

VERTICAL INTEGRATION IN THE APPLICATION OF PESTICIDES IN BRAZIL: A GOVERNANCE PROPOSAL FOR REDUCING SANITARY AND ENVIRONMENTAL RISKS

INTEGRAÇÃO VERTICAL NA APLICAÇÃO DE AGROTÓXICOS NO BRASIL: PROPOSTA DE GOVERNANÇA PARA REDUÇÃO DE RISCOS SANITÁRIOS E AMBIENTAIS

INTEGRACIÓN VERTICAL EN LA APLICACIÓN DE PLAGUICIDAS EN BRASIL: UNA PROPUESTA DE GOBERNANZA PARA REDUCIR LOS RIESGOS SANITARIOS Y AMBIENTALES



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ABSTRACT

This article analyzes the public health and environmental risks associated with pesticide use in Brazil and discusses how governance arrangements can influence the quality of on-farm application. Through a comparative literature review of three models (direct sales, outsourcing, and downstream vertical integration), the study synthesizes evidence on recurrent shortcomings in use (dosage, personal protective equipment, disposal, and resistance management), particularly in settings with limited technical assistance. It proposes an industry-linked technical application service model incorporating mechanisms for traceability, operational standardization, and accountability. The article concludes that a partial shift from a sales-based model to a service-based model can reduce risks, provided it is accompanied by regulation, independent auditing, and safeguards for smallholders.

Keywords: Vertical Integration. Agrochemicals. Sustainability. Environmental Hazards.

RESUMO

Este artigo analisa riscos sanitários e ambientais associados ao uso de agrotóxicos no Brasil e discute como arranjos de governança podem influenciar a qualidade da aplicação no campo. Por meio de revisão bibliográfica (venda direta, terceirização e integração vertical a jusante), sintetizam-se evidências sobre falhas recorrentes de uso (dosagem, EPI, descarte e manejo de resistência), especialmente em contextos de baixa assistência técnica. Propõe-se um modelo de prestação de serviço técnico de aplicação vinculado à indústria, com mecanismos de rastreabilidade, padronização operacional e responsabilização. Conclui-se que a migração parcial de um modelo de venda para um modelo de serviço pode reduzir riscos, desde que acompanhada de regulação, auditoria independente e salvaguardas para pequenos produtores.

Palavras-chave: Integração Vertical. Agroquímicos. Sustentabilidade. Perigos Ambientais.

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RESUMEN

Este artículo analiza los riesgos para la salud y el medio ambiente asociados al uso de plaguicidas en Brasil y examina cómo los mecanismos de gobernanza pueden influir en la calidad de su aplicación en el campo. Mediante una revisión bibliográfica (ventas directas, subcontratación e integración vertical descendente), se sintetiza la evidencia sobre fallas recurrentes en el uso (dosificación, EPI, eliminación y manejo de la resistencia), especialmente en contextos con escasa asistencia técnica. Se propone un modelo para la prestación de servicios técnicos de aplicación vinculados a la industria, con mecanismos de trazabilidad, estandarización operativa y rendición de cuentas. Se concluye que una transición parcial de un modelo de ventas a un modelo de servicios puede reducir los riesgos, siempre que se acompañe de regulación, auditorías independientes y salvaguardias para los pequeños productores.

Palabras clave: Integración Vertical. Agroquímicos. Sostenibilidad. Riesgos Ambientales.

1 INTRODUCTION

Brazil is one of the main agricultural producing countries in the world. In 2018, the participation of Agribusiness reached 21.1% of the Brazilian GDP, it is the world's largest producer of coffee, orange juice and chicken meat and second in the production of sugar, soybeans and beef. Simultaneously with this, agribusiness was responsible for 87.6 billion of the Brazilian trade balance, ensuring its positive balance of 58.7 billion. Brazil is the world's leading exporter of sugar, coffee, orange juice, soybeans, chicken and beef, the second largest exporter of soybean oil, soybean meal and cotton, and is among the main exporters of corn and pork (CNA, 2019).

