



THE REVERSE LOGISTICS OF EMPTY PESTICIDE PACKAGING IN RONDÔNIA IN THE CONTEXT OF THE CIRCULAR ECONOMY

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Abstract: The advance of the agricultural frontier in Rondônia has intensified the use of agrochemical inputs, increasing the need for efficient reverse logistics systems for empty pesticide packaging. This study aimed to analyze the structure and operationalization of the reverse logistics system of these packages in the state of Rondônia, considering its articulation with the principles of circular economy and its contribution to environmental sustainability in Rondônia's agribusiness. The research is characterized as applied, with a qualitative-quantitative approach and exploratory-descriptive nature, based on a bibliographic review, documentary survey of the pertinent legislation and analysis of secondary data from inPEV and IDARON. Data regarding the sale and return of pesticide packaging in the period from 2022 to April 2026 were examined. The results showed that a total of 11,165,115 packages of pesticides were sold in Rondônia, of which 9,203,520 were returned, corresponding to an aggregate gross return rate of 82.43%. Considering the legal lag of up to one year between commercialization and return, the adjusted indexes were 116.30% in 2023, 92.53% in 2024 and 92.69% in 2025, indicating stability in performance in the full years analyzed. Despite this performance, part of the packaging still does not return to the formal flow of destination, and only 14 of the 52 municipalities have receiving units. It is concluded that the system contributes to the circular economy and environmental sustainability, but requires expansion of infrastructure, inspection and educational actions.

Keywords: Environment; recycling; triple washing; sustainability; agribusiness.

REVERSE LOGISTICS OF EMPTY PESTICIDE CONTAINERS IN RONDÔNIA IN THE CONTEXT OF THE CIRCULAR ECONOMY

Abstract: The expansion of the agricultural frontier in Rondônia has intensified the use of agrochemical inputs, increasing the need for efficient reverse logistics systems for empty pesticide containers. In this context, this study aimed to analyze the structure and operation of the reverse logistics system for empty pesticide containers in the state of Rondônia, considering its articulation with the principles of the circular economy and its contribution to environmental sustainability in Rondônia's agribusiness sector. The research is applied in nature, with a qualitative and quantitative approach and an exploratory-descriptive design, based on a literature review, documentary analysis of relevant legislation, and secondary data obtained from inPEV and IDARON. Data on the commercialization and return of pesticide containers from 2022 to April 2026 were examined. The results showed that, during the analyzed period, 11,165,115 pesticide containers were commercialized in Rondônia, of which 9,203,520 were returned, corresponding to an overall return rate of 82.43%. Although this percentage indicates relevant operational capacity

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of the system, 17.57% of the containers did not return to the formal disposal flow, revealing gaps in the reverse cycle. In addition, only 14 of the state's 52 municipalities have receiving units, which highlights territorial and logistical limitations. It is concluded that the system contributes to the circular economy and environmental sustainability; however, it requires the expansion of receiving infrastructure, stronger inspection mechanisms, and educational actions aimed at pesticide users.

Keywords: Environment; recycling; triple rinsing; sustainability; agribusiness.

1 Introduction

Currently, the state of Rondônia stands out as one of the new agricultural frontiers in the country (Balbinot Junior *et al.*, 2022), with the conversion of degraded pasture areas for the production of agricultural crops such as soybeans, corn, and coffee. In the grain sector, for the 2025/2026 harvest, Embrapa (2026) estimates a growth of 2.8% in the planted area with production reaching 5.6 million tons, an increase of 3.1% compared to the previous harvest.

The growing development of agriculture in the state provides growth in the use of agricultural inputs, among which pesticides stand out, chemical products that, if used inappropriately, can cause damage to the health of people, animals and pollute the environment. In addition to the risks of contamination by such products, special attention must be paid to empty packaging, which if disposed of improperly also causes damage to health and the environment.

The Brazilian legislation that regulates the use of pesticides has strict rules regarding empty packaging. According to Law No. 14,785, of December 27, 2023, pesticide users are required to return empty packaging, their lids, and any post-consumption residues of the products to the commercial establishments where they were purchased, within one (1) year, counted from the date of purchase, or from the expiration date, prior to the return, they must carry out the triple washing of washable packaging, and it is up to the producing and marketing companies to dispose of them appropriately, with a view to their reuse, recycling or destruction (Brasil, 2023).

