PROGRAMA ABC NA AGROPECUÁRIA: MITIGAÇÃO DE GEE E FINANCIAMENTO VIA ANÁLISE DE REDES SOCIAIS

ABC PROGRAM IN AGRICULTURE: GHG MITIGATION AND FINANCING VIA SOCIAL NETWORK ANALYSIS

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Resumo

Este estudo tem como objetivo avaliar o impacto estadualizado do Programa Brasileiro de Agricultura de Baixo Carbono (Plano ABC) na mitigação das emissões de gases de efeito estufa (GEE) no setor agropecuário brasileiro no período de 2013 a 2023. Para isso, utiliza-se a metodologia de Análise de Redes Sociais (ARS) associado a uma análise descritiva para examinar a dinâmica espacial do país tanto na distribuição dos financiamentos quanto na identificação dos principais agentes financiadores e tomadores de crédito. Os dados são extraídos da Matriz de Dados do Crédito Rural (MDCR) do Banco Central do Brasil e do Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG). Os resultados das redes mostram que: i) o Banco do Brasil é o principal intermediador financeiro do Programa ABC; e ii) a recuperação de pastagem e plantio direto são as linhas de financiamento que recebem maiores recursos. E a análise descritiva mostra a falta de coordenação entre investimentos realizados e redução de emissões dos gases do efeito estufa. Portanto, a análise dos dados sugere a necessidade de ajustes estratégicos para aumentar a efetividade do Plano.
Palavras-chave: Plano ABC; GEE; Sustentabilidade; Crédito; Agropecuária.

Abstract

This study aims to evaluate the state-level impact of the Brazilian Low-Carbon Agriculture Program (Plano ABC) in mitigating greenhouse gas (GHG) emissions in the Brazilian agricultural sector during the period from 2013 to 2023. To achieve this, the methodology of Social Network Analysis (SNA) combined with descriptive analysis is employed to examine the spatial dynamics of the country, focusing both on the distribution of financing and the identification of key funding agents and credit recipients. The data is sourced from the Rural Credit Data Matrix (MDCR) of the Central Bank of Brazil and the Greenhouse Gas Emissions and Removals Estimation System (SEEG). The network analysis results indicate that: (i) Banco do Brasil is the primary financial intermediary of the ABC program; and (ii) pasture recovery and direct planting are the funding lines receiving the most resources. Furthermore, the descriptive analysis highlights the lack of coordination between investments made and the reduction in greenhouse gas emissions. Therefore, the data analysis suggests the need for strategic adjustments to enhance the effectiveness of the Plan.
Key words: Plano ABC; GHG; Sustainability; Credit; Agriculture and livestock.

1. Introduction

Brazil has a favourable history of implementing policies aimed at mitigating environmental impacts, being a signatory to major international agreements. Discussions regarding climate change and the need to reduce greenhouse gas (GHG) emissions have become central to ensuring sustainable development. In this context, the Brazilian Low-Carbon Agriculture Plan (Plano ABC) was launched as a strategic public policy to promote sustainable practices and contribute to the mitigation of GHG emissions in agriculture.

In Brazil, the agricultural sector stands out economically but is also responsible for a significant share of carbon emissions. Therefore, it holds great potential for adopting sustainable practices that help mitigate environmental impacts. One of the main initiatives adopted by the country to reduce GHG emissions in the agricultural sector is the Low-Carbon Agriculture Program (ABC program). Created to promote sustainable practices and reduce carbon emissions in agriculture, the program offers financial incentives for adopting cleaner and more efficient production technologies.

In this context, this study aims to assess the state-level impact of ABC program in mitigating GHG emissions in the Brazilian agricultural sector during the period from 2013 to 2023. To achieve this, the methodology of Social Network Analysis (SNA) combined with descriptive analysis is applied to examine the country's spatial dynamics, focusing on both the distribution of financing and the identification of key funding agents and credit recipients. Data is sourced from the Rural Credit Data Matrix (MDCR) of the Central Bank of Brazil and the Greenhouse Gas Emissions and Removals Estimation System (SEEG), enabling a comprehensive evaluation of the relationship between investments made and the effective reduction of GHG emissions.

The results of the network analyses indicate that Banco do Brasil is the primary financial intermediary of ABC program, highlighting its central role in providing credit for sustainable initiatives in the agricultural sector. Additionally, it was observed that funding lines aimed at recovering degraded pastures and direct planting receive the majority of resources allocated by the program. However, the descriptive analysis reveals a lack of coordination between investments made and the effective reduction of GHG emissions, emphasizing challenges in ABC's program effectiveness. This scenario suggests the need for strategic changes to improve the policy from an environmental perspective, aiming to meet both national interests and global commitments.

To achieve the objectives of this study, besides the introduction and concluding remarks, the article is structured into three additional sections. The second section addresses Plano ABC and program as a strategy for agribusiness expansion linked to the mitigation of GHG emissions. The third section describes the methodology and data utilized, while the fourth presents the results and discussions.

2. The Plano ABC and program as an agribusiness expansion strategy associated with the mitigation of GHG emissions

2.1 Institutional changes aimed at including the environmental agenda

The Stockholm Conference, held in 1972, marks the beginning of global concern regarding environmental degradation. Following this event, the relationship between humans and nature became central to policies aimed at socioeconomic development. This movement influenced various sectors of society, with participation from both the public and private sectors. The main document resulting from this conference was *Our Common Future*, also known as the Brundtland Report. Published in 1987, this report introduced the concept of sustainable development, defined as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. This paradigm began to guide governmental, corporate, and academic policies, encouraging the adoption of measures aimed at environmental and economic sustainability on an international scale (CMMAD, 1991).