The success of Brazilian agribusiness in agricultural production, assuming great prominence in the international scenario, was guided by successful policies for agriculture, such as investment in research, rural credit, price policies, tax policies, investment policies, export stimulus policy, etc. In the field, new varieties of crops were implemented, adjusting to edaphoclimatic factors, zoning, investments in machinery, equipment, implements, seeds, fertilizers, limestone, agrochemicals and new management techniques. Not only in the field, but adjustments and new methodological and management techniques were implemented throughout the production chain, especially for commodities (CHADDAD, 2017).

As an example, the trend of increase in Brazilian grain production and productivity is being consolidated in recent decades. From the 1976/1977 harvest to the 2018/2019 harvest, there was an increase in the produced area in the order of 1.2% per year, while productivity increased by 2.6% per year and production by 3.9% per year (CONAB, 2019).

Among the actions carried out to increase productivity in the field, the mechanisms to combat pests and diseases stand out, in addition to being one of the pioneers to implement the use of biological control on a large scale in crops, Brazil has advanced in the development of agrochemicals,² which are chemical substances used in agricultural crops with the objective of preventing, destroy, repel or inhibit the occurrence or effect of living organisms that can compromise the performance of agricultural crops (NATIONAL RESEARCH COUNCIL, 2000).

There are about 300 active ingredients, in two thousand different commercial formulations, used in the country. The main agrochemicals are Herbicides, Insecticides, Fungicides, Acaricides, Biological control agents, semiochemical-based agrochemicals, fumigants, rodenticides, molluscocides, nematocides and Household products (SILVA and COSTA, 2012; STOPPELLI AND MAGALHÃES, 2005).

² Also known as pesticides, pesticides, pesticides or phytosanitary products.

According to FAO (2019), from 1990 to 2017, the use of agrochemicals in the world grew at a rate of 2.12% per year; in Brazil, use has been increasing at a rate of 7.5% per year. According to this same source, the country is the third largest consumer in the world with 8.44% of the volume used, it is second in the use of insecticides and herbicides, and third in the consumption of fungicides.

These increasing rates of agrochemical use in Brazil are due to the new technologies used in the field to increase crop productivity. However, it can also be due to the inappropriate use and management of available technologies, leading to the waste of developed technological efficiency. In fact, there are studies that point to serious problems such as the emergence of pest resistance to active ingredients, as a result of inappropriate use, in addition to the widely discussed implications

According to Almeida (2018), rural producers should consider adopting resistance management strategies on their properties, as inadequate management in the use of agrochemicals can compromise the profitability of rural producers, generating a loss of efficiency in the technology used and increasing pest resistance. This generates an increase in the application of the volume of agrochemicals necessary for the crop, causing economic losses, losses of the technological benefit of agrochemicals in terms of their effectiveness in the field.

One of the problems identified within agricultural production is the level of education of rural producers, of the 5,056,525 agricultural establishments, 23.03% of the owners do not know how to read and write, 79.98% do not receive any technical guidance and only 33.15% used agrochemicals, according to data from the 2017 Agricultural Census. Of those who used agrochemicals, 15.58% do not know how to read and write, 77.09% do not have a high school education, and 63.29% did not receive technical assistance (IBGE, 2019).

With these data from the last Agricultural Census, it can be seen that the process of managing agrochemicals in the field needs to be better oriented towards reducing risks in the health of producers, consumers and environmental risks.

From the producer it would be in the correct handling in the field and for his own protection; however, most of them do not have the level of education or access to the technical assistance necessary for the correct management of the use and application of agricultural pesticides, in addition to the adoption of integrated management and other more sophisticated and sustainable techniques that require greater knowledge;

From the consumer, with the incorrect administration of agrochemicals in the field, it is possible to consume products that do not respect the rules for the use of agrochemicals, either

by the use of chemicals in inadequate doses or by disrespecting the grace period, or even by applying products not registered for the crop. This, in part, is inspected by ANVISA through the Program for the Analysis of Pesticide Residues in Food (PARA) (ANVISA, 2019).