The obligation to return such packaging is also provided for in Law No. 12,305, of August 2, 2010, which institutes the National Solid Waste Policy - PNRS, which determines manufacturers, importers, distributors and traders to structure and implement reverse logistics systems, aiming at proper disposal (Brasil, 2010).

The reverse logistics of empty pesticide packaging in the country is managed by the National Institute for the Processing of Empty Packaging - inpEV, a non-profit entity, created in 2001, which represents the crop protection manufacturing industry in the reverse logistics program called Campo Limpo System in compliance with the PNRS. According to inpEV (2026), the Campo Limpo System is the pioneering reverse logistics program in agribusiness that guarantees the environmentally correct disposal of 100% of the empty pesticide packaging received (on average 95% is recycled and 5% incinerated). Since 2017, the System has also received post-consumption leftovers of pesticides.



According to the Brazilian Association of Logistics Operators (2025), the Brazilian model of reverse logistics of these packages is a world reference in circular economy, which in addition to promoting the conservation of natural resources, ensures an environmentally correct destination in order to avoid soil and water contamination, in addition to ensuring food safety and human and animal health.

This dimension acquires additional strategic relevance when considering that Rondônia is part of the Legal Amazon, a territory internationally recognized for its bioeconomy potential — understood as the set of economic activities that use renewable biological resources in a sustainable way to generate products, services, and income (Brasil, 2023). In this context, the proper management of agrochemical waste is not only a legal obligation, but a condition for the preservation of natural capital — fertile soils, water resources, and biodiversity — on which not only Rondônia's agribusiness rests, but also sustainable development and bioeconomy strategies for the Amazon region.

The circular economy is defined as an economic system of production that maintains the circular flow of resources and associates economic activity with the circular management of resources, through the addition, retention or recovery of their values, and which is based on the principles of non-generation of waste, the circulation of products and materials and regeneration (Brasil, 2024). This definition is present in Federal Decree No. 12,082, of June 27, 2024, which establishes the National Circular Economy Strategy, with the purpose of promoting the transition from the linear production model to a circular economy, in order to encourage the efficient use of natural resources and sustainable practices along the production chain.

For the Ellen MacArthur Foundation (2024), the circular economy is a model designed to solve global environmental challenges anchored in three pillars: eliminating waste, circulating materials, and regenerating nature. Unlike the linear system, it seeks a change in the design of the products in order to maximize their useful life and their reuse. In the academic literature, Kirchherr, Reike, and Hekkert (2017), when analyzing 114 definitions of the concept, identified that the circular economy is often understood as a combination of reduction, reuse, and recycling strategies, aimed at preserving natural capital and eliminating negative externalities. Geissdoerfer et al. (2017) complement this perspective by distinguishing circular economy from sustainability, arguing that the former operates as a regenerative system in which resource, energy, and waste flows are minimized through long-term design, maintenance, repair, reuse, and recycling.

In the context of the circular economy, the success of the Campo Limpo System necessarily involves the involvement of the other links in the reverse logistics chain, especially the commitment of the pesticide user, who must strictly follow the packaging hygiene procedures and



return them to the receiving points within the given period.

For Noskoski *et al.* (2024), reverse logistics plays a key role in facilitating the collection, transportation, and recycling of agricultural and agro-industrial waste, but its success depends on efficient and careful management, which addresses all aspects of the process, from collection to final disposal.

In this context, the present research starts from the following problem-question: How is the reverse logistics system for empty pesticide packaging structured and operationalized in the state of Rondônia, and how is it articulated with the principles of circular economy and environmental sustainability in Rondônia's agribusiness?

Thus, the general objective of this study is to analyze the structure and operationalization of the reverse logistics system for empty pesticide packaging in the state of Rondônia, considering its articulation with the principles of circular economy and its contribution to environmental sustainability in Rondônia's agribusiness. Specifically, it seeks to: characterize the reverse logistics system for empty pesticide packaging in the state of Rondônia, considering the agents involved, the legal responsibilities and the procedures for returning, receiving and environmentally appropriate disposal; and discuss the relationship between the reverse logistics of these packages, the principles of circular economy and environmental sustainability in the context of Rondônia's agribusiness.

