerais and Mato Grosso do Sul, in the three scenarios (See Image 16). The location definition of the recovered pasture areas was based on the analysis of degraded pasture areas in 2020[23] in rural properties[24]. Table 27 and Table 28 summarize the results obtained on the total number of pastures recovered in traditional ways (SCE1 and SCE2) and with CLI (SCE2)[25] by state and by rural property size.

According to the RDP allocation projected in SCE1, 10 million hectares of pasture would be recovered in properties with more than 1,000 hectares, with almost half of this recovery being concentrated in the states of Mato Grosso and Mato Grosso do Sul. Properties with less than 50 hectares have the potential to recover just over 5 million hectares, with emphasis on the recovery of 1.3 million hectares in the state of Bahia and 1 million hectares in Minas Gerais. A similar dynamic occurs in the pasture recovery allocation in SCE2, which simulates that 6 million hectares of pasture would be recovered through CLI technology. Of these, the allocation methodology indicates that 2 million hectares would be in the state of Mato Grosso, of which 1.2 million hectares would be concentrated in rural properties with more than 1,000 hectares. It is worth mentioning that, according to the methodology, the RDP allocation carried out with CLI occurs in the best-ranked properties based on agricultural suitability, infrastructure conditions and access to rural credit.

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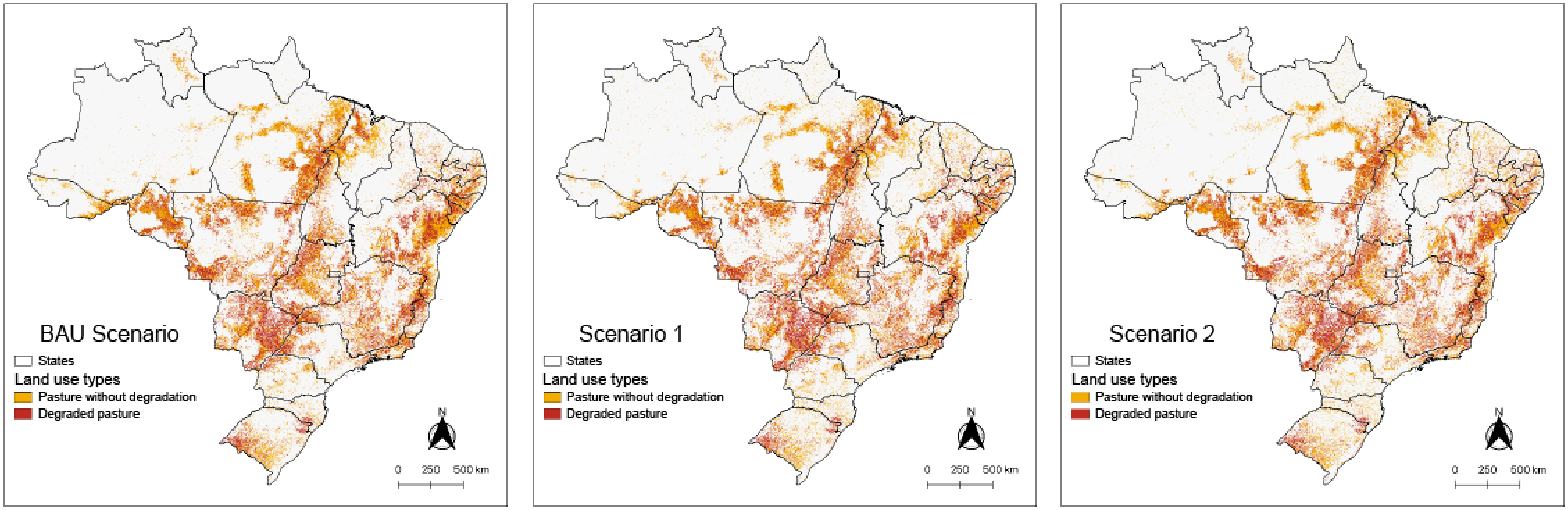
[22] Details of the methodology.
[23] Pasture with intermediate or severe degradation according to LAPIG classification.
[24] Rural properties in Brazil's land network estimated by Freitas et.al, (2018).
[25] Remembering that only part of the pastures recovered in scenario 2 would be via CLI.

Image 16. Spatial distribution of pasture and degraded pasture in the BAU, SCE1 and SCE2 scenarios in 2030



Source: Own elaboration.

Table 28. Pasture area recovered in conventional ways (in thousand hectares) by state and property size (SCE1)

Large Region	State	Property size (in thousand hectares) 0-50	50-100	100-500	500-1,000	>1,000	Total Area (thousand ha)
NORTH	RO	252	273	433	144	262	1,365
	AC	18	13	23	11	53	118
	AM	13	20	52	22	79	186
	RR	3	17	23	12	32	87
	PA	128	220	631	324	1,115	2,417
	AP	0.1	0.1	0.1	0.1	0.0	0,4
	TO	33	54	330	239	551	1,207
NORTHEAST	MA	112	102	317	105	208	844
	PI	116	49	31	7	19	222
	CE	122	60	85	16	24	306
	RN	59	23	40	11	10	143
	PB	142	39	81	14	14	290
	PE	339	107	164	32	38	680
	AL	115	31	80	24	26	276
	SE	107	39	73	15	14	247
	BA	1,332	403	796	316	542	3,388
SOUTHEAST	MG	1,010	663	1483	434	476	4,066
	ES	133	73	140	34	32	413
	RJ	91	56	125	27	21	320
	SP	317	62	347	101	121	1,047
SOUTH	PR	144	55	148	43	36	426
	SC	51	25	75	26	16	194
	RS	118	95	409	207	273	1,102
CENTRAL-WEST	MS	66	64	542	566	2,264	3,501
	MT	155	191	906	563	2,605	4,420
	GO	168	177	779	482	992	2,598
	DF	5	1	5	2	8	21
Brazil		5,149	3,012	8,117	3,776	9,830	29,885

Source: Own elaboration.

Table 29. Pasture area recovered in conventional ways/carried out in CLI (in thousand hectares) by state and property size (SCE2)

Large Region	State	Property size (in thousand hectares) 0-50	50-100	100-500	500-1,000	>1,000	Total Area (thousand ha)
NORTH	RO	244 / 8	265 / 9	419 / 14	139 / 4	253 / 8	1.320 / 44
	AC	18 / 0	13 / 0	23 / 0	11 / 0	53 / 0	118 / 0
	AM	13 / 0	20 / 0	52 / 0	22 / 0	79 / 0	186 / 0,1
	RR	3 / 0	15 / 1	21 / 2	11 / 1	29 / 3	80 / 7
	PA	125 / 3	214 / 5	615 / 15	316 / 8	1,087 / 26	2,357 / 58
	AP	0.1 / 0	0.1 / 0	0.1 / 0	0,1 / 0	0 / 0	0.4 / 0

Large Region	State	Property size (in thousand hectares)					Total Area (thousand ha)
		0-50	50-100	100-500	500-1,000	>1,000	
	TO	31 / 3	49 / 4	303 / 27	219 / 20	506 / 45	1,108 / 99
NORTHEAST	MA	96 / 16	87 / 14	273 / 45	90 / 15	179 / 28	725 / 118
	PI	76 / 40	32 / 17	9 / 23	3 / 4	12 / 6	132 / 90
	CE	90 / 32	45 / 16	55 / 30	11 / 6	17 / 6	217 / 89
	RN	34 / 24	13 / 9	20 / 21	6 / 6	6 / 4	79 / 64
	PB	121 / 21	33 / 6	68 / 13	12 / 2	12 / 2	246 / 44
	PE	305 / 34	96 / 11	148 / 16	29 / 3	34 / 4	612 / 68
	AL	105 / 11	29 / 3	73 / 7	21 / 2	24 / 2	251 / 25
	SE	103 / 4	37 / 1	70 / 3	14 / 1	13 / 0	237 / 9
	BA	1,248 / 84	377 / 25	746 / 50	296 / 20	508 / 34	3,175 / 213
SOUTHEAST	MG	923 / 87	606 / 57	1,355 / 128	397 / 37	437 / 38	3,719 / 347
	ES	91 / 43	50 / 23	95 / 44	24 / 11	22 / 10	282 / 131
	RJ	70 / 21	43 / 13	97 / 28	21 / 6	17 / 4	249 / 71
	SP	317 / 0	162 / 0	347 / 0	101 / 0	122 / 0	1,047 / 0
SOUTH	PR	58 / 86	22 / 33	59 / 89	17 / 26	14 / 21	171 / 256
	SC	0 / 51	0 / 25	1 / 74	0 / 26	0 / 16	2 / 192
	RS	55 / 63	45 / 51	192 / 217	97 / 109	129 / 144	518 / 584
CENTRAL-WEST	MS	55 / 10	54 / 10	456 / 85	477 / 89	1,902 / 357	2,945 / 552
	MT	81 / 74	100 / 91	476 / 430	295 / 267	1,367/ 1.238	2,320 / 2,100
	GO	116 / 52	122 / 55	538 / 241	333 / 149	686 / 307	1,795 / 803
	DF	1 / 4	0 / 1	1 / 4	1 / 2	2 / 6	5 / 16
Brazil		4,379/ 770	2,531 / 481	6,511/1.607	2,962 / 814	7,513/ 2.311	23,897 / 5,983

Source: Own elaboration.