Environmental risks, depending on the toxicity of the agrochemical, the form of application, the amount or dose used, can compromise the soil, subsoil, surface and groundwater, and the entire ecosystem (BRASIL, 2020; SPADOTTO et. al, 2004)

Outsourcing the application of agrochemicals could be one of the ways to reduce risks. This form of service is provided for in Federal Law No. 7,802/1989 in its Article 4, and in Federal Decree No. 4,074/2002, which says that both individuals and legal entities can provide services in the application of agrochemicals, as long as all legal criteria are observed. However, within this outsourcing process, it is possible to find companies that do not comply with the legislation, and it is common for the responsible bodies to suspend their licenses, that is, it cannot be said that outsourcing guarantees the reduction of health and environmental risks (SEAPDR, 2020; ANVISA, 2019; BAMFORD, 2015; MIOLA, 2013; MARQUES, 2005).

Faced with the new challenges regarding the use of agrochemicals in Brazilian agriculture, the National Congress (NC) has discussed and processed the Bill (PL) 6299/02, which deals with the registration, inspection and control of agrochemicals in the country, with the objectives of reducing bureaucratic dysfunctions in the registration process until its applicability in the field, health risks and environmental risks. However, this project has received resistance from the National Health Surveillance Agency (ANVISA), which according to ANVISA, withdraws its competence to carry out toxicological and environmental assessment. This bill is already ready to be discussed in the plenary of the NC (BRASIL, 2018; ANVISA, 2018).

According to the Embrapa Agency for Technological Information (2020) and Spatolo et. al (2004), Brazil is a tropical country and has several crops and crops throughout the year of various agricultural products, which favors the incidence of pests and diseases; along with this, the inappropriate use of chemical products, the lack of technical preparation to adopt an integrated management resulting in products that can generate health and environmental risks. Consequently, it is necessary to point out a managerial solution that involves a change in the coordination relations in part of the production chain.

Therefore, this work aims to suggest the possibility of Vertical Integration in the application and administration of agrochemicals in the field.

2 METHODOLOGY

2.1 STUDY DESIGN

This study adopted an exploratory and qualitative approach, combining a review of narrative literature with a comparative method, with the objective of analyzing how different governance models associated with the use and application of agrochemicals can influence health and environmental risks and productive/economic implications.

The comparative method allows us to examine similarities and differences between institutional and economic arrangements, highlighting relevant relationships between analyzed elements, with the potential for analytical generalization when applied systematically (GIL, 2008; MARCONI; LAKATOS, 2003). Thus, the study structured the study through empirical evidence and available institutional references.

2.2 UNITS OF COMPARISON: GOVERNANCE MODELS ANALYZED

Governance models of the use and application of agrochemicals in the Brazilian context were analyzed in a comparative way:

1. Direct sales to producers;
2. Outsourcing of the application by individuals or legal entities, provided for in Law No. 7,802/1989 and related regulations.
3. Vertical integration downstream by the industries, as a managerial proposition, in which the supply of the input is articulated with the provision of technical service of application and monitoring in the field.

The comparison was guided by the recurring challenges pointed out in the literature and in the public debate, including aspects such as the use of PPE, handling and disposal, training/technical assistance, resistance management, regulatory compliance, and risks of contamination in workers, food, and the environment.

2.3 NARRATIVE LITERATURE REVIEW: SCOPE AND SELECTION OF MATERIAL

A narrative review was carried out (CORDEIRO et al., 2007; ROTHER, 2007) in order to map national and international empirical evidence related to:

- health and occupational risks associated with the use of agrochemicals;
- environmental risks (soil, water, ecosystems) and operational factors that increase exposure;
- recurrent failures in the application (training, reading of labels and package inserts, PPE,

- disposal of packaging, inadequate handling);
- residue monitoring and compliance in food.