2 Theoretical framework

The expansion of the Brazilian agricultural frontier has reconfigured the productive organization of different regions, especially in areas where the conversion of degraded pastures into intensive crops increases the demand for agrochemical inputs, management technologies and environmental control systems. In the case of Rondônia, this process acquires particular relevance due to the advance of crops such as soybeans, corn, and coffee (Embrapa, 2026), which intensify the use of pesticides and, consequently, increase the generation of empty post-consumption packaging. Thus, reverse logistics becomes a strategic dimension of sustainability in agribusiness, as it articulates agricultural production, environmental responsibility, and adequate management of hazardous waste (Balbinot Junior *et al.*, 2022; Brazil, 2010).

Reverse logistics can be understood as an environmental management instrument aimed at returning waste, packaging and post-consumer products to their respective production cycles or to environmentally appropriate forms of disposal. Within the scope of the National Solid Waste Policy, established by Law No. 12,305/2010, this mechanism is associated with the principle of shared responsibility for the life cycle of products, which distributes obligations among



manufacturers, importers, distributors, traders, consumers and public authorities. In this way, reverse logistics goes beyond the operational dimension of collection and becomes part of a systemic logic of impact prevention, reuse of materials and reduction of environmental externalities (Brasil, 2010).

In view of this, in the case of empty pesticide packaging, reverse logistics takes on greater complexity due to the potential for chemical contamination associated with the remaining residues in the packaging. Brazilian legislation establishes that pesticide users must return empty packaging, its lids and any post-consumption residues to the commercial establishments or places indicated, observing the legal deadline and previously carrying out the triple washing or pressure washing, when it comes to washable packaging. It is the responsibility of the producing and marketing companies to ensure the proper disposal of these materials, with a view to reuse, recycling, or rendering useless, as provided for in Law No. 14,785/2023 (Brasil, 2023).

The Brazilian normative structure, therefore, establishes a chain of co-responsibility in which the rural producer, resellers, cooperatives, the manufacturing industry, the receiving units and the public authorities perform complementary functions. This configuration shows that the effectiveness of reverse logistics does not depend only on the existence of the legal rule, but on the articulation between agents, territorial infrastructure, document control, technical guidance and inspection. In this sense, the reverse logistics of pesticide packaging should be analyzed as a socio-institutional system, and not only as a technical procedure for return (Brasil, 2010; Brazil, 2023).

In Brazil, the operationalization of this system is strongly associated with the Campo Limpo System, coordinated by the National Institute for the Processing of Empty Packaging. inpEV acts as a managing entity for the reverse flow of empty crop protection packaging, articulating manufacturers, distribution channels, receiving units and rural producers. According to the institute itself, the Campo Limpo System ensures the environmentally appropriate disposal of the packaging received, with most of it being sent for recycling and a portion destined for incineration when it does not have technical conditions for reuse (inpEV, 2026).

The relevance of the Campo Limpo System stems from its ability to institutionalize a reverse flow in a production chain marked by the territorial dispersion of users and the diversity of agents involved. However, its effectiveness depends on strict compliance with the stages of washing, temporary storage, return, receipt, sorting, transportation and final disposal. In this sense, Aragos *et al.* (2021) in an article entitled "Reverse logistics of empty pesticide packaging and the difficulties for effective implementation" concluded that the main bottlenecks for the effective implementation of reverse logistics are the bureaucratization of the Brazilian state, cases of omission of the law, lack of structure of the agents in the agribusiness chain, with an important



emphasis on the lack of strict inspection by the government. These same authors point out the need for an effective structuring of the law and better environmental awareness through pertinent education as a way to facilitate the effective implementation of reverse logistics of empty pesticide packaging in Brazil.

For Noskoski *et al.* (2024), reverse logistics in agribusiness plays a fundamental role in the collection, transportation, and recycling of agricultural and agro-industrial waste, but its success depends on efficient and careful management of the entire process, from collection to final disposal. This understanding is consistent with the very problematization of the article, which seeks to analyze how the system is structured and operationalized in Rondônia.

