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Research Article

Toward Agricultural Resilience: Analyzing Brazil's National Fertilizer Plan

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Abstract

This study aimed to analyze the National Fertilizer Plan presented by the Brazilian government, with the goal of developing and expanding the sector, given the prominent role of the country as a significant food producer, facing significant challenges in this domain. The research was conducted through bibliographic reviews and a qualitative approach to the subject. The results indicate that, due to the current scenario in the fertilizer sector in Brazil, a policy of this magnitude is not only timely but also crucial. The plan is based on important guidelines such as modernizing the sector, investing in the fertilizer chain, promoting competitiveness for Brazilian products, robustly investing in science, technology, and development, and improving the logistics environment for the fertilizer chain. Additionally, it is noteworthy that the presented plan exhibits robustness by conscientiously addressing environmental sustainability. It aspires not only to modernize the Brazilian fertilizer industry but also to expand domestic production, accompanied by substantial investments in research, development, and innovation. The plan outlines goals and actions to be implemented by 2050; however, it is imperative that these objectives be closely monitored and periodically reviewed to ensure the success of the initiative. In summary, it can be asserted that the National Fertilizer Plan represents a significant step toward a more resilient, sustainable, and productive Brazilian agriculture.

Keywords

Food Production, Guidelines, Innovation, Research

1. Introduction

Brazil is globally recognized as one of the leading food producers, taking the lead in the global production of various agricultural products such as soybeans, coffee, orange juice, and sugar. Additionally, it stands out as the second-largest producer of beef and the third-largest producer of poultry [1]. In a context where approximately 800 million people face hunger and with an estimated population growth of around 20% in the next twenty-five years [2, 3], Brazil will play an even more crucial role in combating food insecurity. It is anticipated that by 2050, the country will be responsible for at least 40% of the world's food supply [3]. This projection positions Brazil prominently in the quest for solutions to ensure adequate global food provision.

Despite having factors such as a favorable climate for

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various crops, available arable land, and skilled and competent farmers, Brazil faces a scarcity of an essential input for high-performance cultivation: fertilizers. The Brazilian territory primarily consists of tropical soils, naturally poor in fertility, making agricultural production practically unviable without the use of this input [4].

Most fertilizers used in Brazil originate externally, approximately 85% [5]. Consequently, this scenario of high dependence on an input renders the country susceptible to fluctuations in the international market. In early 2021, with the recovery of China and the United States after the COVID-19 pandemic, these countries directed their fertilizer production for domestic supply. Additionally, in early 2022, the conflict between Ukraine and Russia began, leading to restrictions on fertilizer exports and a reduction in global supply. As a result of high demand and low supply, fertilizer prices in Brazil soared to rarely reached levels, impacting the national agricultural sector.

Given the increasing external dependence and the potential for exponential growth in the Brazilian agricultural sector, with the aim of adopting a long-term strategic approach, it was decided in 2022 to establish an interministerial working group to develop a National Fertilizer Plan (NFP) [6]. The objective of the NFP is to develop policies to enhance the competitiveness of fertilizer production and distribution in Brazil sustainably. Caligaris et al. [7] argue that this succession of crises may be an opportunity to recognize that, for the national agriculture to maintain a prominent global position, attention must be paid to its foundations. According to the authors, the availability of affordable fertilizers and plant nutrition inputs should be understood as a bottleneck not only for national agriculture but also for the planet's food security.

A public policy can be defined as "a course of governmental action proposed or adopted to address a specific problem or issue" [8]. Another important definition is presented by [9], describing public policies as "actions or decisions made by government authorities with the aim of achieving goals and solving public problems." Birkland [10] defines public policy as "government decisions to act, or not act, to change or maintain aspects related to certain matters of public interest." Considering these definitions, the NFP clearly emerges as a public policy.

This article aims to study public policies related to the fertilizer sector and their implications in various economic sectors such as agriculture, industry, science and technology, and the services sector, correlating them with the objectives proposed in the NFP.