As it is a narrative review, the selection of the material was intentional and not exhaustive, guided by the pertinence to the research problem and by the contribution of the studies to describe risk mechanisms and operational conditions associated with the application.

Within this scope, empirical studies such as those by Schmidt and Godinho (2006), Veiga et al. (2007), Malaspina et al. (2011), Bedor et al. (2009), Casali et al. (2015) and Petermann et al. (2019) were mobilized, among others, as they address complementary dimensions of the problem (poisoning/underreporting, PPE, epidemiological profile, social vulnerabilities, training and food residues).

2.4 SECONDARY DATA AND INSTITUTIONAL SOURCES

In addition to the academic literature, the study used secondary data and information from institutional databases for contextualization and analytical support of the Brazilian scenario, including sources such as:

- 2017 Agricultural Census (IBGE, 2019 publication);
- databases and reports from agencies and institutions related to regulation and monitoring (e.g., ANVISA, including waste monitoring programs);
- agricultural production and productivity bases and sectoral context (e.g., CONAB, FAO, Embrapa).

These sources were used to support the characterization of the productive and regulatory context and to reinforce the interpretation of the evidence discussed in the literature review, without pretense of causal statistical inference.

2.5 STUDY LIMITATIONS

This study has limitations inherent to the adopted design:

- as it is a narrative review, there is no claim of exhaustiveness or formal synthesis goals;
- the comparison between models configures a conceptual and interpretative analysis, based on secondary evidence and selected literature;
- Primary collections (e.g., interviews, surveys, or case studies) were not conducted, which restricts inferences about operational feasibility, costs, and measurable impacts in specific contexts.

Even so, the design is adequate to the exploratory objective of discussing governance alternatives and their possible implications for the reduction of health and environmental risks.

3 RESULTS AND DISCUSSION

3.1 VERTICAL INTEGRATION

According to Zylbersztajn and Neves (2000), market competition is the necessary stimulus for companies to seek to reduce costs in an Economic System. For this, companies belonging to a competitive market structure adopt several strategies, such as competition strategies (price formation, collusion, price war, sunk costs); growth strategy (acquisition, mergers, market segmentation, differentiation, diversification and vertical integration).

These authors state that vertical integration is a particular type of diversification of a company's growth strategy. The company's objective in adopting this strategy is to acquire greater control in the production chain to reduce costs, employ strategic actions against rival companies and better explore the market for products downstream in the production chain.

Vertical integration within the agro-industrial context is defined as a set of activities of the links in the production chain, assuming previous and/or subsequent stages of some process within the agricultural production chain. In Brazil, the most common integrations are the chain of poultry, pork, seeds, vegetables (industrial tomatoes and peas), silks, flowers addressing various systems or part of the production process (ARAÚJO, 2013).

According to Batalha (2014), vertical integration becomes attractive to sectors that identify cost reduction, appropriate market profits, favor the company's main activity, obtain greater control of operations and strategies to be adopted. However, according to the author, it can increase the risk of the integrating company, and it can also bring greater concerns about bureaucratic dysfunctions and divert the main focus from the company's management.

Vertical integration can reduce or save expenses with taxes, uncertainties, that is, it aims to reduce exchange relationship costs, migrating this market transaction relationship into the company. Vertical integration can be done upstream (e.g., a company that acquires a distributor of inputs, machinery, and equipment) or downstream (e.g., a company acquires logistics control or networks of companies oriented to the end consumer), for this type of strategy to be efficient, it is necessary to establish contracts and conduct agreements with customers and key partners to sustain minimum levels of products and inputs (ZYLBERSZTAJN; NEVES and CALEMAN, 2015).