In 1992, the United Nations Conference on Environment and Development (Rio-92) established guidelines for reconciling socioeconomic development with the sustainable use of natural resources. Discussions on sustainable development, as defined by its main schools of thought and international bodies, do not exclude the possibility of economic growth. To some extent, economic growth is desirable, provided those environmental capacities are respected (Mueller, 2007).

Since Rio-92, Brazil has committed itself to and become a signatory of major global resolutions to mitigate environmental degradation. The country joined international agreements such as the Kyoto Protocol in 1997, which already emphasized concerns about climate change and the need to reduce greenhouse gas (GHG) emissions. To consolidate its commitment to sustainability, Brazil pledged during the 15th Conference of the Parties (COP15) to reduce its GHG emissions by 36.1% to 38.9% by 2020. This commitment was reinforced at COP21, through Brazil's nationally determined contributions (NDCs) under the Paris Agreement, highlighting the nation's commitment to reducing GHG emissions by 37% by 2025 and 43% by 2030, compared to 2005 levels (Schmidt, Da Silva, Santoyo, 2023).

Aligned with the international trend, Brazil adopted more practical initiatives for monitoring wildfires in the Amazon, promoting greater transparency and control over deforestation rates beginning in 2004 (Da Silva, Vieira Filho, 2020). In 2009, Brazil advanced further by instituting the National Policy on Climate Change (PNMC), aimed at reconciling economic and social development with the protection of the global climate system (Brasil, 2009).

According to Tsai et al. (2024), agriculture accounted for 74% of Brazil's climate pollution in 2023. This impact stems both from emissions resulting from deforestation and land-use changes for agricultural purposes and from direct emissions in the sector, associated with processes such as enteric fermentation, soil management, agricultural residue burning, animal waste disposal, and rice cultivation. Within this context, agriculture contributed 20% of the sector's emissions, while livestock accounted for 80%. Data organized by Tsai et al. (2024) also indicates a 2.2% increase in agricultural emissions in 2023 compared to 2022. This growth represents the fourth consecutive record of emissions in the sector. Thus, the agricultural sector becomes critical for meeting Brazil's GHG reduction targets.

Brazil's greenhouse gas (GHG) reduction targets exist within a context where climate impacts are already evident across various sectors, including agriculture. Enhancing agricultural resilience is essential to reducing exposure to climate risks. For example, the Brazilian agricultural sector loses a significant portion of its production value due to extreme climate events. Beyond monitoring measures, it is necessary to promote climate-smart agricultural practices. This includes increasing agricultural productivity and fostering diversified, inclusive growth in rural areas through economic activities based on forests. As a result of rising average temperatures and an increase in the number of dry days, agriculture in Brazil's North and Central-West regions will face significant climatic stress (World Bank Group, 2023).

The Northeast, historically prone to severe droughts, is particularly affected due to its reliance on rain-fed agriculture. Climate change is expected to alter the suitability of various crop-growing areas. Crops such as wheat and corn are particularly sensitive to heat, while soybeans and cotton show a moderate impact in response to climate stress. Livestock productivity will also be affected, especially due to rising temperatures and heat waves, which impact dairy production (World Bank Group, 2023).

The intensification of environmental damage in Brazil's Central-West and Southeast regions is linked to the advancement of agricultural modernization. Modern agriculture has brought significant transformations to land use by incorporating new technologies and practices aimed at agribusiness. Modernization has resulted in a significant increase in land concentration and the transformation of properties into large agricultural enterprises, leading to the conversion of land into extensive monocultures, such as soybeans and sugarcane, to the detriment of traditional crops. This shift has resulted in socioeconomic impacts, such as the marginalization of local farmers and heightened competitiveness, as well as environmental concerns related to biome degradation and biodiversity loss (Matos, Pessôa, 2012).

A shift in the historical trajectory of agricultural expansion, driven by modernization without environmental considerations, towards a sustainability-based agriculture model does not preclude growth. Pre-modernization agriculture was largely based on the exploitation of virgin lands, leading to deforestation, soil fertility loss, and water resource degradation. However, the technological advancements that occurred were also detached from biodiversity conservation concerns, being more focused on addressing the loss of agricultural productivity and the inefficiency of natural resource exploitation (Igari, Pivello, 2011).

2.2 Institutionalization of the Plano ABC and Program for low-carbon agriculture

The Sectoral Plan for Mitigation and Adaptation to Climate Change, known as Plano ABC, was established under the National Policy on Climate Change (PNMC) to mitigate emissions and promote sustainable production systems (Gianetti, Ferreira Filho, 2021). Its design follows the agricultural modernization model, adopting a market-oriented perspective where sustainable technologies and practices are implemented to translate into productivity growth and market expansion. Plano ABC began implementation in 2012, reconfiguring existing credit lines and incorporating initiatives such as the recovery of degraded pastures and the expansion of low-emission technologies (Chechi, Grisa, 2020; Schmidt, Da Silva, Santoyo, 2023).

The main advancements of Plano ABC include the development of agroclimatic risk zoning for different crops, the recovery of degraded areas, the implementation of agroforestry systems, approval of state-level plans, and the training of technicians and rural producers. However, the plan faces challenges such as the lack of coordination among stakeholders, interest rates that impede credit access, the need to demonstrate the economic feasibility of sustainable practices, and insufficient financial resources for program execution. Building partnerships and reducing bureaucracy in credit access are also vital for the continued success of ABC's plan initiatives (Schmidt, Da Silva, Santoyo, 2023).