2. Government Policies for Fertilizers and Environmental Sustainability

Historically, fertilizer policies have evolved to meet the constantly changing demands of agriculture and environmental sustainability. Quizon [11] reports that in the 1960s, a few countries provided subsidies and price controls to ensure affordable access to fertilizers. In some cases, this was viewed with suspicion [12], the authors criticized these policies due to their potential to encourage excessive use and environmental degradation.

In recent years, governments have shifted towards promoting sustainable fertilization practices. Globally, there has been a push for the adoption of balanced nutrient management in agriculture, emphasizing the precise application of nutrients based on soil analyses and crop needs [13]. These approaches aim to optimize fertilizer use efficiency while minimizing environmental impacts.

Governmental policies are evaluated for their effectiveness in achieving sustainability objectives. Studies reported by Pretty et al. [14] and Tilman et al. [15] have shown that nutrient management policies, such as precision agriculture and site-specific application, have positive effects on crop productivity, farmer income, and environmental conservation.

While sustainable fertilizer policies hold promise, their successful implementation faces various challenges, such as financial constraints, lack of farmer awareness, and inadequate extension services that may hinder the adoption of best practices [16]. Additionally, fragmented policies and weak enforcement can compromise regulatory effectiveness [17].

Fertilizer use is a global issue, and international cooperation is crucial to address transboundary environmental challenges. Organizations like the Food and Agriculture Organization (FAO) and the International Fertilizer Association (IFA) have worked to harmonize fertilizer policies and promote sustainable practices worldwide [18]. In this regard, a policy aiming to expand and optimize fertilizer use must also address environmental sustainability to be effective in all aspects.

One of the primary challenges faced by the contemporary world is environmental sustainability. Increasing pressures on natural resources, rising greenhouse gas emissions, and accelerated loss of biodiversity demand a coordinated and efficient response from global societies. In this context, public policies play a crucial role in promoting sustainable development, ensuring a balance between human needs and environmental conservation.

The transition to clean and renewable energy sources is one of the most important goals for achieving environmental sustainability. Public policies that encourage the use of renewable energies, such as wind and solar, and promote energy efficiency, are essential to reduce greenhouse gas emissions and mitigate the impacts of climate change [19].

Water scarcity and pollution of water bodies are growing challenges in many regions worldwide. Public policies should address sustainable water resource management, encouraging efficient water use practices, wetland restoration, and protection of aquatic ecosystems [20].

Biodiversity loss is a global concern, requiring urgent actions to protect terrestrial ecosystems and threatened species. Public policies for biodiversity conservation may include creating protected areas, incentives for ecosystem restoration, and implementing sustainable agricultural practices that minimize impacts on fauna and flora [21].

Concerning fertilizer use, a major global issue is the eutrophication of water bodies due to leaching of compounds such as nitrate and phosphate. This promotes the uncontrolled growth of macrophytes, reducing oxygen levels in the water and potentially leading to the death of aquatic fauna [22-25]. Therefore, a policy aimed at promoting fertilizer use must include awareness of appropriate, rational, and efficient use to prevent future problems.

Public policies for environmental sustainability should include mechanisms for social participation and engagement. Involving different stakeholders, such as local communities, indigenous peoples, NGOs, and the private sector, is crucial for building more comprehensive and successful solutions. Transparency and accountability are key elements to ensure that implemented policies reflect collective interests in favor of sustainability. Public policies can use economic incentives to promote the adoption of sustainable practices. Mechanisms like subsidies for clean technologies, environmental taxation, and carbon markets can stimulate the adoption of more sustainable business strategies [26]. Additionally, public investments in green infrastructure and circular economy can also drive the transition to a more sustainable economic model.

Environmental sustainability plays a vital role in the success of the proposed policy, and the key to best practices lies in research and development. Research is essential to drive innovation in fertilizer technologies, seeking sustainable solutions that promote both agricultural productivity and environmental preservation.