Image 17 shows the spatial distribution of pastures without degradation[26], degraded pastures[27] and recovered pastures in scenarios 1 and 2. In the state of Mato Grosso, pasture recovery would be concentrated in the north, east and southwest portions of the state. More than 50% of the 4.4 million hectares of RDP projected in the state are located in 14 of its 141 cities. Already 53% of the pasture recovery carried out with CLI designed in the state would be in just 7 cities in Mato Grosso.

[26]Pasture areas without degradation are those that were not identified as degraded and areas that transitioned to pasture (that is, they were identified as native vegetation, agriculture or others and in the 2030 projection were classified as pasture).

[27]The pasture areas of the scenarios were classified as degraded based on degraded pasture data (LAPIG) from 2020.

In Goiás, the São Miguel do Araguaia and Rio Vermelho microregions would be responsible for 53% of the RDP projected in the state by SCE1. And related to the RDP carried out with CLI, the São Miguel do Araguaia microregion would concentrate 77% of the area projected for the state.

A similar concentration would occur in the state of Mato Grosso do Sul, where 57% of the RDP area would be in the micro-region of Três Lagoas. By adding the RDP from the Alto Taquari and Paranaíba microregions, 85% of the state's RDP area would be reached. Furthermore, the micro-region of Três Lagoas would concentrate 69% of the RDP carried out with CLI.

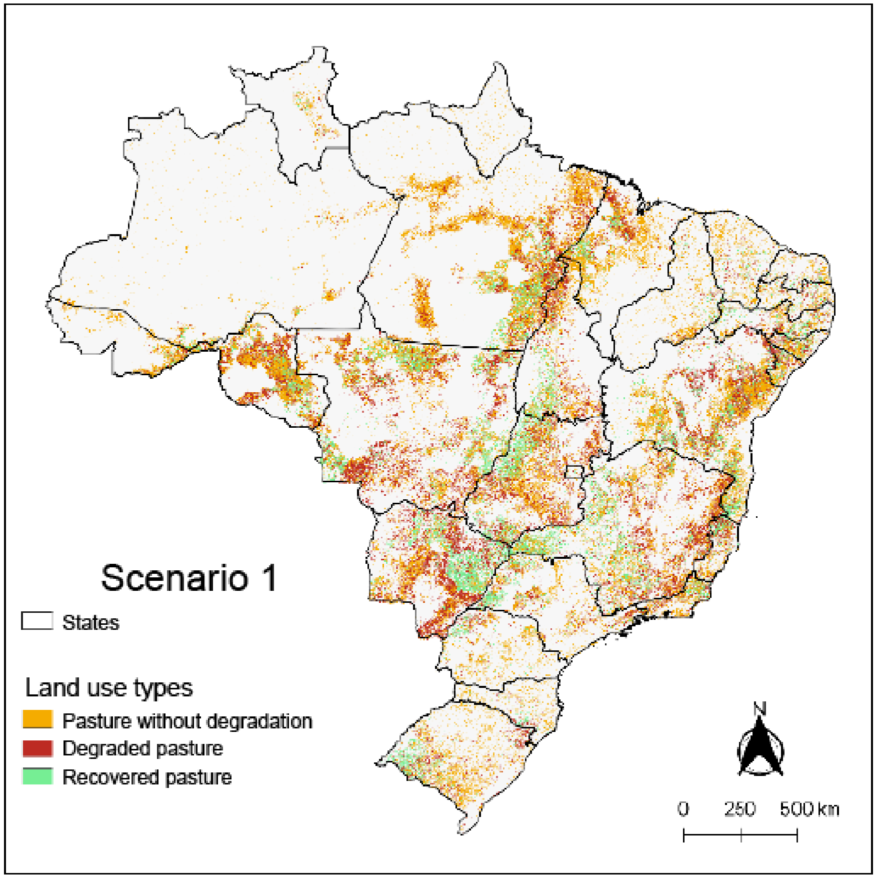
In Bahia, the RDP area would be well distributed across the state, with a greater concentration in the Guanambi and Porto Seguro microregions. Likewise, in Minas Gerais, the conventional RDP allocation would be more concentrated in its western portion. In the case of pasture recovered through CLI technology, the almost 350 thousand hectares would also be in the western portion of the state, mostly in the Triângulo Mineiro and Alto Paranaíba.

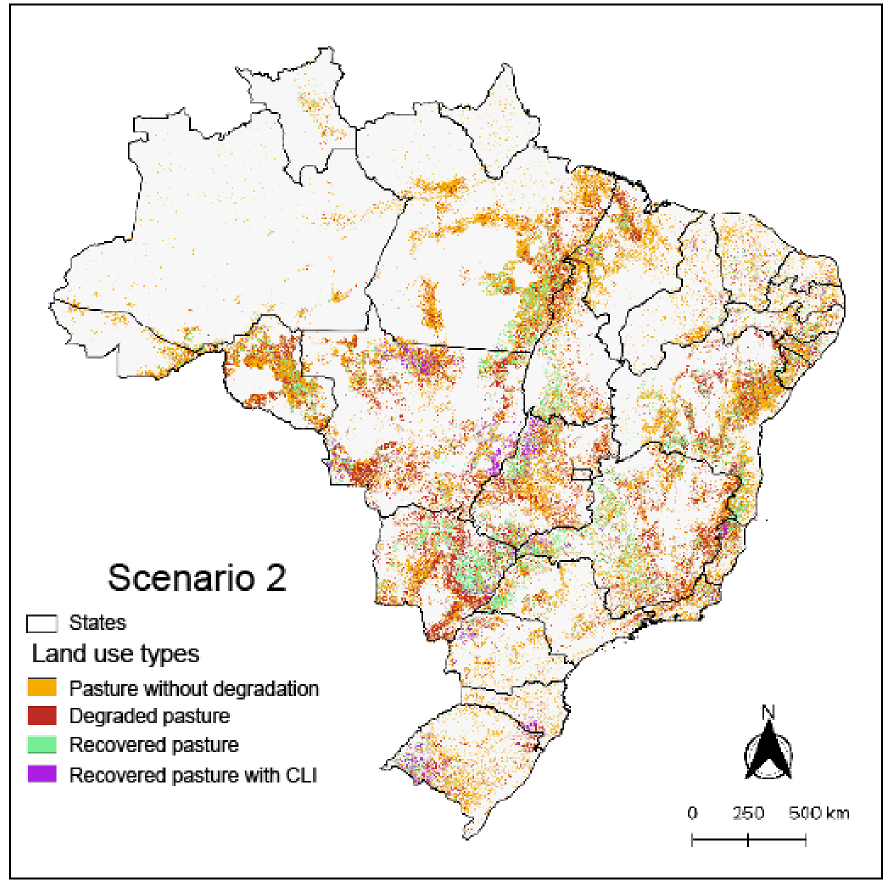
In Paraná, the micro-regions of Umuarama and Paranavaí would concentrate more than 50% of the state's RDP and RDP area carried out with CLI. The Campanha Oeste and Campanha Central microregions in Rio Grande do Sul would concentrate 80% of the RDP area and 86% of the RDP area carried out with CLI in the state.

In turn, in Pará, RDP occurs mainly in the Southeast Pará mesoregion, with emphasis on the São Félix do Xingu and Redenção microregions, with 34% and 21% of the state's RDP area, respectively. In Tocantins, the RDP would only occur in the western mesoregion of Tocantins, mainly in the micro-regions in the south of the state (Rio Formoso and Gurupi), which would concentrate more than 79% of the RDP area.

In general, in all states, the location of RDP and RDP areas carried out with CLI are concentrated in some micro-regions. This is a direct consequence of the access to rural credit indicator used in the property ranking.

Image 17. Spatial distribution of pasture without degradation, degraded pasture, recovered pasture and recovered pasture through CLI technology, in 2030





Source: Own elaboration

Subsection 3.3.2 answered the following guiding question:

	Where will the policy likely act? (producer profile)
Social Capital	For SCE1, the largest portion of the recovered areas (10Mha) would be in properties with more than 1,000 ha, mainly concentrated (more than 50%) in the states of Mato Grosso and Mato Grosso do Sul. However, smaller properties (< 50 hectares) have the potential to recover just over 5 Mha, especially in Bahia and Minas Gerais. Similar dynamics would occur at SCE2. Of the 6 Mha of pasture planned for recovery with this technology, the majority (2 Mha) would be in Mato Grosso, mainly concentrated in rural properties with more than 1,000 ha.

3.3.5 ***Effects on soil erosion***

3.3.5.1 Results for the baseline

To be able to answer whether the technology for recovering degraded pastures results in less soil erosion, the universal soil loss equation (RUSLE) was used. RUSLE is an empirical equation that estimates soil loss rates (A) in Mg ha^{-1} year^{-1} and uses as input parameters rainfall erosivity (R), soil erodibility (K), topographic factors (L and S), soil cover (C) and soil management (P), the latter omitted in this study. To model the scenarios, the soil coverage factor was adjusted according to the pasture recovery technology, while the other factors were kept constant in each scenario. With all spatially estimated factors, we proceeded with the estimation of soil loss for the baseline (BAU) for the year 2030 (Image 18). The BAU scenario was defined by degraded pasture conditions for the locations where recovery potential via RDP (SCE 1) and RDP+CLI (SCE 2) was identified, in addition to the other portions of pasture under normal conditions that were not used by the allocation model in none of the scenarios, or other use according to the land use allocation model.