The Low-Carbon Agriculture Program (ABC program) represents a key initiative within Brazilian agricultural policy, offering preferential credit lines to farmers who adopt integrated systems of crops, pastures, and forests, aimed at promoting sustainable agricultural practices. Between 2010 and 2018, the Program ABC provided differentiated credit lines across seven initiatives: recovery of degraded pastures, Crop-Livestock-Forest Integration (ILPF) and Agroforestry Systems (SAFs), No-Till Farming Systems (SPD), biological nitrogen fixation, afforestation, animal waste management, and adaptation to climate change (Carauta et al., 2018; Da Silva, Vieira Filho, 2020).

Regarding the program's technologies, Lovato, Schultz, and Revillion (2020) observed that the recovery of degraded pastures, integrated production systems, and no-till farming systems have the greatest capacity to reduce GHG emissions per area compared to other processes such as biological nitrogen fixation and animal waste management. Concerning resource allocation, Gianetti and Ferreira Filho (2021) identified a regional concentration in the Central-West and Southeast in select sustainable production systems within high aptitude municipalities, which are areas with greater economic return potential.

Carauta et al. (2018) identified positive outcomes from the implementation of ABC credit, noting a significant increase in the adoption of integrated systems, with a doubling of land dedicated to these systems. Additionally, they highlighted that farmers' perceptions of the economic viability and benefits of integrated practices vary widely across regions, emphasizing the importance of tailoring financing conditions to specific areas. Although the program is an effective tool to promote low-carbon agricultural practices, it faces challenges limiting its adoption by producers (Lovato, Schultz, Revillion, 2020).

Regarding the attractiveness of the Program ABC, interest rates were differentiated to encourage the adoption of technologies. Between 2010 and 2018, program interest rates remained mostly below 6%, while the average basic rate was higher. From the 2016/2017 season onward, rates began converging, reducing the appeal of subsidized credit. Farmers faced uncertainties regarding the adoption of the program's practices, and while subsidies initially incentivized adoption, they became less appealing over time (Da Silva, Vieira Filho, 2020; Schmidt, Da Silva, Santoyo, 2023).

As for challenges, Carauta et al. (2018) highlighted the lack of clear definitions for Crop-Livestock-Forest Integration (ILPF) systems in official documentation, insufficient qualification of bank managers to evaluate projects, disinterest from financial institutions, excessive bureaucracy, and stringent requirements. Lovato, Schultz, and Revillion (2020) pointed to issues such as misallocation of credits to technologies with higher mitigation potential, lack of accessible information on the benefits of low-carbon practices, and underutilization of available financial resources. Finally, Schmidt, Da Silva, and Santoyo (2023) emphasized the need to demonstrate the economic viability of sustainable practices for small farmers and the lack of financial resources for program execution.

Gianetti and Ferreira Filho (2021) suggested improvements for the program, advocating that low aptitude municipalities should receive greater advantages to acquire loans since they are considered priorities in GHG mitigation efforts. Chechi and Grisa (2020) noted that the program's design was heavily tied to financial and productivity gains. Consequently, highly degraded areas were overlooked, with loans favouring more productive regions, corroborating the observations of Gianetti and Ferreira Filho (2021). Emphasis was placed on financial gains rather than emission mitigation.

The implementation of the program by street-level bureaucrats ("workers who directly interact with citizens in the course of their tasks") does not reflect a necessity or vision for mitigating greenhouse gas (GHG) emissions. As such, the Plano ABC is often perceived as merely another credit line with greater acquisition difficulties, it requires more complex projects, specific licenses, detailed documentation, and a longer average time for resource approval (Chechi, Grisa, 2020). The program faces challenges due to its design, which prioritizes productivity and profitability increases, as other credit lines can achieve similar results with fewer requirements. As highlighted by Marques (2016), there is a significant difficulty in reconciling profitability and sustainability within capitalism.

Despite some challenges, the program, assessing its achievements and advancements over the years, was extended for a second stage, prolonging its duration for another ten years (2020–2030) and introducing Plano ABC+. This updated plan aims to reduce carbon equivalent emissions by 1.1 billion tons in the agricultural sector by 2030. The government seeks to strengthen the Plano ABC by promoting the diversification of economic instruments and financing to reduce dependence on subsidized financial resources. To monitor ABC+ actions and goals, the Integrated Information System of the Sectoral Plan and a Technical Committee were created to ensure that initiatives align with technological innovations and the needs of agribusiness (Schmidt, Da Silva, Santoyo, 2023).

It is worth noting that most research conducted on the program thus far has focused on document analysis, data and information organization, interviews, and qualitative data analysis. This focus is primarily due to the lack of data for conducting empirical evaluations. Empirical results include the studies of Da Silva and Vieira Filho (2020), who applied the synthetic control method; Gianetti and Ferreira Filho (2021), who used Spearman correlation to link the allocation of Plano ABC credit with other variables at the municipal level; and Carauta et al. (2018), who employed bioeconomic modelling.

Da Silva and Vieira Filho (2020) conducted a study to determine whether the program's strategy, including credit subsidies for adopting GHG mitigation practices, is the best policy to promote low-carbon production. Their findings revealed that the program had null effects on the increase of agricultural production per total GHG emissions during the post-intervention period. Meanwhile, Gianetti and Ferreira Filho (2021) analysed the regional allocation of resources to various Sustainable Production Systems (SPS) of Plano ABC from 2013 to 2017. Their study concluded that the program's resource distribution concentrates regionally and primarily on RPD, SPD, FLP, and ILPF systems. Technology implementation challenges mainly occur in regions where resources should be applied, such as low-aptitude municipalities. Economic and agricultural production variables show a stronger connection to Plano ABC adoption than environmental characteristics.

Lastly, Carauta et al. (2018) aimed to evaluate whether preferential credit programs, such as Plano ABC, could accelerate the adoption of low-carbon agricultural systems in Mato Grosso. Their findings showed that ABC credit significantly contributed to the adoption of integrated systems in Mato Grosso. Without preferential credit lines, the adoption of integrated systems would have been modest, covering only about 11% of agricultural land use.