3. The Role of Research and Development in the Innovation of Fertilizer Technologies

The innovation in fertilizer technologies is essential for balancing agricultural productivity and sustainability. The agricultural sector has witnessed an increase in innovative fertilizer technologies aiming to optimize nutrient delivery, minimize environmental footprints, and maximize crop performance [5]. Numerous innovations have emerged in the field of fertilizer technologies with the goal of improving nutrient use efficiency and reducing environmental impacts. Some noteworthy innovations include: i) Controlled-release fertilizers; ii) Slow-release fertilizers; iii) Nanofertilizers; iv) Precision agriculture; and v) Biological fertilizers [27-31].

Research, development, and innovation (RD&I) are fundamental to the progress of fertilizer technologies. Investments in RD&I drive innovation by encouraging the creation of new fertilizer products and application practices, representing a crucial pathway for advancement. RD&I efforts aid in adapting fertilizers for specific crops and soil types, ensuring the precise delivery of nutrients in optimal proportions [32]. RD&I assesses the environmental implications of new fertilizer technologies, facilitating the development of ecologically sound and sustainable alternatives [33].

In addition to creating alternatives, RD&I enables the incorporation of emerging technologies such as artificial intelligence, machine learning, and biotechnology in fertilizer development and application [34]. RD&I helps bridge the knowledge gap, providing farmers with updated information on best practices, thereby promoting the adoption of innovative fertilizer technologies [35].

Innovation in fertilizer technologies is crucial for sustainable agriculture, ensuring food security while minimizing environmental impacts. The role of research and development cannot be underestimated as it drives the advancement of fertilizer efficiency and environmentally friendly practices. Continuous investment in RD&I will be pivotal in shaping the future of agriculture and promoting a harmonious balance between productivity and sustainability.

4. Brazilian National Fertilizer Plan

To achieve this goal, the NFP is based on five fundamental guidelines (Table 1). As a globally sensitive topic, environmental sustainability is not merely an isolated directive within the plan but rather a requirement that permeates the entire NFP.

Table 1. *Guidelines of the National Fertilizer Plan 2022–2050.*

Guidelines	i	Modernization, reactivation, and expansion of existing fertilizer plants and projects in Brazil.
	ii	Improvement of the business environment in the country, aiming to attract investments to the fertilizer and plant nutrition chain.
	iii	Promotion of competitive advantages in the global fertilizer production chain for Brazil.
	iv	Expansion of investments in Research, Development, and Innovation (RD&I) for the fertilizer and plant nutrition sector in Brazil.
	v	Adaptation of infrastructure for the integration of logistics hubs and the feasibility of new ventures.

When mentioning modernization in the previously cited guideline i, the aim is to update production models, seeking to minimize environmental impacts and promoting the reuse of waste. Regarding the attraction of investments in guideline ii, it requires the implementation of policies that seek not only financial return but also bring social and environmental benefits aligned with ESG (Environmental, Social, and Governance) concepts. Currently, ESG investments represent a growing part of the capital market, with global values estimated at around USD 30 trillion in assets managed by sustainable strategy funds [36]. Additionally, investments in RD&I must also align with ESG principles; otherwise, they may jeopardize investments, among other issues.

The NFP has clear objectives in two important aspects. The first is to encourage companies involved in fertilizer production in Brazil to adhere to environmental and social sustainability criteria. This will drive the adoption of more responsible and eco-friendly practices throughout the fertilizer production and distribution chain [7]. Secondly, the program aims to reduce the waste and tailings generated by mining activities while seeking to enable innovative technologies to recover nutrients and transform them into new fertilizers, contributing to circular economy principles and the preservation of natural resources.

In addition to the aspects mentioned above, the NFP will seek to implement an effective communication and scientific dissemination strategy on fertilizers. The goal is to raise awareness among the population and farmers on fundamental topics such as good nutrient usage practices, alternative sources, and technologically advanced products.

Given the importance of RD&I in meeting the growth demand sustainably, possibly among the NFP guidelines, investment in research, development, and innovation is one of the most important, if not the most important. In addition to all the contributions mentioned above, Brazil has soil characteristics that differ from practically all other agricultural powers worldwide. Thus, innovation and the creation of "tropicalized" products become necessary as they will be able to efficiently meet the demands of Brazil, being tailored to the country's conditions [6].