The results showed that the highest rates of soil loss would be seen in the states of the Southern region, with emphasis on a large part of the territory of Paraná, the western portion of Santa Catarina and the northern portion of Rio Grande do Sul. It is worth considering that, in general, several studies point to high rates of rain erosivity in the south of the country (Borrelli *et al*., 2017; Panagos *et al*., 2017). Especially in the west of Santa Catarina and Paraná, soil erosion rates are quite considerable and comparatively higher than other South American countries. In the Amazon region, significant loss values were estimated for the western portion (Amazonas and Acre), northern portion (Amapá and northern Pará) and eastern portion, which comprises a large part of the state of Pará. In these locations there are also high rates of rain erosivity (Borrelli *et al*., 2017; Panagos *et al*., 2017). In the North region, around 40% of the territory of Pará has soils with more restricted agricultural use, mainly because the susceptibility to soil erosion is greater due to the textural ratio in depth and more accentuated relief (Gama *et al*., 2020). Combined with the increasing advancement of land change in the region, recovery technologies become strong allies in mitigating the environmental impacts of soil erosion. The lack of more adequate planning in agricultural areas is associated with a greater risk of erosion and soil degradation in the state of Pará (Carneiro *et al*., 2017).

The state of Minas Gerais, in the Southeast region, would also present significant rates of soil loss. The Pantanal region in Mato Grosso do Sul and the Araguaia valley on the border of Mato Grosso, Tocantins and Goiás would present the lowest rates of soil loss. It is important to mention, however, that climate projections indicate an increase in erosion rates for the Cerrado biome, where the presence of degraded pasture areas or intensive land use by agriculture further increases the risk of soil loss in the future (Borrelli *et al*. al., 2022).

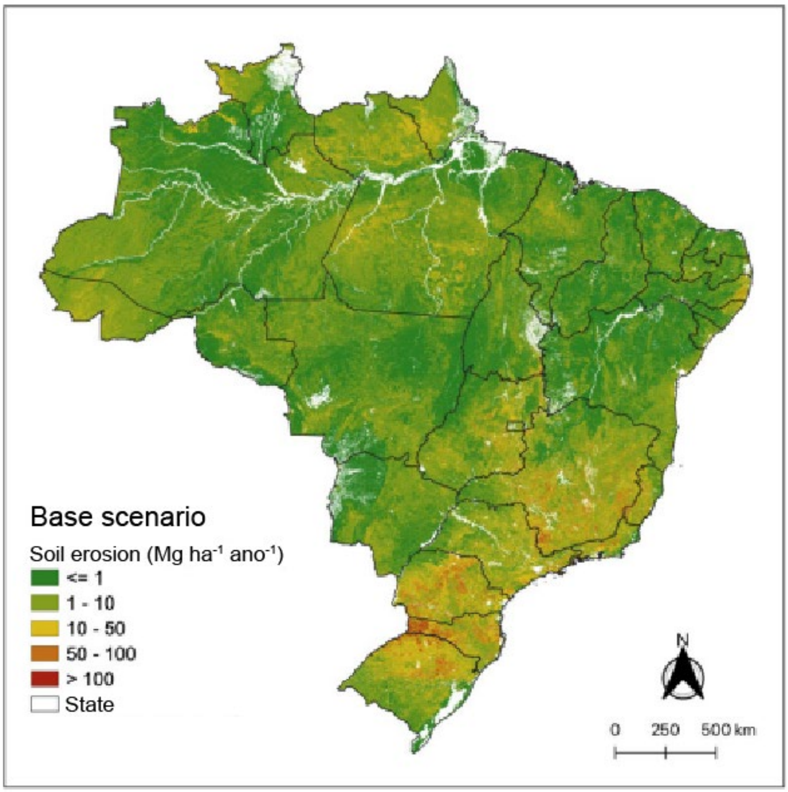
The relative differences in soil erosion rates between the pasture recovery technology adoption and baseline scenarios are presented in Table 29.

Table 30. Average soil loss rates (Mg. ha^{-1}. year^{-1}) for the baseline (BAU), SCE1 (RDP – carried out conventionally) and SCE2 (RDP +CLI) for the federative units of Brazil

Region	state	Erosion BAU	Erosion SCE1	Erosion SCE2	Difference SCE1 and BAU	Difference SCE2 and BAU
			Mg. ha^{-1}. year^{-1}			%
South	Santa Catarina	30.40	27.67	27.82	-8.99	-8.50
	Paraná	21.51	21.92	21.98	1.87	2.16
	Rio Grande do Sul	14.91	13.15	13.21	-11.82	-11.39
	Regional average	***20.48***	***19.01***	***19.09***	***-7.21***	***-6.81***
North	Tocantins	2.63	2.48	2.48	-5.64	-5.60
	Rondônia	2.41	2.10	2.11	-12.64	-12.40
	Amazon	2.30	2.30	2.30	-0.11	-0.10
	Pará	3.98	3.83	3.84	-3.64	-3.57
	Roraima	2.65	2.65	2.65	-0.03	-0.02
	Acre	5.80	5.82	5.82	0.35	0.38
	Amapá	5.43	5.36	5.36	-1.31	-1.26
	Regional average	***3.16***	***3.03***	***3.03***	***-4.10***	***-4.02***
Southeast	São Paulo	9.85	9.41	9.41	-4.47	-4.49
	Rio de Janeiro	13.89	14.56	14.65	4.78	5.47
	Espírito Santo	14.40	13.73	13.91	-4.67	-3.45
	Minas Gerais	12.69	12.31	12.35	-2.96	-2.67
	Regional average	***12.43***	***12.16***	***12.22***	***-2.21***	***-1.74***
Northeast	Sergipe	2.81	2.80	2.81	-0.28	-0.10
	Paraíba	2.68	2.60	2.61	-3.11	-2.69
	Pernambuco	3.28	2.99	2.99	-8.98	-8.91
	Piauí	1.46	1.48	1.48	1.35	1.56
	Rio Grande do Norte	1.74	1.67	1.67	-4.38	-4.00
	Alagoas	5.41	3.99	4.00	-26.35	-26.06
	Bahia	2.10	2.27	2.27	7.85	8.13
	Ceará	2.06	2.13	2.13	3.32	3.61
	Maranhão	2.83	2.83	2.84	-0.13	0.27
	Regional average	***2.37***	***2.33***	***2.33***	***-1.98***	***-1.69***
Central-West	Distrito Federal	6.82	7.25	7.35	6.32	7.77
	Goiás	6.89	7.32	7.36	6.26	6.81
	Mato Grosso	2.15	2.21	2.23	2.93	3.96
	Mato Grosso do Sul	2.73	2.61	2.63	-4.27	-3.47
	Regional average	***3.56***	***3.61***	***3.64***	***1.28***	***2.22***
	National average	***3.55***	***3.47***	***3.48***	***-2.26***	***-1.94***

Source: Own elaboration.

Image 18. Baseline Soil Loss Rates (BAU)