3. Methodology and database

Social Network Analysis (SNA) emerged as a prominent field of study following Jacob Moreno’s (1953) foundational work. As a pioneer of this approach, Moreno identified that interactions between individuals—and the differentiated importance some hold in specific contexts and themes—lead to the formation of social networks. Within these networks, certain "nodes"—representing individuals—stand out as more relevant compared to others. Furthermore, Moreno demonstrated the possibility of analysing how these various nodes connect, whereby multiple individuals ("edges") relate to others, granting greater significance to the most well-connected nodes within a social network (Wasserman & Faust, 1994; Freeman, 2009).

Since then, SNA has been extensively utilized across fields such as communication, economics, geography, computer science, organizational research, and development studies. Generally, SNA visualization tools possess fundamental characteristics, including the nature of the data, visualization methods, and visual interactions that enable in-depth analyses. These tools can process one-dimensional data (such as matrices and time series), two-dimensional data (such as geographic coordinates and graph points), as well as algorithms or programs (such as information flows and debugging operations). It is noteworthy that, in social networks, the spatial position of nodes ("geography") plays a significant role, reinforcing the need to complement visual analysis with micro-analytical calculations (Veerspagen, 2007; Freeman, 2009).

According to Jackson (2010), in a social network, it is crucial to evaluate elements such as node centrality (degree, closeness, and betweenness), network metrics (eccentricity, graph density, average path length), and clustering measures (modularity). Centrality statistics provide a framework for comparing the roles of different nodes within the network, aiding in the identification of aggregate patterns. Centrality is divided into three primary categories: degree, which measures a node's level of connection; closeness, which determines the ease of a node's access to others; and betweenness, which assesses a node's role as a bridge between others.

Specifically, degree centrality has two dimensions: in-degree, which counts the connections directed toward a node, and out-degree, which measures the connections originating from a node. Closeness centrality, a commonly employed global metric, indicates a node's topological proximity to all others (Freeman, 1979; Jackson, 2010; Borgatti, Everett, & Johnson, 2018).

Betweenness centrality reflects the intensity of connections between actors in the network, while eccentricity, related to the diameter of each vertex, should present values greater than the average path length to ensure the network's optimal performance. This relationship indicates that, even with variations in the average path length across samples, values consistently lower than eccentricity guarantee efficient information flow, demonstrating the network's effectiveness (Brandes, 2001; Newman, 2008; Borgatti, Everett, & Johnson, 2018).

Finally, modularity was applied to segment the network into clusters, highlighting its community structure. These metric groups nodes based on common characteristics. In this study, algorithms such as those by Gilvan & Newman (2002); Newman (2004); and Zhang & Peixoto (2020) were employed to determine the optimal configuration of communities. Additionally, all network analysis graphs presented here follow the spatial distribution algorithm proposed by Fruchterman & Reingold (1991).

The data sources cover the period from 2013 to 2023, considering the launch of Plano ABC and data availability to date. The primary data source is the Rural Credit Data Matrix (MDCR) of the Central Bank of Brazil (BACEN), retrieved through tools capable of capturing indicators such as the region where credit was acquired each year, the amount invested, the number of contracts, the impacted area (in some cases), and subprograms used to justify credit under Plano ABC (optional).

In addition to financial data, information on equivalent carbon emissions from agriculture and land management is utilized. These data are provided by the Greenhouse Gas Emissions and Removals Estimation System (SEEG) and made available on the platform by IPAM (Amazon Environmental Research Institute) for studies on land-use change, and by Imaflora (Institute for Agricultural and Forest Management and Certification) for agriculture.

It is important to highlight that not all essential information for this study can be made available in SNA models. This is because three-dimensional variables (state/municipality, greenhouse gas emissions volume, investments) and intermittent data—such as yearly investment volumes—are not yet well-modelled by social network applications. To address this limitation, a second round of descriptive data analysis will be conducted. These data are drawn from the same sources used in the SNA, specifically the BACEN and SEEG databases.