To meet these needs, the investment in RD&I of the NFP, like the other guidelines, will have goals and actions to be fulfilled in stages until 2050, which will be periodically assessed, reviewed, and redesigned/updated if necessary. Since there are many actions and goals, listing them here would be quite cumbersome; therefore, readers can refer to them more comprehensively in the NFP text [6].

It is crucial not only to outline the strategic results aimed to be achieved over the next years with the NFP but also to clearly establish the management and governance structure of the Plan. This must be done considering the dynamic nature of federal administration, as well as the complexity and interdisciplinary nature of the fertilizer sector. It is essential to strictly observe the pre-established deadlines and incorporate insights from various management and control instruments to ensure effective and successful guidance.

As the NFP aims to ensure farmers' access to essential inputs to maximize agricultural productivity, successful implementation and continuous evaluation are indispensable. For this, a robust monitoring and evaluation system is mandatory. Thus, effective monitoring methods need to be established, including indicators such as i) Crop Yield: The increase in crop yield is a key indicator of fertilizer effectiveness. Monitoring yield over time can indicate the policies' contribution to increased productivity. ii) Access and Use of Fertilizers: Analyzing farmers' access to fertilizers and their proper use provides insights into the penetration of policies and their practical application. iii) Price Variation: The stability of fertilizer and agricultural commodity prices can indicate the success of policies in mitigating fluctuations and improving predictability. iv) Food Security: Evaluating changes in the food and nutritional security of agricultural communities helps determine if policies are contributing to meeting basic needs. v) Environmental Sustainability: Indicators related to soil health, water quality, and environmental impacts can provide insights into the effects of fertilizer policies on the environment.

5. Conclusions

In this study, it was possible to verify that the National Fertilizer Plan (NFP) emerges as a strategic and necessary response to the challenges and opportunities that Brazil faces in the agricultural sector. This document examined public policies related to the fertilizer sector, highlighting the importance of environmental sustainability, research, and development (R&D) in fertilizer technologies, and the discussion about the NFP itself.

Global food security faces increasing threats, with a rapidly growing population and increasingly intense environmental pressures. Brazil, as one of the major food producers, plays a fundamental role in addressing this challenge. However, excessive dependence on imported fertilizers places the country in a vulnerable position in the face of fluctuations in the international market. If successful, the NFP can assist in increasing domestic fertilizer production, promoting sustainability, and reducing this vulnerability.

The approach of the NFP is not limited to merely increasing fertilizer production. It recognizes the need to align production with the principles of environmental and social sustainability. The pursuit of clean energy sources, responsible water resource management, and biodiversity conservation are essential elements that permeate the plan. This holistic approach is crucial to ensuring that agricultural sector growth is ecologically viable and socially responsible.

Innovation in fertilizer technologies is identified as a central component in the pursuit of a balance between productivity and sustainability. Through continuous investment in

R&D, Brazil can develop fertilizers adapted to its unique soil and climate conditions, optimizing nutrient use efficiency, and reducing environmental impacts. The application of innovative approaches, such as controlled-release fertilizers and precision agriculture, has the potential to revolutionize the way fertilizers are used, promoting more efficient and sustainable agriculture.

The successful implementation of the NFP will require not only the clear definition of goals and guidelines but also a robust management and governance structure. The participation of multiple stakeholders, including the private sector, local communities, and non-governmental organizations, is crucial for the plan's success. Additionally, continuous evaluation through relevant indicators will allow adjustments and improvements over time, ensuring that the NFP achieves its objectives effectively.

In conclusion, the National Fertilizer Plan represents a significant step toward a more resilient, sustainable, and productive Brazilian agriculture. By addressing the dependence on imported fertilizers, promoting environmental sustainability, encouraging technological innovation, and ensuring effective management, the NFP has the potential not only to boost the agricultural sector but also to contribute significantly to global food security. Rigorous implementation and monitoring of the NFP will be crucial to ensure that Brazil achieves its goals and plays a leadership role in the quest for food and environmental solutions on the world stage.

Conflicts of Interest

The authors declare no conflicts of interest.

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