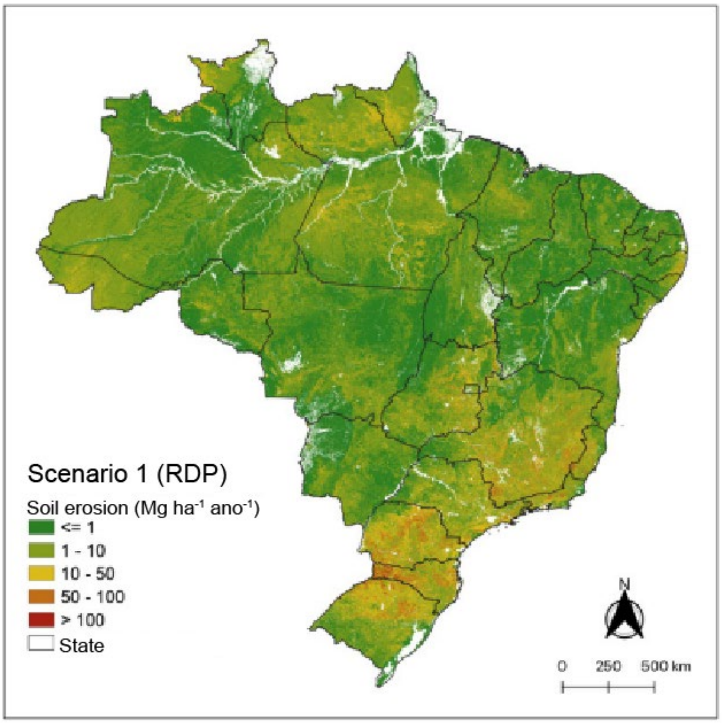


Source: own elaboration

3.3.5.2 Erosion: Scenario 1

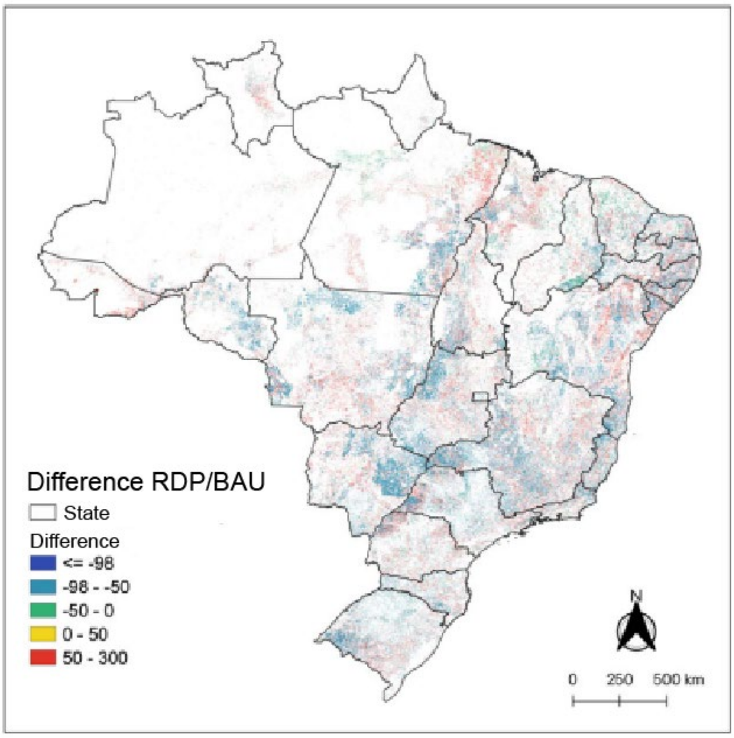
Considering the recovery scenario of 30Mha of conventionally degraded pastures (RDP), soil loss rates for the Brazilian territory would be slightly minimized related to the baseline (BAU) as represented in Image 19. The spatial patterns are very similar to the BAU. However, the map of relative difference between soil loss rates shows that there would be a significant reduction for the Brazilian territory, mainly in the Amazon deforestation arc, northwest of Goiás and south of Tocantins, in the region that forms the border between Mato Grosso do Sul, Goiás and São Paulo and in the Gaucho plains, in the extreme southwest of the state of Rio Grande do Sul (Image 20).

Image 19. Soil loss rates for scenario 1 – recovery of degraded pastures (RDP) in a conventional way



Source: Own elaboration

Image 20. Difference between soil loss rates between SCE1 (RDP) and baseline (BAU)



Source: Own elaboration

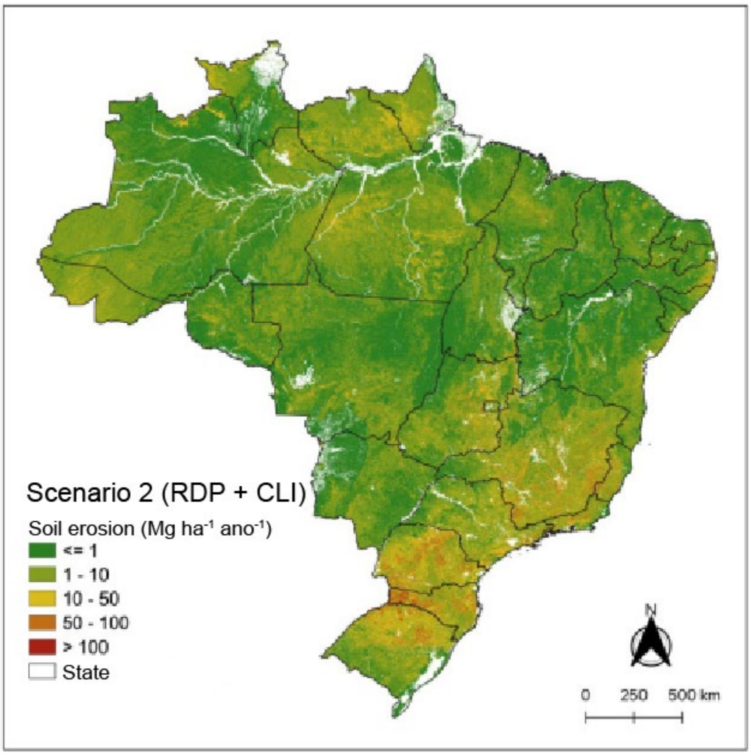
These spatial patterns were confirmed by estimates of state-level soil loss rates (Table 29). Although the South region presents the highest absolute values of soil loss, with emphasis on the state of Santa Catarina, the reduction in soil loss via RDP would be 7.21% on average, the highest value among the country's regions. In relative terms, the Central-West region would show the lowest reduction in erosion rates, reaching a reduction of just over 1%. The states in the North region would show a slight increase (Acre, 0.35%) or a reduction of up to 12.64% (Rondônia), resulting in an average reduction of 4.10%. The national average, in turn, would have a 2.26% reduction via RDP.

3.3.5.3 Erosion: Scenario 2

With the additional indication of 6 Mha for pasture recovery via Crop-Livestock Integration (CLI) within the total amount of 30 Mha to be recovered by 2030, soil loss rates showed spatial variability in the Brazilian territory close to that presented in previous maps, but with magnitudes between those found in the baseline (BAU) and in SCE1 (RDP) (Image 21). As the allocation of 6 Mha is nested within the amount of 30 Mha, the difference spatial patterns between SCE2 (RDP+CLI) and BAU are quite similar to the difference map between SCE1 (RDP) and BAU, with emphasis on a smaller tone in some places in Brazilian territory due to the lower capacity to reduce soil erosion rates via CLI. This occurs because the CLI arrangement presents a year of agriculture preceded by 5 years of pastures in good conditions, which partially compromises soil protection via coverage (annual crops require soil disturbance for correction, preparation and planting, resulting in greater erosion related to pastures).

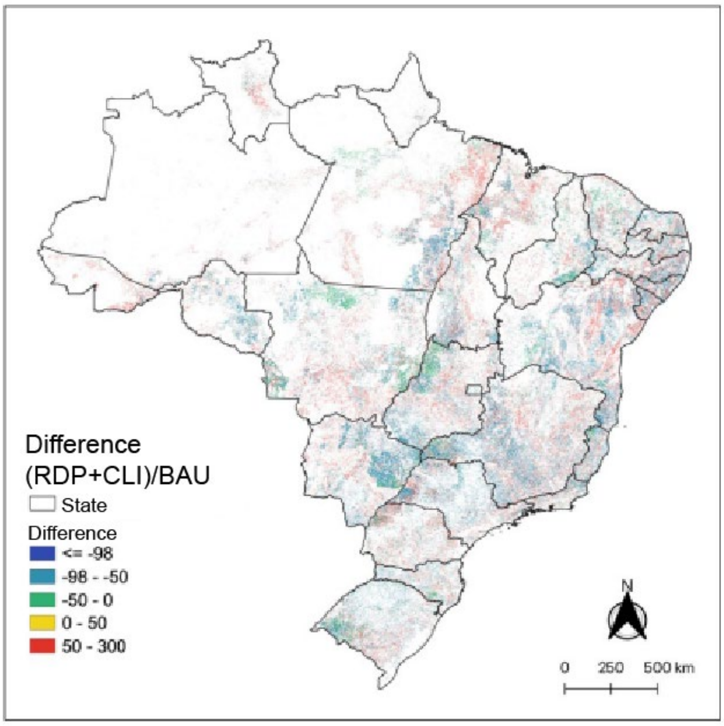
State erosion rate estimates for scenario 2 resulted in smaller soil loss reductions when compared to BAU (Image 22 and Table 29). The South region would present the highest absolute loss values, yet with a greater reduction capacity, of -6.81%. With the exception of the state of Mato Grosso do Sul, the other states in the Central-West would show greater soil losses, with an average increase of 2.22%. This amount is greater than the regional average for scenario 1 (1.28%), indicating that the Central-West region would be negatively impacted by pasture recovery technology in the context of soil erosion. The North region would have an average reduction of 4.02%, while the national average erosion reduction would be 1.94%, a relative value lower than scenario 1, which would reach an average reduction of 2.26%.

Image 21. Soil loss rates for scenario 2 – Degraded pastures recovery via conventional methods (RDP) + Crop-Livestock Integration (CLI)



Source: Own elaboration

Image 22. Difference between soil loss rates in scenario 2 (RDP+CLI) and the BAU scenario

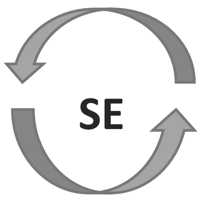


Source: Own elaboration

Therefore, results showed a reduction in soil erosion rates for both scenarios, in relation to the baseline. In fact, pasture recovery technology is an efficient mechanism to promote greater soil coverage in the long term and consequently reduce erosion rates. Some studies document the benefit of this technology using photographic records (Vischi-Filho *et al*., 2007). However, when pasture areas have a high degree of soil compaction, there is a need for intervention with soil preparation with subsoiling and harrowing. This management increases susceptibility to the erosion process in a shorter time window, making it necessary to pay attention to the time of year and topographic characteristics of the site when planning preparation (Pereira *et al*., 2013; Duarte *et al*., 2018).

Regarding arrangements for recovering degraded pastures, the introduction of pasture that provides greater soil coverage is normally very efficient in controlling surface water runoff, and consequently, erosion (Duarte *et al*., 2018; Vilela *et al*., 2011). The reversal of the degradation process, where soils generally have low vegetation cover and low physical quality, in itself already demonstrates the potential of RDP technology in controlling erosion.

Subsection 3.3.2 answered the following guiding question:



Does the recovery of degraded pastures via RDP and CLI result in less soil erosion?