Vertical integration can be done downstream or upstream in the production chain. When the company seeks forward integration, it seeks to differentiate the product, have better access

to marketing channels, better access to market information, improve distribution and take advantage of higher prices of products or services. In the case of backward integration, the company seeks to patent inputs, replace inputs purchased from other companies and start to supply its own input with the desired standard and quality, differentiating itself in the market (PORTER, 2004; KON, 2017).

Integration contracts are provided by Federal Law No. 13,288, of May 16, 2016, which aims to guarantee contracts and relationships of obligations and responsibilities between integrated producers and integrators. Its 14 articles establish the relationships, permissions, prohibitions, technical parameters, deadlines, rights and duties of the contract and procedures that each interested party must correspond to (BRASIL, 2016).

According to Stern et al. (1996), there are several reasons for companies to seek the vertical integration strategy, such as the complex characteristics of buying inputs or selling products; the high cost of changing suppliers or partners; the need for chain coordination to ensure product quality; uncertain environment; Transactions flow easily and with high frequency.

As an example of research that developed empirical studies of this market strategy, we find the works of Kilmer, Andre and Stevens (2001) who analyzed the relationship between vertical integration and pesticide residues in strawberries and tomatoes in the state of Florida-USA. Sologuren (2004) sought to identify the advantages of soybean processing companies in adopting vertical integration in the acquisition of fertilizer companies as a form of competitive advantage.

Lima et. al. (2009) sought to understand the strategy adopted by a pulp and paper company and identified the possible advantages and risks associated with the strategy employed. Lima (2011) identified the competitive challenges for the family oilseed agroindustry in the semi-arid region of Bahia by adopting verticalization. Marques, Souza and Machado Júnior (2015) sought to describe the arrangement determined in the Microregion of Anápolis - GO for the integrated production of chicken under the competitive strategy of verticalization of operations.

Araújo (1996) calculated the profitability of broiler chicken production that had vertical integration contracts in the State of Minas Gerais. De Souza (2007) investigated the reasons for the agro-industrial sector of grain processing in Brazil to adopt as a vertical integration strategy. Proença (2012) analyzed, from the 2000s onwards, the growth of the sugarcane sector in the mesoregion of Araçatuba and ascertained the possibility of increased industrial concentration in the sector and whether companies were strategically adopting vertical and horizontal integration.

Souza (2007) elaborated a synthesis (Table 1) that shows the advantages and disadvantages of vertical integration as a result of the presence of high transaction costs.

Table 1

Advantages and Disadvantages of the Vertical Integration strategy

Advantages of Vertical Integration	Disadvantages of Vertical Integration
<ul style="list-style-type: none"> • Ensure savings in combined operations; information; coordination and internal control; • Avoiding the market • Ensure supply and/or demand • Eliminate bargaining • Increase barriers to entry and mobility • Enter a high-return business • Defend against market closure • Facilitate adaptation in sequential decision-making • Mitigating opportunism • Promote convergent expectations (reduce uncertainties) • Dominate and promote information gain • Achieve an atmosphere of greater satisfaction • Rationalize inventory levels • Savings in operations arising from technological interdependence; elimination of risk premium; reduced transaction costs; economies of scale; stable relationships and resource retrieval; • Achieve product and price differentiation 	<ul style="list-style-type: none"> • Costs of Going Through Mobility Barriers • Increased operating leverage • Reduced flexibility to change partners • High global exit barriers • Need for capital investments • Closing access to the market research provider or know-how • Need to provide incentives • Different administrative needs • Predisposition to favor maintenance or extension of internal operations • Distortion in communication • Internal opportunism • Bounded rationality • Adding bureaucracy • Loss of moral engagement • Capital imbalance • Reduced flexibility • Loss of specialization • Lack of savings with unbalanced stages of integrated operations; Administration and lower returns • Increased operating leverage

Source: Adapted from Souza (2007)

3.2 BENEFITS OF VERTICAL INTEGRATION IN THE APPLICATION OF AGROCHEMICALS

3.2.1 The Pesticide "Concessionaire" Model: A Proposal for Technical and Safe Application

At the heart of this proposal is the formation of a network of service and application centers, managed or supervised directly by the agrochemical producing companies. responsible for the entire product cycle in the process: from the technical recommendation, based on precise diagnoses, through the application carried out by highly trained and certified teams, to the post-application follow-up and the proper disposal of the packaging. structure goes beyond a simple logistical change; It is, in fact, an essential restructuring of responsibilities and incentives, harmonizing the interests of the manufacturer with those of the producer and, consequently, of society.