4. Results and discussion

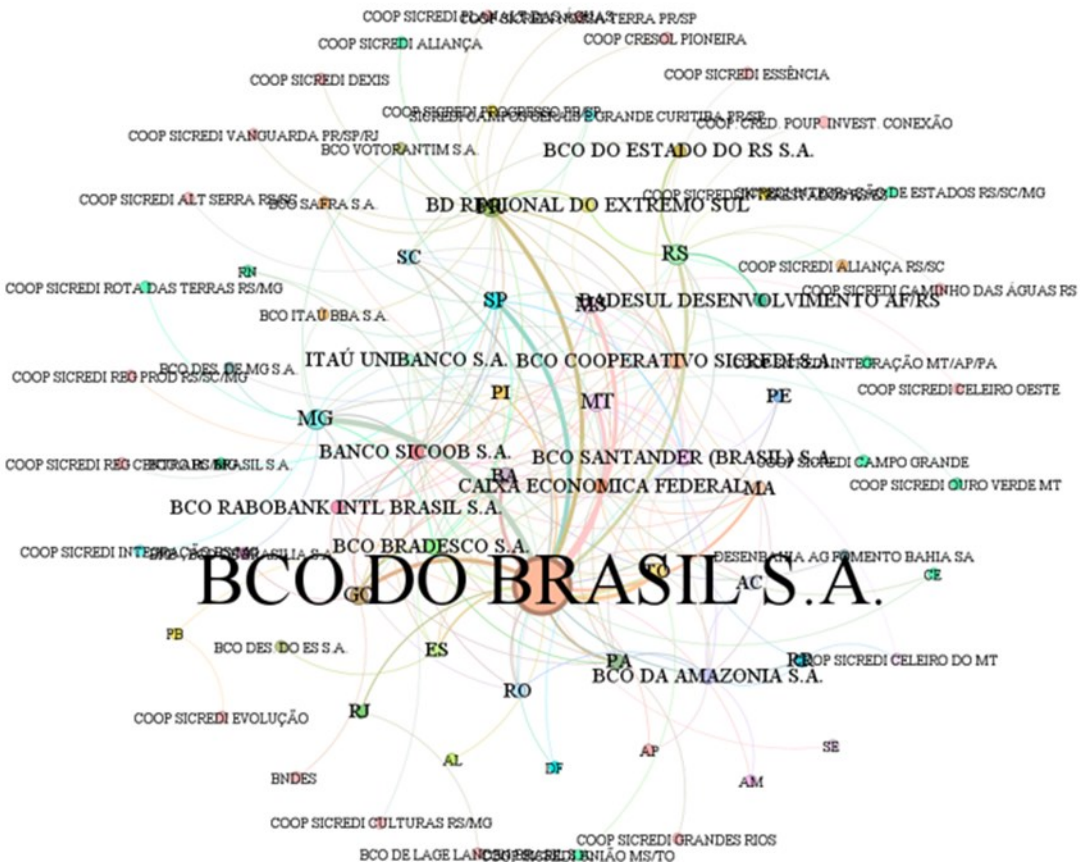
This study primarily aims to evaluate the state-level impact of Plano ABC in mitigating greenhouse gas (GHG) emissions in Brazil's agricultural sector during the period from 2013 to 2023. To achieve this, the study analyses the volume of resources allocated through financing to each federal entity, as well as their corresponding outcomes in terms of greenhouse gas emissions (whether reduced or increased).

In this sense, it is first imperative to identify the principal financial institutions behind the largest volume of financing and second, to determine which categories within ABC program receive the majority of these funds. Once this has been accomplished, together with the goals outlined in program ABC's framework (specified in section 2.2), there will be sufficient resources to explain and understand the movement of funds across regions and their outcomes in the final tables, as well as to assess whether the results align with the program´s objectives.

Figure 1 illustrates the network of connections between banks offering resources and the states demanding resources from these banks. Banco do Brasil leadership in disbursing funds is expected; however, what stands out are the states most demanding of the bank for these resources: Pará, Rondônia, Espírito Santo, Tocantins, Goiás, Bahia, Maranhão, Minas Gerais, Mato Grosso, and Piauí—some of which are not closely aligned with the plan's central goals.

Furthermore, a notable presence of regional credit cooperatives is observed. Although these cooperatives do not occupy central positions in the figure like other traditional banks, they remain well-connected to their reference states—a pattern that is also evident in states with development banks, demonstrating a clear financing ecosystem.

Figure 1: Network of banks offering and states requesting financing through the ABC



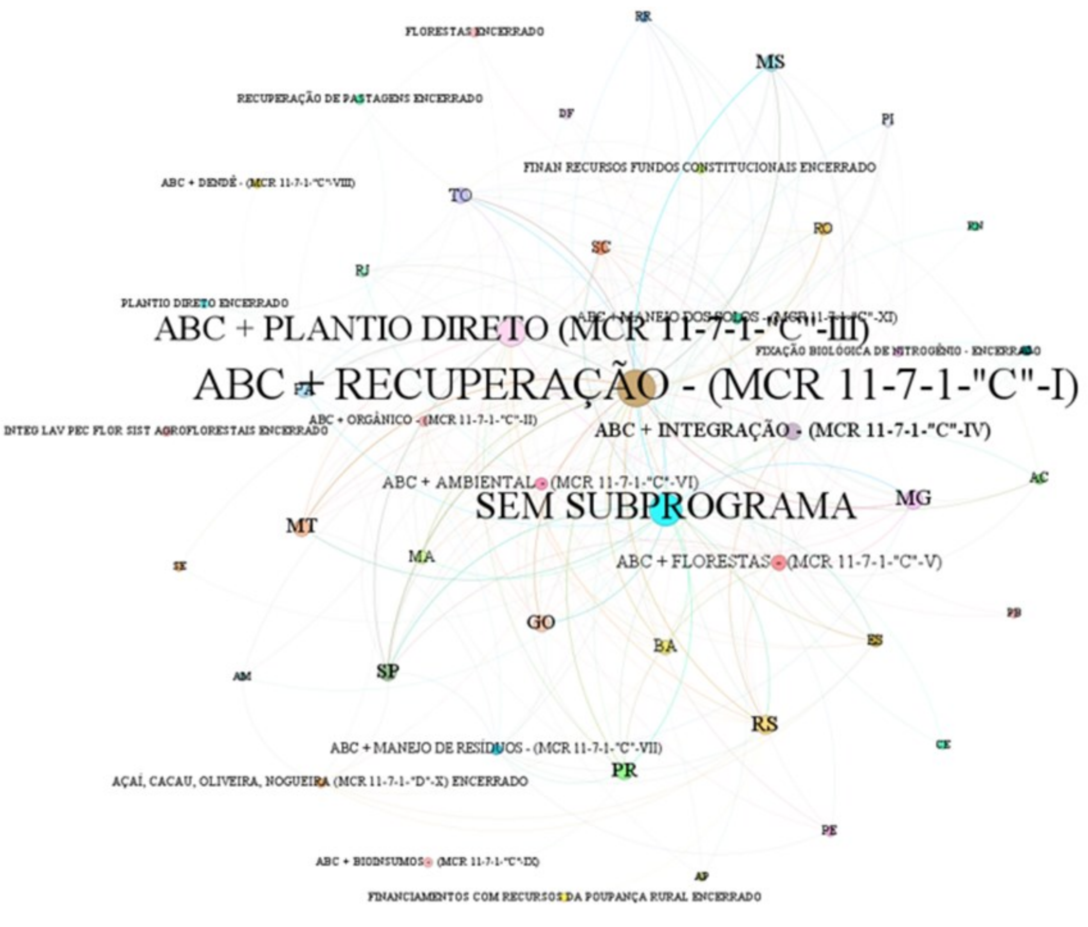
Source: Central Bank of Brazil, 2025.