Both scenarios contribute to reducing erosion rates, with scenario 1 (RDP) having a greater positive impact than scenario 2 (RDP+CLI). This occurs because the temporal arrangement of the CLI in scenario 2 presents a year of agriculture followed by 5 years of pastures in good conditions, which may partially compromise the soil's protection capacity when agriculture becomes present in the location. In general, the average reductions in soil loss for the Brazilian territory are -2.26% for scenario 1 and -1.94% for scenario 2.

4. RECOMMENDATIONS FOR THE ABC+ PLAN

This document aimed to present a consolidated description of the analysis results of the impacts and dependencies on the economic, social, human, and environmental capital of the ABC+ Plan within the scope of the degraded pastures recovery in Brazil. The results presented reflect an intense and continuous process of discussion, in which the technical team relied on contributions collected from the Technical and Management Committees, created to technically support and guide the study. The two Committees were composed of a wide diversity of players, research institutions members, public managers (national and regional), private and non-profit sectors representatives.

This section of the study provides recommendations for implementing the goal of recovering 30 million hectares of degraded pastures from the ABC+ Plan and explores the possibilities of synergies between the benefits generated as well as identifying possible trade-offs, considering the agricultural sector, society, and nature. Such recommendations are based both on the results of the four methodological fronts and bibliographic review and on contributions from several key players, collected at different moments throughout the study: field immersions carried out in the states of Pará and Mato Grosso, meetings with the Technical and Management Committees, a workshop on pasture degradation organized by EMBRAPA and the World Bank in Brasília, in addition to a series of meetings in groups of three to four people with members from academia, civil society, public authorities and the private sector.

The recommendations are organized into proposals for four main themes: (1) Technical Assistance and Rural Extension, (2) Policy Financing and Credit, (3) Family Agriculture and Rural Labor and (4) Governance. It is important to highlight that the thematic division was adopted to ease the content presentation. However, the different themes are interconnected. For instance, it is not enough to strengthen technical assistance and rural extension without actions that enable access to financing via rural credit from the ABC+ Plan, and vice versa. Furthermore, the governance must consider the interdependence between themes, which means an intersectoral, coordinated and multi-level effort in order to enhance the positive effects and act on identified difficulties, making it possible to achieve the goal.

4.1 Proposal 1: Strengthen Technical Assistance and Rural Extension

The Technical Assistance and Rural Extension (ATER) is an essential factor for the effective transition to low-carbon agriculture in Brazil. Supported by capacity-building actions, it is considered by the Brazilian government the primary transformative instrument of the first cycle of the ABC Plan (2010-2020). In this sense, the recovery of degraded pastures depends mainly on three conditions in relation to ATER. The first is to ensure access to public ATER primarily to the most vulnerable producers. The second is to strengthen the trends observed in the 2017 Agricultural Census of the growth of in-house ATER and ATER from cooperatives in regions with more consolidated agriculture. These trends mean that more structured producers have ATER to obtain credit lines that require a technical project, such as the ABC+ Plan. A study conducted in 2018 reinforces the strong correlation between receiving ATER, cooperatives, and access to rural credit. Finally, it is necessary to ensure that extension technicians are trained to convey knowledge and low-carbon agriculture technologies to rural producers. It's not just about providing technical information, but also about the ability of extension workers to build with farmers a new understanding of low-carbon agriculture, assisting them to plan their farms financially and economically. In other words, it's a question of financial literacy on the part of ATER agents, which allows them to bring farmers a perspective of better economic returns and gains in environmental conservation as well as in social and human aspects.

Furthermore, in ATER actions, it is necessary to adopt a systemic and dynamic approach to the rural landscape that goes beyond the cultivated area, seeking to ensure the maintenance of ecosystem services. One possibility would be establishing ecological corridors for fauna and flora, for example, by restoring and conserving Permanent Preservation Areas and Legal Reserves. This strategy, in addition to being aligned to compliance with environmental legislation, also seeks to guarantee benefits such as establishing gene flow for species of fauna and flora (for example, creating a favorable environment for pollinators and biological control agents) and offering producers greater climate resilience. This vision is shared by the ABC+ Plan, which adopts the Integrated Landscape Approach (ILA) as one of its guiding principles for tackling the adverse impacts of climate change. This approach advocates for the efficient use of areas suitable for agricultural production, while simultaneously encouraging the valuation of the landscape to guarantee the conservation of soil quality, water, and biodiversity, as well as the appreciation of local specificities and regional cultures. Sustainable production systems, practices, products, and processes ($SPPS_{ABC}$), including RDP and integrated systems such as CLI (objects of this study), also induce the integrated use of landscape components. These and other sustainable production systems (SPS) should be part of the scope of action for extension workers, who must be prepared to guide producers towards a more integrated understanding of low-carbon agriculture practices that go beyond conventional pasture reform.

A significant portion of Brazil’s cattle farming is carried out in small rural establishments, including family farmers and medium-sized producers, many of whom do not have access to ATER, whether public or private. Or else they receive public ATER in a discontinuous and unspecialized way. Therefore, it is necessary to improve and universalize this service to expand the reach of the objectives of the ABC+ Plan. There is also the issue of heterogeneity in receiving ATER within specific groups of farmers. An analysis of the National Household Sample Survey of 2014, published in 2020, for instance, showed, that even among family farmers, there are regional and socioeconomic disparities regarding access to ATER. An indicator was that as household income and schooling increased, so did access to ATER. Additionally, the analysis indicated that less schooling rural producers and those from the Northeast have a lower probability of having access to ATER than other family farmers. Thus, to tackle inequalities such as these and to ensure that rural producers are trained and able to employ technologies to recover degraded pastures and other (SPSABC), it is necessary to strengthen ATER on different fronts, such as financial resources, hiring new staff, training extension workers, among others.

There are state public ATER institutions in all 27 Brazilian states. According to a study carried out in 2021 by the Brazilian Association of Technical Assistance and Rural Extension Entities, Agricultural Research, and Land Regularization (ASBRAER), around BRL 3 billion a year are allocated for the operation of this structure, covering more than 80% of Brazilian municipalities, bringing together about ten thousand extension workers and mainly aimed at family farming (around 1 million families are assisted annually). Thus, it can be noted that state public ATER has enormous reach, but there has been a downward trend in the number of professionals and resources provided by state agencies. The last Agricultural Census (2017) showed that there were no significant increases in ATER coverage in Brazil over the previous 10 years (the penultimate Agricultural Census was conducted in 2006). However, there were clearly demarcated roles, with public ATER concentrated on serving the poorest sectors (including family farming), proprietary ATER predominating in the most productive sectors (more capitalized and generally larger producers), and cooperatives, traders, and other private companies increasing their participation in providing ATER to producers who are part of a more vertically integrated production chains or who can afford more specialized ATER.

According to the ASBRAER document, it is up to the federal government to understand the importance of expanding ATER coverage and, in a scenario of fiscal crisis, to encourage the private sector to expand its services to some sectors of Brazilian agriculture. In the case of public ATER, it is necessary to train municipal extension workers (municipalities represent the second source of funding for state ATER agencies) in an organized and coordinated manner with the federal and state spheres so that they receive support such as planning, training, computer management systems, subsidies for setting up demonstration units, among others. These supports have transaction costs that are very high for each municipality, but can be minimized when strategically planned by states and the federal government. All these sources and instances of ATER must be able to prepare their technical staff to work towards an effective transition to low-carbon agriculture, in the broadest sense of the definition, i.e., disseminating the concept of the Integrated Landscape Approach advocated in the ABC+ Plan and making a reality the adoption of SPS_{ABC}. This is still a major gap in ATER services.

A study on the first phase of the ABC Plan (2010-2020) pointed out a mismatch between the dissemination of the techniques envisaged in the Plan and the possibility of applying them, especially in the North and Northeast regions. That is, producers lack specific knowledge of the technologies, leading to the need for technical assistance so that they became interested in seeking them out. There is also a knowledge gap regarding financing, such as how to access credit through RenovAgro and build the financial project that will be analyzed by the bank. Furthermore, there is also a lack of knowledge regarding the application of degraded pasture recovery technology, whether in conventional forms or through crop-livestock integration. In some cases, there is a lack of awareness of the existence of the Plan itself.

Finally, it is important to emphasize that rural producers may not find it attractive to change their production methods, management or even land use on their properties to adapt them to the recommended proposals for mitigating and adapting to climate change. There may also be reluctance on the part of producers to “lose” part of their cultivated area to the conservation of native vegetation, without this resulting in benefits or compensation. Therefore, it is up to extension workers to be well-informed in order to guide them towards incorporating Integrated Landscape Approach (ILA) into their properties, as recommended in the ABC+ Plan.

Key points

- Strengthen the network of public ATER service providers to improve their service and increase the number assisted producers, offering state ATER agencies the conditions to coordinate the ATER offered at the municipal level and to provide direct assistance to producers. This must be done by: (i) ensuring budgetary stability for Technical Assistance and Rural Extension Companies (EMATERs) and their operating resources, allowing for an increase in the number of extension workers and improved working conditions; (ii) innovating ATER by strengthening both public ATER and establishing partnerships with the private sector to train technicians and increase outreach of specialized services; (iii) regionalized planning, coordinated by state agencies, in order to establish and strengthen local arrangements to make ATER available to a growing number of rural producers;

- Update the profile of extension workers to prepare them for the challenges of sustainable production and low-carbon agriculture, as well as adopting a systemic and dynamic approach to the rural landscape that goes beyond the cultivated area in order to guarantee the maintenance of ecosystem services. This requires: (i) changes in the training process for graduates and technicians in agricultural sciences (curriculum adjustments); (ii) strengthening and expanding the Agronomic Residency in ATER; (iii) systematizing and making available knowledge about ILA, SPS_{ABC} and other content related to low-carbon agriculture for technicians and extension workers; (iv) integrating research and rural extension, in a coordinated way and through cooperation between institutions; (v) training extension workers to prepare financing projects to access RenovAgro.