3.2.2 Guarantee of Technicality in Application and Optimization of Resources

The main highlight of this model is the increase in the technical level of the applications. Currently, the lack of technical knowledge among several rural productions, combined with the lack of assistance, results in inadequate applications and improper use of equipment (SILVA; OLIVEIRA, 2020). In this new model of vertical integration, the application teams would be composed of specialists: agricultural technicians, agricultural technicians and machine operators trained and constantly updated with the latest practices and technologies available. We consider protective equipment, such as GPS sprays, drones, and remote sensing systems, which act in constant permanence and real-time weather monitoring, all with the aim of reducing drift and avoiding contamination of adjacent areas (EMBRAPA, 2022).

Manufacturers, who have the most in-depth knowledge about their products, will establish standardized usage protocols to ensure maximum efficacy and minimize negative effects. In addition, a systematic collection of data on application and performance in the field would generate a virtuous cycle of learning and constant improvement. With the big data generated, it would be feasible to adjust dosages, improve recommendation algorithms, and consider success or failure patterns, converting the use of agrochemicals into an authentic science of applied data (CHEN et al., 2021).

The producer would not only maximize their investment, but also have a rationalization in the use of inputs – a double benefit for the economy and the environment. Consider the practical benefits: reduced machine passes result in less fuel consumption, less soil compaction, and more time for the producer to focus on strategic decisions for his property (SANTOS; PEREIRA, 2023).

3.2.3 Resistance Management and Product Longevity: An Economic Sustainability Perspective

The application made with the proper technique and proper use without the risk of accelerated development of resistance in pests, diseases and weeds (NEVES et al., 2018; SHAW; LEWANDOWSKI, 2019). Insufficient doses or applications at the wrong times end up selecting the most resistant individuals, which, over time, makes agrochemicals ineffective. This forces them to look for new molecules, a very expensive and time-consuming process, with diminishing returns (GAO et al., 2020). The loss of effectiveness of an agrochemical, due to resistance, not only causes direct losses to the producer – who needs to resort to more expensive or less efficient alternatives – but also represents a significant loss of intellectual and financial capital for the industry that developed it.

In the proposed model, the strict control of the application, added to a constant monitoring of the effectiveness in the field, would allow the implementation of much more effective and proactive resistance management strategies. Manufacturers have a direct interest in extending the life of their products. This would encourage it to promote the distribution of active ingredients, the use of mixtures, and the application only when necessary, following the principles of Integrated Pest Management (IPM) (MAPA, 2021). This alignment of interests between the manufacturer and agronomic sustainability is a critical differentiator.

Instead of focusing only on the sale, the manufacturer would focus on the solution and the longevity of the effectiveness. This translates into lower selection pressure, greater sustainability of the available chemical arsenal, and ultimately less need for heavy R&D investments for new molecules, benefiting the industry in the long run. The ability to obtain data on efficacy in different regions and crops would allow manufacturers to adjust their recommendations and develop customized resistance management programs, strengthening the resilience of agricultural systems (FERREIRA; GOMES, 2022).