The resources acquired through regional banks or cooperatives, under the framework of ABC program, are primarily directed toward pasture recovery. As expected, the edges and nodes of the state’s Mato Grosso, Mato Grosso do Sul, Tocantins, Minas Gerais, São Paulo, and Goiás stand out prominently, showing strong demand from these states for resources within this category of the program.

Another noteworthy category involves resource allocation for projects aimed at improving direct planting. In this category, states such as Tocantins, Mato Grosso, São Paulo, Goiás, Bahia, Rio Grande do Sul, Paraná, and Santa Catarina show greater relevance. Moreover, during several years analysed, there was a lack of connection to any specific subprogram. Hence, the significant attention given to the "sem subprograma" category. Interestingly, the leading beneficiaries of resources without a declared or identified subprogram destination are the states of Minas Gerais, Mato Grosso, and Mato Grosso do Sul. This suggests that a substantial portion of these resources is likely allocated to the recovery of degraded pastures (Borghi et al., 2018; Terra et al., 2019).

Additional relationships can be inferred from the connections represented in Figure 2, although the most relevant for the study's objectives are those highlighted above.

Figure 2: Main subprograms requested by the states



Source: Central Bank of Brazil, 2025.

The network data allows us to verify that the resources obtained through financing are primarily directed toward improvements in direct planting and pasture recovery—two lines of action that, respectively, should reduce equivalent carbon emissions and capture carbon from the atmosphere. This leads us to infer, even without conducting a descriptive analysis of the data, that financing tends to reduce the volume of state-level emissions in the states analysed.

In this context, knowing the main sources of financing and the primary destinations of resources, the next step is to examine the volume of these resources and whether the ABC program successfully reduced carbon emissions. Thus, we proceed to a state-level analysis capturing the years from 2013 to 2023, correlating the volume of resources obtained with the volume of carbon emissions over the same historical period.

The descriptive results immediately show that the ten states receiving the largest share of resources from the ABC program—namely Goiás, Rio Grande do Sul, Mato Grosso, Minas Gerais, Mato Grosso do Sul, São Paulo, Bahia, Paraná, Tocantins, and Pará—reveal no direct and positive relationship between acquiring these resources and reducing emissions in agriculture and land use. Except for the states of Mato Grosso, Bahia, and Pará, the volume of emissions peaked in years close to the final period of this analysis, especially in 2021, 2022, and 2023.

Reinforcing this finding, 19 of Brazil's 27 states experienced an increase in emissions after 2020, with 12 of them reaching their peak resource acquisition aimed at reducing emissions in the years before 2020. This further supports the notion that higher volumes of investment did not achieve the intended outcomes.

It is also acknowledged that, between 2020 and 2023, there were relaxations in the use of agrochemicals and pesticides, an increase in Amazon deforestation, and a dismantling of environmental control agencies, such as the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and other relevant preservation bodies. Additionally, the public discourse dominant at the time failed to prioritize environmental issues (Silva; Santos, 2023; Fernandes, 2022; Nigro, 2022).

Thus, with the notable exceptions already mentioned, the ABC program, when analysed broadly, shows results poorly aligned with its stated goal of reducing greenhouse gas emissions in agriculture and land use.

That said, we must be cautious and avoid concluding that the ABC program had no impact on reducing greenhouse gas emissions. This is because we lack a counterfactual comparison with other "mirror" states that did not receive such resources and their corresponding emission volumes. Based on the available data, the results appear adverse or minimally effective as per the established correlations. However, this does not imply, by any means, that the ABC program is ineffective or that, without it, emissions could not have been worse.

Table 1 presents the total investments received by states during the study period, under the structure of the ABC program (first column in millions of reais), the year with the highest volume of investments and its amount (second and third columns, respectively). These are followed by data related to greenhouse gas emissions from agriculture and land use, highlighting the volume of emissions in these sectors in 2013 and 2023, as well as the year when each state's emission peak occurred (all emissions data are in millions of tons of carbon dioxide equivalent – MTCO2e), with the corresponding volume in one column and the year in the next.

Table 1: Volume of investments and greenhouse gas emissions, highlighting the years of maximum (2013 to 2023)