- Plan and monitor ATER results with a focus on ILA and SPS_{ABC}. The planning of each property and its monitoring can be done through the use of qualitative and quantitative indicators organized in a continuous feeding platform. For example, the implemented area of SPS_{ABC} on the rural property could be included, allowing for the monitoring of the results of the ABC+ Plan's goals

4.2 Proposal 2: Financing of the ABC+ Plan and credit uptake by producers

An important economic result of this study is that the ABC+ Plan can bring a return of between 11.6 and 13.9 times for every BRL invested in the technology to Recover Degraded Pastures advocated by the policy, which benefits the economy and the society. Part of such returns could be allocated to implementing the policy itself, strengthening low-carbon agriculture. At the same time, it is crucial to ensure resources in the public budget so that the Plan can be fully implemented.

As well as securing resources, it is also important to develop a system for monitoring funding and its impact on economic, social, human and environmental capital. An analysis of the ABC Program (now RenovAgro) showed that the correlation between the amount of credit granted and the area of degraded pasture was moderate (0.4029). This information points to the need to build a transparent data system that allows understanding and monitoring the use of public resources directed towards the recovery of degraded pastures. It is necessary to create an official data system to provide updated and spatially clear statistics, and considering metrics and variables of different kinds in order to track the variation in the extent and condition of pastures. A promising example is the System of Environmental-Economic Accounting (SEEA[28]), which follows an accounting structure similar to that of the System of National Accounts (SNA) and which can be an important instrument for directing and monitoring public policies, generating internationally comparable statistics and

[28] SYSTEM of Environmental-Economic Accounting. Disponível em: https://seea.un.org/. Acesso em: 18 dez. 2023.

accounts capable of supporting public authorities as well as the industry, the third sector, and other relevant actors through a more comprehensive and multifunctional view of the economy-environment interrelationship. Monitoring over the medium and long term is also essential to ensure that the pastures recovered by the ABC+ Plan are maintained at high levels of productivity or that they quickly revert to the stage of degradation before the resource application, benefiting producers who keep pasture with low degradation levels for a longer period. Otherwise, the RDP may become another source of greenhouse gas emissions, not adequately offset by the long-term organic carbon fixation in the soil. Finally, a robust data system would also allow an analysis of which other rural credit lines outside RenovAgro and PRONAF ABC+ finance practices that are also offered by the Plan, contributing to monitoring and the communication regarding financing and the adoption of sustainable agricultural practices.

Once a monitoring protocol for SPS_{ABC} areas is established so as to ensure the effective implementation tracking, it is possible to think about creating mechanisms, as long as they are supported by a consolidated methodology, that strongly encourage producers to achieve significant results, as outlined in the policy. This may include bonuses for producers who perform well in reducing CO2 emissions. As seen previously, one possibility is to develop an 'ecosystem accounting' system, like the SEEA, with an integrated and comprehensive statistical structure that organizes data on habitats and landscapes, measures ecosystem services, tracks changes in ecosystem assets, and links this information to economic and other human activities. In the case of the recovery of degraded pastures and ILA, such a system could include metrics regarding the quality of fragments, the functional connectivity of the landscape, soil erosion rates, and social and human impacts on the labor market, household income and consumption.

The lack of knowledge about the possibilities for financing the recovery of degraded pastures is another obstacle to achieving the goal of the ABC+ Plan. RenovAgro is one of the Plan's main financing instruments and allows medium and large producers to finance projects aimed at practices to reduce greenhouse gas emissions from agricultural activities. There is this specific line, RenovAgro Recovery/Conversion, directed at recovering degraded pastures. Although there may be difficulties in accessing credit, many medium and large producers generally have better conditions than the average family farmer, as they are better capitalized and have greater access to technical assistance capable of preparing the projects required by financial institutions (please see Proposal 1).

Family farmers, on the other hand, as mentioned above, generally need to rely on public ATER support and complementary policies to access credit for livestock and low-carbon agriculture (such as PRONAF ABC+). Therefore, to better assist them, among other initiatives, it is necessary to reduce the bureaucracy involved in accessing credit, adapting it to the reality of small production units and making the process faster. The reduction of bureaucracy must consider potential trade-offs and be carried out in such a way that the simplification of operations does not result in a loss of quantity and the quality of information in relation to the effective adoption of low-carbon agriculture and other metrics relevant to assessing the impact of the policy. It is important to note that family producers are generally not credit borrowers, they avoid contracts requiring a significant payment guarantee or that depend on the preparation of projects (as is the case with the ABC+ Plan). As a result, they end up needing to hire and be assisted by technicians in order to access credit. Additionally, family livestock farmers often access PRONAF mainly for the purchase of cattle, as there is a quick return on investment and a greater capacity to balance the debt with financial institutions. A possible approach to alleviate this situation is to use of blended finance instruments, which allow part of the costing to be provided on a non-repayable basis under supervision, or the creation of mechanisms that encourage and ensure that the financial agent provides funding so as to promote a transformation of production systems, such as RDP.

In addition to promoting a systemic and dynamic approach to the rural landscape (see Proposal 1), ATER could incorporate a more economic and managerial view of the rural property. In practice, this could be done through financial education for livestock farmers and teaching property management in a more systematic way. A first step would be to train bank managers to work with extension workers so that they can provide guidance to producers, facilitating their access to credit (RenovAgro and PRONAF ABC+), while improving the productive practices of the units as a whole.

Credit for low-carbon livestock farming could reach production units in the Brazil's regions and states through partnerships between the National Development Bank (BNDES) and regional public banks such as the Banco do Nordeste or the Banco da Amazônia. Deconcentrating resources could help the ABC+ Plan gain capillarity and breadth, establishing closer relationships with State Management Groups (see Proposal 4) and adapting the implementation of the ABC+ Plan to the different scenarios of each state. Such arrangements may bring an additional level of complexity to credit management; however, the proximity to different realities can make it easier to understand the needs of each location. An example of how reallocating credit to regional or state management could be beneficial is the case of the priority areas of the then ABC Program (now RenovAgro). A study indicated that the most degraded areas and with higher environmental needs had greater economic and logistical deficiencies, showing that states and municipalities will have to deal with different realities and investment demands among themselves.

Key points

- Ensure the necessary budget for the implementation of the ABC+ Plan, combining public resources and part of the return on investment in the policy itself.

- Create an official data system for monitoring the implementation of ABC+ (RDP) in the field, providing updated statistics and taking into account different metrics and variables so that it is possible to monitor variation in the extent and condition of pastures. One option would be to develop the United Nations' System of Environmental Economic Accounting (SEEA)[29].

- Reduce bureaucracy for small producers to access ABC+ credit and study the possibility of using blended finance instruments, which allow part of the costing to be carried out on a non-repayable basis under supervision.

- Add an economic and managerial vision of rural property based on financial education for livestock farmers and teaching property management in a more systemic way. A first step would be to train bank managers to work with extension workers so that they can provide guidance to producers, facilitating their access to credit (RenovAgro and PRONAF ABC+), while at the same time improving the productive practices of the units as a whole.

- Providing affordable specialized technical assistance for the development of low-carbon projects for family farmers.

- Decentralize resources through partnerships between the National Development Bank (BNDES) and regional public banks such as Banco do Nordeste or Banco da Amazônia, so that credit for low-carbon livestock farming gains in capillarity and breadth, reaching production units in the regions and states.

4.3 Proposal 3: Establish specific mechanisms to assist family farming and less qualified rural workers

This study indicated that just over 5 million hectares of degraded pastures could potentially be recovered by 2030 on rural properties of less than 50 hectares, mainly in Piauí, Bahia and Minas Gerais. It is therefore necessary for the ABC+ Plan to establish specific mechanisms to assist smaller production units such as family farms. Some of the features of this target-group mean that it is essential to design the plan's implementation in such a way as to amortize the risks for these producers, while at the same time providing technical assistance and facilitating access to technologies and credit (see Proposals 1 and 2).