3.2.4 Impact on Public and Occupational Health: From Exposure to Active Prevention

The use of agrochemicals by specialized teams, under the direct supervision of manufacturers, would result in a significant change in public and occupational health. The focus shifted from harm mitigation to proactive prevention. Applicators received constant and rigorous training on the proper use of state-of-the-art Personal Protective Equipment (PPE), safety procedures, related to concentrated products (including external transfer systems) and first aid. The direct responsibility of the manufacturer in promoting full adherence to occupational safety standards, the implementation of occupational health programs, and the continuous monitoring of employee health, considerably avoiding cases of acute and chronic poisoning among rural workers (FIOCRUZ, 2019; PEREIRA et al., 2022).

The standardization of processes and rigorous internal inspection would be key elements to ensure the safety of operators, who would become highly qualified and valued professionals.

The standardization of procedures and strict internal supervision will be fundamental to ensure the safety of operators, highly competent and recognized and valued professionals. A more technical application would lead to a reduction in agrochemical residues in food for the final consumer. The precise application of chemical substances, strictly respecting the withdrawal periods and recommended doses, reducing exposure to these substances. The full traceability of the application, ensured by the "concessionaire" and digitally registered, would enable a more efficient control of the quality of food "from the door to the inside". This would

increase consumer confidence in food safety and make it easier to identify potential problems (ANVISA, 2023).

This strict control would help certify products with less environmental and health impact, adding value and highlighting Brazilian production in the global market, especially in export markets with high sanitary standards. Transparency in the production chain, made possible by this model, could become a competitive factor for Brazilian agribusiness, responding to the growing demand for safe food and production in a sustainable way (UN, 2021).

3.2.5 Environmental Benefits and Ecological Sustainability

An optimized application of agrochemicals, with an emphasis on precision, and the reduction of losses, would result in considerably lower environmental impacts. A reduction in the contamination of soils, water resources (both surface and dense) and adjacent ecosystems would represent a direct and easily measured benefit (RODRIGUES; ALVES, 2021).

The reduction of the total amount of agrochemicals applied, maintaining effectiveness, helping to preserve biodiversity and fundamental ecosystem services, such as pollination and natural biological control. In addition, the centralized and professional management of the disposal of empty packaging and leftover products, under the responsibility of the manufacturer, would reinforce reverse logistics and considerably reduce environmental contamination by hazardous waste (IBAMA, 2020).

The search for greater efficiency and lower environmental impact would be perfectly in tune with the growing sustainability standards of modern agriculture and with the global sustainable development goals. This model has the capacity to place Brazil at the forefront of sustainable agricultural practices, not only by implementing new technologies, but also by a systemic restructuring that incorporates the negative externalities associated with the use of agrochemicals, fostering cleaner food production and a healthier rural environment. The reduction of the carbon footprint related to agricultural production, obtained through the optimization of the use of inputs and reduction in the demand for new cultivation areas due to higher productivity per hectare, would also represent a very positive result (IPCC, 2022).

3.2.6 Challenges, Implications and Perspectives for Implementation

While it brings clear benefits, adopting this model would not be free from complex and varied challenges, which required detailed analysis and well-designed mitigation strategies.

- **Economic Feasibility and Business Structuring:** Market restructuring would require manufacturers to make a significant initial investment in building the entire infrastructure

of the "dealerships" (service centers, equipment, vehicles) and training personnel. The main question is: how would this cost be transferred and what would be the pricing model for the farmer? Would there be a cost for use? A tariff per hectare? Or maybe a subscription model that encompasses the product and the service? The attractiveness for the farmer will depend on the perception of added value in relation to the direct cost, considering aspects such as higher productivity, lower risk, regulatory compliance, time and labor savings for the farmer will depend on the perception of added value in relation to the direct cost, considering aspects such as higher productivity, lower risk, regulatory compliance, time and labor savings. For small producers, government subsidies, special credit lines or cooperative models can be essential to guarantee access to technology and avoid exclusion, ensuring that benefits are distributed equitably (COSTA; LIMA, 2023).