Estado	Total	Major resource year	Year	GHG emissions (MTCO2e)		High point GHG emissions (MTCO2e)	
	Investiments (R$ Million)			**2013**	**2023**	**value**	**Year**
Goiás	1.022,20	152,00	*2017*	86,27	92,83	92,83	*2023*
Rio Grande do Sul	905,10	175,00	*2022*	22,84	26,61	28,89	*2021*
Mato Grosso	858,00	197,00	*2022*	11,75	88,52	117,52	*2013*
Minas Gerais	618,90	103,00	*2022*	77,22	77,04	79,82	*2021*
Mato Grosso do Sul	423,70	89,30	*2022*	72,90	79,21	79,21	*2023*
São Paulo	371,04	71,50	*2022*	9,06	9,63	10,44	*2021*
Bahia	349,63	101,00	*2022*	170,76	154,78	170,76	*2013*
Paraná	273,71	71,80	*2022*	28,92	36,48	42,55	*2022*
Tocantins	265,83	31,50	*2018*	3,95	6,02	10,93	*2022*
Pará	243,44	42,10	*2018*	79,65	68,21	79,65	*2013*
Maranhão	210,59	58,40	*2022*	65,70	88,70	88,70	*2023*
Piauí	192,63	52,40	*2021*	26,91	29,62	74,01	*2022*
Santa Catarina	136,18	21,40	*2021*	8,49	10,51	10,51	*2023*
Rondônia	125,00	23,80	*2019*	10,65	15,48	15,48	*2023*
Espírito Santo	61,51	14,90	*2018*	54,90	92,92	205,31	*2022*
Roraima	56,75	12,50	*2022*	12,24	13,22	13,43	*2014*
Acre	40,46	14,70	*2022*	275,27	312,26	538,92	*2021*
Rio de Janeiro	31,12	5,34	*2013*	34,31	29,57	35,11	*2015*
Pernambuco	17,20	4,37	*2022*	28,73	35,36	35,36	*2023*
Paraíba	2,57	2,30	*2022*	49,59	46,45	51,17	*2021*
Alagoas	1,95	0,97	*2014*	250,58	298,57	336,85	*2022*
Rio Grande do Norte	1,15	0,97	*2014*	22,77	28,63	37,87	*2019*
Amazonas	0,41	0,94	*2018*	181,23	169,76	181,23	*2013*
Sergipe	0,24	0,92	*2019*	7,88	7,27	8,64	*2014*
Distrito Federal	0,21	0,92	*2018*	89,78	99,63	154,96	*2022*
Ceará	0,19	0,19	*2013*	103,00	134,96	134,96	*2023*
Amapá	0,0	0,00	-	118,90	173,42	173,42	*2023*

Source: BACEN, 2025; SEED, 2025.

Thus, this study successfully identified and linked fundamental characteristics for profiling the investments made through the ABC program, its beneficiaries, and the areas to which these resources are directed. When these findings are related to the primary goal of the ABC program—to decarbonize agriculture—they reveal limited alignment between the financed initiatives, the intended objectives, and the observed outcomes of the program.

5. Concluding remarks

The ABC Plan/Program was developed in alignment with global sustainable development objectives, primarily focusing on mitigating greenhouse gas (GHG) emissions in the agricultural sector to positively influence the reduction of climate change effects. The analysis of data and results from 2013 to 2023 demonstrates that the ABC Plan/Program is a relevant initiative for promoting sustainability in Brazil. However, the policy's effectiveness faces challenges in ensuring better outcomes.

The state-level analysis made it possible to understand the distribution of financing, primarily through Banco do Brasil, and the allocation of resources, revealing a strong concentration in lines aimed at recovering degraded pastures and implementing direct planting. Nevertheless, empirical results indicate that, in most states, the increase in investment volumes targeted at mitigating GHG emissions has not directly translated into an effective reduction in these emissions. The lack of coordination between the volume of investments and environmental outcomes, particularly regarding GHG emissions mitigation, highlights the existence of operational and structural barriers.

From an operational perspective, factors such as inefficient resource allocation, weaknesses in the implementation of incentivized practices, and disconnection between environmental and agricultural policies may contribute to the program's challenges. Furthermore, it was observed that the financing lines aimed at pasture recovery and direct planting receive the majority of the resources provided by the program. From a structural perspective, the recent political and institutional context, characterized by relaxed environmental regulations and increased deforestation, may have further hindered the program's objectives. This suggests the need for environmental policies to be articulated with other policies—whether economic, social, or institutional—as well as for more integrated analysis and monitoring of resource allocation and outcomes.

While the ABC Program shows evidence suggesting that its implementation has not been sufficient to generate widespread and consistent impacts in reducing GHG emissions in the agricultural sector, it cannot be considered entirely ineffective. The exceptions observed in states like Mato Grosso, Bahia, and Pará underscore the need for further investigation to identify the specific factors enabling better performance in these regions.

In this context, it is recommended to enhance monitoring and strategic evaluation of the ABC Program, with greater alignment between financing allocations and environmental objectives, strengthening monitoring and evaluation mechanisms, and encouraging more effective practices in reducing carbon emissions in agriculture. This includes reconsidering whether states classified as low aptitude should continue to receive fewer advantages for accessing loans or whether this logic should be reversed. Only through the adoption of more robust and coordinated measures can the program effectively fulfil its role in promoting low-carbon agriculture and meeting the climate commitments undertaken by Brazil at both national and global levels.

References

BACEN. *Matriz de Dados do Crédito Rural.* Available at: <Matriz de Dados do Crédito Rural - MDCR - Conjunto de dados - Portal de Dados Abertos do Banco Central do Brasil>. Access in: 20, feb. 2025.

BRANDES, U. (2001). A faster algorithm for betweenness centrality. *Journal of mathematical sociology,* 25(2), 163-177.

BORGATTI, S. P., Everett, M. G., & Johnson, J. C. (2018). *"Analyzing Social Networks."* London: SAGE Publications.

BORGHI, E., Neto, M. M. G., RESENDE, R. M. S., ZIMMER, A. H., De ALMEIDA, R. G., & MACEDO, M. C. M. (2018). Recuperação de pastagens degradadas. *Agricultura de baixo carbono: tecnologias e estratégias de implantação*. Brasília, DF: *Embrapa*, 4, 105-138.

BERGER, Thomas. Can preferential credit programs speed up the adoption of low-carbon agricultural systems in Mato Grosso, Brazil? Results from bioeconomic microsimulation. *Regional Environmental Change,* v. 18, n. 5, p. 117-128, 2018.

BRASIL. *Lei nº 12.187, de 29 de dezembro de 2009.* Institui a Política Nacional sobre Mudança do Clima e dá outras providências. Diário Oficial da União: seção 1, Brasília, DF, 29 dez. 2009.