Furthermore, in the social dimension, the study points out that the recovery of degraded pastures and crop-livestock integration have the potential to generate two unfavorable consequences. The first is the reduction in labor demand, especially from less qualified workers who are generally allocated to less intensive

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[29] UNITED NATIONS. System of Environmental-Economic Accounting. *System of Environmental-Economic Accounting – Ecosystem Accounting*. Pré-edição, [s.l.]: ONU, 2021. Disponível em: https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_white_cover_final.pdf. Acesso em: 18 dez. 2023.

livestock farming. The second would be lower wage gains for lower-income families. These elements can lead to an increase in inequality in rural areas, affecting the workers and families primarily involved in the livestock sector. Therefore, it is essential to seek complementary public policies that address the sector to provide better training and qualification for these workers, helping them to remain in rural areas, performing tasks that require a higher degree of specialization, which are vital to a more technical agriculture, mechanical technicians for agriculture machinery and devices, technicians specialized in irrigation facilities, among others. These activities provide better remuneration. It is also necessary to integrate other social policies such as food and nutritional security, for example, to ensure that the less well-off families have their right to adequate food. Part of these additional actions, programs, and policies could be financed from the positive return derived from the investment in the ABC+ Plan itself (between 11.6 and 13.9 times for each BRL invested in the policy), so as to mitigate these inequalities

Avoiding the potential concentration of land is another element that must be considered. As family farming units may face greater difficulties in financing and implementing the recovery of degraded pastures, there is a risk of indebtedness on the part of farmers who might eventually have to abandon and sell their lands. Moreover, there may be a disparity in production efficiency gains among different types of farmers. Family farmers may struggle to intensify livestock production, while larger producers may become more efficient. In the long run, this dynamic could lead to the abandonment of livestock activities by family farmers, while the larger ones, incentivized by greater capital use in the activity resulting from the implementation of RDP technology, could expand and eventually buy smaller properties. Such dynamics would represent a social and human cost and could generate even more inequalities in the Brazilian agrarian situation. Therefore, it is necessary to think about actions or mechanisms that allow the recovery of degraded pastures to be carried out in a way that is economically feasible and socially just.

It is worth noting that pasture recovery and livestock intensification are not the only forces capable of leading to land concentration and the transformation of rural areas towards commodification, especially through the replacement of pastures with soybean cultivation, a trend that has been widely observed in Brazil. Therefore, in order to prevent subsidized credit from becoming an element that favors this movement, it is necessary to promote the ability of smaller producers to remain on their properties, which implies greater support instruments beyond credit. Examples of these instruments are the Bolsa Verde (Green Grant) and other instruments in the food safety, health and education networks in rural areas as well as strengthening command-and-control instruments (to comply with the Native Vegetation Protection Act) and a nationwide policy based on territorial planning to prevent commoditization from advancing into smaller-scale, food-producing agricultural areas.

Finally, the ABC+ Plan needs to consider climate adaptation measures aimed especially at less capitalized rural producers. This is a fundamental paradigm to be addressed, not least to ensure that the goal of recovering 30 million hectares of degraded or deteriorating pastureland by 2030 is achieved. The most vulnerable producers will have less resilience to face climate change, encouraging the process of deepening inequalities in the rural areas.

Key points

- Adopt complementary public policies aimed at improving the qualifications of livestock workers, helping them to remain in the job market and with better remuneration;

- If it is not possible to keep these workers in livestock farming, evaluate the deployment of relocation policies to other sectors of the economy, preferably in rural areas, minimizing the negative effects of migration to urban areas

- Adopt other social policies to minimize the possible inequalities in the rural areas resulting from the intensification of livestock farming by the RDP, such as food and nutrition security policies. Part of the positive return from investment in the ABC+ Plan could be used for policies to mitigate these inequalities

- Implement instruments that inhibit the rebound effect of RDP, such as command-and-control instruments (such as the Forest Code, PPCDAm and PPCerrado, mentioned in Proposal 4).

- Adopt climate change adaptation measures aimed at the most vulnerable and undercapitalized rural producers, in order to reduce inequalities.

4.4 Proposal 4: Ensure good governance and coordinate intersectoral policies

A key body for implementing the objectives of Plan ABC+ is the State Management Groups - committees formed by various institutions linked to the agricultural sector. They are responsible for drawing up and implementing the respective State Action Plans (PAE). The state-level approach makes it possible to customize the implementation of the Plan to the different realities and scenarios of each state. According to data from the Ministry of Agriculture, Livestock and Supply (MAPA), in 2023 only ten states had Management Groups and only eight Plans had been elaborated. A first step would be to guarantee resources (human, financial, material, among others) to encourage the continuation or reactivation of the Groups in the states (Chart 2). According to MAPA, the estimated budget cost for Plan ABC+, including promotion, coordination, communication, meetings with the states, support for research, and consultancy, is BRL 17.5 million until 2030, with BRL 2.5 million (two million and five hundred thousand reais) per year, a still limited budget for actions in the states.

Chart 1. MAPA's planning for reactivating the State Management Groups (GGEs) and the effective participation of states in Plan ABC+ and the implementation of State Action Plans (PAEP) in the states

(A) Reactivation of the GGEs and effective participation of the states in the ABC+ policy, and implementation of the State Action Plan (PAEP) in the states:

No.	Description	Year			
		2023	2024	2025	2026
1	State Management Groups (GGEs)	10	20	25	27
2	State Action Plans (PAEPs)	8	14	20	25

Source: https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/agricultura-de-baixa-emissao-de-carbono/resultados-e-levantamentos

The governance of Plan ABC+ can also be improved by reconciling it with other policies and programs. As mentioned earlier, it is crucial to have coordination between the goals of mitigating greenhouse gas emissions in Brazilian livestock through RDP and Integrated Landscape Approach (ILA) with the agenda to tackle inequalities and promote social inclusion.

Another area that could benefit from better integration is the environmental sector. There could be an improvement in achieving the objective of reducing emissions and adapting to climate change if there was integration between Plan ABC+ and other existing policies in the Ministry of the Environment and Climate Change, such as the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), the Action Plan for the Prevention and Control of Deforestation and Fires in the Cerrado (PPCerrado), and the National Plan for Adaptation to Climate Change, among others. It is also worth noting that the Integrated Landscape Approach (ILA), recommended in Plan ABC+, encourages the environmental regularization of rural properties, which implies compliance with the Native Vegetation Protection Law (Law 12,651/2012, known as the New Forest Code). Other integrated systems, such as Crop-Livestock-Forest Integration (CLFI) and Agroforestry Systems (AFSs), are SPS_{ABC}s that can be implemented as part of the recovery of Legal Reserves on properties.

This study indicated that, with the recovery of 30 million hectares of degraded pastures, to observe in some states (Amapá, Ceará, Distrito Federal, Mato Grosso, Piauí, Paraná, and Rio de Janeiro) it would be possible a "rebound" effect, that is, the intensification of livestock farming, instead of "saving land," it would lead to the search for new production lands, increasing deforestation. However, this result considers only the isolated effect of applying the Plan ABC+, highlighting the need to strengthen agencies and command-and-control methods to fight deforestation in different Brazilian biomes. It also shows the importance of implementing Plan ABC+ across the entire Brazilian territory, not just in certain locations, in order to minimize the rebound effect. Moreover, the study revealed that in several states, despite an increase in native vegetation cover with the application of the policy, this would not necessarily improve habitat quality indicators (such as size and core area of fragments and functional connectivity), requiring attention to the planning of priority areas for native vegetation restoration, which takes into account the installation of ecological corridors and fragments with configurations favorable to biodiversity maintenance.

In addition to command-and-control methods, economic mechanisms that value the maintenance of native vegetation on rural properties, coupled with good agricultural practices, also deserve attention. Agricultural certification is one such mechanism (with various seals currently available), as are credit lines linked to the issuance of green bonds, financial instruments issued with the specific objective of financing projects or activities that have a positive impact on the environment. Another example is the Green Agribusiness Receivables Certificate (Green CRAs), or (*CPR Verde*), a financial instrument that aims to make it possible to finance a sustainable and environmentally responsible agricultural. Mechanisms such as carbon market and Payment for Environmental Services (PES) should also evolve to become viable alternative for producers. This study showed that the policy's implementation generates direct benefits in terms of environmental services (through carbon sequestration in the soil of recovered pastures) and indirect ones (through carbon sequestration and retention of sediments from erosion processes by native vegetation, that would be kept due to avoided deforestation), and which could be accounted for, leading to a financial return for the producer and improving human well-being.

Meanwhile, another federal government program that could be planned annually in line with the goals of the ABC+ Plan is the Safra Plan, a federal government program created to support the agricultural sector by offering lines of credit, incentives and agricultural policies for rural producers. A study published in 2020 showed that only 2% of the Safra Plan was set aside for low-carbon agriculture, indicating a huge potential for investments towards decarbonizing Brazilian agriculture.

Research institutions could also be more involved in the low-carbon agriculture agenda. A 2016 article mentions that the Brazilian Agricultural Research Corporation (EMBRAPA), universities and other research entities are key institutions for generating relevant research to disseminate the ABC Plan (2010-2020) in the country. Likewise, it is possible to extend this consideration to the ABC+ Plan and consider ways of bringing it closer to research institutions that can collaborate both in adapting production systems to local realities and different producer profiles, and in evaluating and monitoring the impacts of the ABC+ Plan.

The dissemination of the ABC+ Plan with regard to pasture recovery must simultaneously address technical, financial, socio-economic, and demographic barriers, as well as those of institutional coordination. The diverse array of public policies, producer and rural property profiles, regional characteristics, and market aspects highlight the need for federal, state, and municipal governance. Beyond individually implemented programs, it is crucial to have coordinated implementation with other policies and agendas that collaborate with low-carbon agriculture and overcome difficulties in technical assistance and extension services, credit and financing, support family farming, and strengthen governance. An organizational option would be territorialized arrangements that leverage governance spaces in different government spheres and allow for the implementation according to each local reality (such as the municipal scale). Strengthening the state's public ATER service providers network in order to coordinate the ATER offered at municipal level, as mentioned in Proposal 1, is one possibility for making these arrangements on a public level. Another possibility, which could run simultaneously, is to establish partnerships with the private sector within the cattle farming chain to improve training in pasture and herd management. This would make it possible to manage potential economic, social, and environmental externalities more efficiently while boosting the gains of the of the Integrated Landscape Approach (ILA).