- **Regulation and Competition:** It would be important to develop a robust regulatory framework that encourages fair competition, ensures transparency in pricing and services, and avoids monopolistic or oligopolistic practices. The creation of specific regulatory agencies or the adaptation of existing ones (such as CADE and consumer protection agencies) would be essential to monitor this new market, protecting the interests of producers and society (CADE, 2024). A clear definition of legal responsibilities in case of application failures or environmental damage would also be essential.
- **Acceptance and Autonomy of the Rural Producer:** The acceptance by rural producers, who would have to adapt to a new way of acquiring and applying agrochemicals, is a critical factor. Many farmers value autonomy in their management decisions and may initially resist the idea of outsourcing such an important step in their production process. The transition would require a significant effort of communication, demonstration of concrete results (increased productivity, long-term cost reduction, greater security) and, above all, the building of trust. Flexible models, which allow different levels of producer involvement – perhaps with assisted self-management options or specialized consulting – could facilitate the transition, respecting the farmer's culture and experience (EMATER, 2020).
- **Logistics and Infrastructure:** Brazil, with its continental dimensions and vast agricultural area, often in remote regions and with precarious infrastructure, presents an immense logistical challenge. The creation of a network of "concessionaires" with sufficient capillarity to serve all producers would require robust logistics planning and

massive investment in transportation, storage and communication infrastructure. Digitalization and connectivity would be essential to manage this network efficiently, allowing for service scheduling, remote monitoring, and real-time data collection. Public-private partnerships could be explored to enable the expansion of infrastructure in hard-to-reach areas (CNT, 2023).

- **Social Aspects and Equity:** It is essential to ensure that this model does not accentuate the inequalities that already exist in the countryside. Smallholder farmers and traditional communities, which often already face limited access to technologies and technical assistance, cannot be marginalized. Public policies of inclusion, differentiated financing programs and the adaptation of the model to meet these realities would be imperative. The formation of producer cooperatives to access the services of the "concessionaires" or the creation of itinerant service models could be solutions to ensure that no producer is excluded (MDA, 2022). The training of local labor to work in the "concessionaires" would also generate jobs and regional development.

However, the gains in safety, efficiency and sustainability are so significant that they justify in-depth exploration of this topic. Overcoming these challenges will require constructive dialogue and strategic collaboration between the government, the agrochemical industry, rural producers, academia and civil society. The transition to a more responsible system of agrochemical use is not just a technical issue, but a social and environmental demand that requires an innovative vision and the courage to redefine paradigms.

4 CONCLUSION

This study proposed and debated an innovative model for the application of agrochemicals in Brazil, based on the vertical integration of manufacturers. These manufacturers would become directly responsible for the application service in the field, similar to the model of dealership deliveries. The results suggest that this strategy can transform the risk management linked to these inputs, fostering a safer, more effective and sustainable agriculture.

The creation of agrochemical "concessionaires", managed by specialized technical teams and under the direct supervision of manufacturers, is proposed as a multifaceted solution. It is expected that this encourages the model of technicality in the application, leading to a more efficient control of the resistance of sentences and diseases and increasing the durability of the products.

This model is expected to promote technicality in application, resulting in more effective management of pest and disease resistance, extending the shelf life of products and optimizing resources.

In addition, a significant improvement in the occupational health of those applied is expected through specific training and proper use of PPE, as well as in the food safety of the final consumer, due to the reduction of residues in food and increased traceability. The environmental benefits, resulting from precise application and responsible disposal, are important, helping to preserve biodiversity and natural resources.

Although challenges related to investments, regulation, competition, accessible by rural producers, logistics and heritage need to be approached with caution, the idea of vertical integration in the use of agrochemicals indicates a promising path for safer, more effective and sustainable agriculture in Brazil.

It is recommended that future research investments in in-depth economic forecast studies for various scales of production, governance models for governance as "concessionaires" that ensure competition and producer protection, in addition to the regulatory impact necessary for the transition to this new paradigm. For Brazil to become an example in sustainable agricultural practices, it is essential that government, industry, the productive sector and civil society work together to transform this vision into a reality that benefits everyone.

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