CHECHI, Leticia Andrea; GRISA, Catia. Dos acordos globais às interpretações locais sobre agricultura sustentável: tradução e implementação do Plano e do Programa ABC. *CONFINS (PARIS)*, v. 46, p. 1, 2020.

COMISSÃO MUNDIAL SOBRE MEIO AMBIENTE E DESENVOLVIMENTO. (CMMAD). *Nosso futuro comum.* 2. ed. Rio de Janeiro: Fundação Getúlio Vargas, 1991.

DA SILVA, Felipe Pinto; VIEIRA FILHO, José Eustáquio Ribeiro. *Texto para discussão*: avaliação de impacto do programa de abricultura de baixo carbono no Brasil. Instituto de Pesquisa Econômica Aplicada: Rio de Janeiro, 2020.

FERNANDES, R. M. S. (2022). A política mineral do governo Bolsonaro para a Amazônia Legal: Um balanço a partir dos processos minerários ativos. AMBIENTES: *revista de geografia e ecologia política*, 4(2), 149-172.

FREEMAN, L. C. (1979). "Centrality in Social Networks: Conceptual Clarification." *Social Networks*, 1(3), 215-239.

FREEMAN, L. C. (2009) Methods of Social Network Visualization. *Encyclopedia of Complexity and Systems Science*, 1-17.

GIRVAN, M. y Newman, M.E. (2002). Community Structure in Social and Biological Networks. Proceedings of the National Academy of Sciences, 99(12), 7821-7826.

GIANETTI, Giovani William; FERREIRA FILHO, Joaquim Bento de Souza. O Plano e Programa ABC: uma análise da alocação dos recursos. *Revista de Economia e Sociologia Rural,* v. 59, n. 1, p. e216524, 2021.

IGARI, Alexandre T.; PIVELLO, Vânia R. Crédito rural e código florestal: irmãos como Caim e Abel? **A***mbiente & Sociedade*, v. 14, p. 133-150, 2011.
Jackson, M. O. (2010). "Social and Economic Networks." Princeton: Princeton University Press.

LOVATO, Luiz Gustavo; SCHULTZ, Glauco; REVILLION, Jean Philippe Palma. Crédito agrícola para a mitigação das mudanças climáticas: uma análise do Programa ABC. **R***evista em Agronegócio e Meio Ambiente*, *[S. l.]*, v. 13, n. 3, p. 897–913, 2020. DOI: 10.17765/2176-9168.2020v13n3p897-913. Available in: https://periodicos.unicesumar.edu.br/index.php/rama/article/view/7324. Access in: 27 feb. 2025.

MARQUES, Luiz. *Capitalismo e colapso ambiental.* Campinas: Editora UNICAMP, 2 ed., 2016.

MATOS, Patricia Francisca; PESSÔA, Vera Lúcia Salazar. O agronegócio no cerrado do sudeste goiano: uma leitura sobre Campo Alegre de Goiás, Catalão e Ipameri. *Sociedade & Natureza,* n. 1, p. 37-50, jan./abr. 2012.

MUELLER, C. C. *Os Economistas e as Relações entre o Sistema Econômico e o Meio Ambiente.* Brasília: Editora UnB, 2007.

MORENO, J. (1953) *Who Shall Survive? Foundations of sociometry, group psychotherapy and psychodrama,* Beacon House Inc., New York.

NEWMAN, M. E., & Girvan, M. (2004). Finding and evaluating community structure in networks. *Physical review E*, *69*(2), 026113.

NEWMAN, M. E. (2002). Assortative mixing in networks. *Physical review letters*, 89(20), 208701.

NEWMAN, M. E. (2008). The mathematics of networks. *The new palgrave encyclopedia of economics*, *2*(2008), 1-12.

SCHMIDT, Nádia Solange; DA SILVA, Christian Luiz; SANTOYO, Alain Hernández. Análise do plano de agricultura de baixo carbono (ABC) no Brasil: resultados e perspectivas. *Universidad y Sociedad,* v. 15, p. 279-291, 2023.

SILVA, E. M. D., & Santos, J. S. (2023). A "escalada" dos agrotóxicos no governo Bolsonaro. *Serviço Social & Sociedade*, 146(2), e6628321.

TSAI, David et al. **A***nálise das emissões de gases de efeito estufa e suas implicações para as metas climáticas do Brasil*: 1970-2023. Piracicaba: Observatório do Clima, 2024. Disponível em: https://seeg.eco.br/wp-content/uploads/2024/11/SEEG-RELATORIO-ANALITICO-12.pdf. Acesso em: 13 de março de 2025.

SEEG. *Série histórica das emissões de gases estufa.* Available in: SEEG - Sistema de Estimativa de Emissão de Gases Access in: 20, feb. 2025.

TERRA, A. B., FlORENTINO, L. A., REZENDE, A. D., & SILVA, N. C. (2019). Leguminosas forrageiras na recuperação de pastagens no Brasil. *Revista de Ciências Agrárias*, *42*(2), 11-20.

VERSPAGEN, B. (2007). Mapping technological trajectories as patent citation networks: A study on the history of fuel cell research. *Advances in complex systems*, *10*(01), 93-115.

WASSERMAN, S., & Faust, K. (1994). "*Social Network Analysis: Methods and Applications."* Cambridge: Cambridge University Press.

WORLD BANK GROUP. *Brazil Country Climate and Development Report*. CCDR Series. 2023.

ZANG, L, Peixoto, T (2020). *Statistical inference of assortative community structures Phys*. Rev. Research 2 043271. https://dx.doi.org/10.1103/PhysRevResearch.2.043271.