Key Points

- Ensure human, financial, and material resources to promote the continuity or reactivation of State Management Groups.

- Integrate the ABC+ Plan with other policies to combat inequalities, promote social inclusion, control deforestation, conserve biodiversity as well as command-and-control and economic mechanisms to value ILA (agricultural certification, credit lines linked to the issue of green bonds, Green Agribusiness Receivables Certificate [Green CRAs], carbon market and Payment for Environmental Services (PES) are some examples).

- Specifically in relation to the environmental agenda, the integration of the ABC+ Plan with other policies already in place at the Ministry of the Environment and Climate Change, such as the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) and the Action Plan for the Prevention and Control of Deforestation and Fires in the Cerrado (PPCerrado) can help achieve the goal of reducing emissions and adapting to climate change. It is also worth noting that the Integrated Landscape Approach (ILA), recommended in the ABC+ Plan, encourages the environmental regularization of rural properties, which implies compliance with the Native Vegetation Protection Law (Law 12,651/2012, known as the New Forest Code). Other integrated systems, such as Integrated Crop-Livestock-Forestry (ICLF) and Agroforestry Systems (AFS) are Systems, Practices, Products and Sustainable Production Processes (SPS_{ABC}s) that can be implemented as part of the recovery of properties' Legal Reserves.

- Plan priority areas for restoring native vegetation, taking into account the establishment of ecological corridors and fragment configurations favorable to maintaining biodiversity.

- Designing the Safra Plan, a federal government program that aims to support the agricultural sector, in line with the goals of the ABC+ Plan, offering credit lines, subsidies, and agricultural policies for rural producers. Subsidies, and agricultural policies for rural producers. A study published in 2020 showed that only 2% of the Safra Plan was earmarked for low-carbon agriculture, indicating that there is enormous potential for investments in Brazilian agriculture to be decarbonized.

- Organize territorialized arrangements that use spaces of governance in the different spheres of the government, as well as establish public-private partnerships to more efficiently manage potential economic, social and environmental externalities of the RDP, boosting the gains from the policy's implementation.

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APPENDIX

Table 31. Model results. Impact on work in the agriculture sectors, SCE1 and SCE2. Accumulated % variance in 2030

Agriculture	SCE1 (var. in relation to baseline)	SCE2 (var. in relation to SCE1)	SCE2 (var. in relation to baseline)
CC1	-2.24	0.73	-1.53
OCC2	-3.18	2.19	-1.06
OCC3	-2.88	4.51	1.50
OCC4	-2.86	4.69	1.69
OCC5	-3.13	4.62	1.35
OCC6	-3.34	4.06	0.58
OCC7	-3.54	4.20	0.51
OCC8	-3.70	3.25	-0.57
OCC9	-3.71	3.44	-0.41
OCC10	-3.95	4.05	-0.05

Source: own elaboration

Table 32. Model results. Impact on real wages in the agricultural sectors, SCE1 and SCE2. Accumulated % variance in 2030

Agriculture	SCE1 (var. in relation to baseline)	SCE2 (var. in relation to SCE1)	SCE2 (var. in relation to baseline)
OCC1	0.13	-0.08	0.05
OCC2	1.63	0.10	1.74
OCC3	1.45	1.93	3.40
OCC4	1.67	3.93	5.67
OCC5	2.40	3.91	6.41
OCC6	2.88	3.00	5.96
OCC7	3.21	2.60	5.90
OCC8	3.48	1.97	5.52
OCC9	3.43	1.79	5.28
OCC10	3.76	1.82	5.65

Source: own elaboration.

Table 33. Model results. Impact on work in the cattle sectors, SCE1 and SCE2. Accumulated % variance in 2030

Cattle farming	SCE1 SCE2 (var. in relation to baseline)	SCE1 (var. in relation to SCE1)	SCE2 (var. in relation to baseline)
OCC1	-9.99	-1.54	-11.38
OCC2	-10.88	-1.83	-12.52
OCC3	-10.29	-2.81	-12.81
OCC4	-9.76	-3.35	-12.78
OCC5	-10.02	-3.14	-12.84
OCC6	-9.87	-2.86	-12.45
OCC7	-9.79	-3.05	-12.54
OCC8	-10.12	-2.80	-12.64
OCC9	-10.04	-3.02	-12.75
OCC10	-10.38	-2.95	-13.02

Source: own elaboration

Table 5. Model results. Impact on real wages in the cattle sectors, SCE1 and SCE2. Accumulated % variance in 2030

Cattle farming	SCE1	SCE2	
	(var. in relation to baseline)	(var. in relation to SCE1)	(var. in relation to baseline)
OCC1	-0.62	0.01	-0.62
OCC2	1.47	0.18	1.66
OCC3	1.33	2.12	3.48
OCC4	1.84	3.55	5.46
OCC5	2.51	3.15	5.75
OCC6	2.95	2.40	5.41
OCC7	3.20	2.65	5.93
OCC8	3.57	2.04	5.68
OCC9	3.36	2.15	5.58
OCC10	3.30	2.29	5.67

Source: own elaboration

Table 6. Model results. Impact on work in the meat sector, SCE1 and SCE2. Cumulative % variance in 2030

Meat	SCE1 (var. in relation to baseline)	SCE2 (var. in relation to SCE1)	SCE2 (var. in relation to baseline)
OCC1	15.02	-0.92	13.97
OCC2	17.82	-1.04	16.60
OCC3	19.45	-1.58	17.55
OCC4	19.11	-1.61	17.19
OCC5	18.81	-1.64	16.86
OCC6	18.70	-1.59	16.81
OCC7	18.35	-1.57	16.50
OCC8	17.90	-1.51	16.12
OCC9	17.83	-1.56	15.98
OCC10	18.57	-1.55	16.73

Source: own elaboration

Table 7. Model results. Impact on real wages in the meat sector, SCE1 and SCE2. Accumulated % variance in 2030

Meat	SCE1 (var. in relation to baseline)	SCE2 (var. in relation to SCE1)	SCE2 (var. in relation to baseline)
OCC1	1.47	0.06	1.53
OCC2	2.10	0.09	2.19
OCC3	2.01	1.01	3.04
OCC4	2.56	1.36	3.96
OCC5	3.52	1.35	4.92
OCC6	3.99	1.16	5.20
OCC7	4.15	1.19	5.39
OCC8	4.38	1.01	5.44
OCC9	4.41	1.03	5.49
OCC10	4.75	1.16	5.97

Source: own elaboration

Table 37. Model results. Impact on work in other agribusinesses, SCE1 and SCE2. Cumulative % variance in 2030

Other Agribusinesses	SCE1 (var. in relation to baseline)	SCE2 (var. in relation to SCE1)	SCE2 (var. in relation to baseline)
OCC1	-3.54	-1.27	-4.76
OCC2	-4.45	-1.41	-5.80
OCC3	-4.35	-1.62	-5.90
OCC4	-4.23	-1.59	-5.75
OCC5	-4.40	-1.53	-5.86
OCC6	-4.51	-1.47	-5.91
OCC7	-4.52	-1.45	-5.90
OCC8	-4.43	-1.37	-5.73
OCC9	-4.42	-1.37	-5.73
OCC10	-4.32	-1.26	-5.53

Source: own elaboration

Table 38. Model results. Impact on real wages in another agribusiness, SCE1 and SCE2. Accumulated % variance in 2030

Other Agribusinesses	SCE1 (var. in relation to baseline)	SCE2 (var. in relation to SCE1)	SCE2 (var. in relation to baseline)
OCC1	0.42	0.04	0.46
OCC2	1.43	0.09	1.51
OCC3	1.79	0.80	2.61
OCC4	2.23	0.98	3.23
OCC5	2.89	0.88	3.79
OCC6	3.27	0.76	4.05
OCC7	3.27	0.73	4.03
OCC8	3.32	0.65	4.00
OCC9	3.32	0.65	3.99
OCC10	2.96	0.59	3.56

Source: own elaboration

ANNEX

Table presented in Report 2.

Table 1. Degraded pastures, RDP target for 2030 and productivity shock of 2021

Regions TERM	Degraded Pastures in 2020 (Mha)	Degraded Pastures in 2020 (%)	RDP Target 2030 (Mha)	Average Annual Productivity Shock (%)
Rondonia	4.7	4.6	1.4	3.9
AmazACRR	1.3	1.3	0.4	1.5
ParaAP	8.3	8.1	2.4	2.7
PiBa	12.5	12.2	3.6	3.2
MaTo	7.0	6.8	2.1	3.0
Rest of Northeast	6.9	6.7	2.0	3.8
Minas Gerais	13.9	13.6	4.1	2.6
São Paulo	3.6	3.5	1.0	4.3
Rest of Southeast	2.5	2.4	0.7	3.7
Parana	1.5	1.4	0.4	2.2
Rest of South	4.4	4.3	1.3	3.3
MtGrSul	12.0	11.7	3.5	4.9
MtGrosso	15.2	14.7	4.4	3.7
GoiasDF	9.0	8.7	2.6	3.2
Brazil	102.8	100.0	30.0	3.5

Source: own elaboration. * In bold, regions that are totally or partially part of the Legal Amazon.