The circular economy offers an adequate analytical matrix to understand the reverse logistics of empty pesticide packaging, as it shifts the focus from final destination to the permanence of materials in production or environmentally controlled cycles. Decree No. 12,082/2024 defines the circular economy as an economic system that maintains the circular flow of resources and associates economic activity with the circular management of materials through the addition, retention, or recovery of value. This perspective is based on the principles of non-generation of waste, the circulation of products and materials, and the regeneration of natural systems (Brasil, 2024).

The relationship between reverse logistics and circular economy, however, should not be reduced to recycling. Although recycling represents an important step in circularity, the circular economy involves process redesign, waste reduction, material traceability, shared responsibility, and supply chain governance. In the case of pesticide packaging, circularity depends on the ability to prevent this waste from being disposed of in informal streams, burned, buried, improperly reused, or abandoned on rural properties. Thus, reverse logistics acts as a practical mechanism for the transition between the linear model of production-consumption-disposal and a model of circular management of materials (Brasil, 2010; Brazil, 2024).

In this sense, Noskoski *et al.* (2024) reinforce that reverse logistics in agribusiness plays a fundamental role in the collection, transportation, and recycling of agricultural and agro-industrial waste, being an essential component for the effectiveness of the circular cycles recommended by the circular economy, since without the organized return of materials to the formal flow of destination, circularity remains incomplete.

In the context of agribusiness, environmental sustainability requires that productivity gains be associated with the reduction of ecological, health, and social risks. Improperly disposed of pesticide packaging can contaminate soil and water resources, compromise human and animal health, and affect the safety of food systems. Therefore, the proper return of packaging does not



only represent formal compliance with a legal obligation, but an essential practice for mitigating risks and conserving natural resources. Brazilian legislation makes this concern explicit by defining responsibilities for users, merchants, and manufacturers in the management of post-consumer waste and packaging (Brasil, 2023).

The effectiveness of reverse logistics in Rondônia needs to be analyzed in light of the territorial specificities of the state. Agricultural expansion in productive frontier areas tends to occur in spaces with infrastructure asymmetries, long distances between rural properties and receiving units, and different levels of access to technical assistance. Such conditions can make it difficult to return packages regularly and increase the costs of user participation in the system. In this way, the capillarity of the receiving units becomes a decisive variable to evaluate the operationalization of the reverse system of empty packages (Balbinot Junior *et al.*, 2022; inpEV, 2026).

The evaluation of the reverse logistics of empty pesticide packaging can be operationalized through indicators capable of measuring the relationship between the amount of packaging sold, the amount of packaging returned, the territorial coverage of the receiving units, and the capacity for environmentally appropriate disposal. From the perspective of the National Solid Waste Policy, the effectiveness of reverse systems depends on the co-responsibility between the agents in the chain and the existence of mechanisms that ensure the return of waste to the formal flow of treatment, reuse or environmentally appropriate final disposal (Brasil, 2010). Thus, the analysis of the difference between packaging placed on the market and packaging actually returned is a relevant parameter to understand the performance of the reverse cycle.

The difference between sold and returned packages can be interpreted as an indicator of logistics efficiency, user adherence, and institutional control capacity. In analytical terms, any gaps between commercialization and return may result from time delays in meeting the legal deadline, registration failures, difficulties in accessing receiving units, prolonged storage on rural properties, low technical guidance or improper disposal. In this sense, the non-return of packaging to the formal flow should not be understood only as residual data, but as possible evidence of institutional, territorial, logistical, and behavioral bottlenecks that affect the sustainability of the reverse system (Brasil, 2023; Noskoski *et al.*, 2024).

The behavioral dimension is central to the operation of reverse logistics, as the correct return of packaging depends on the users' adherence to the standards of washing, packaging, temporary storage and delivery to the indicated locations. Law No. 14,785/2023 establishes that pesticide users must return empty containers, their lids, and any post-consumption residues to commercial establishments or receiving units, observing technical hygiene procedures when



applicable (Brasil, 2023). In this way, the sustainability of the system is not restricted to the existence of legislation or infrastructure, but involves educational practices, a culture of compliance, environmental responsibility and the commitment of the different links in the production chain.

Environmental education, in this sense, should be understood as a structuring component of reverse logistics. The permanent guidance of rural producers, workers, cooperatives, resellers and other agents involved contributes to reducing inappropriate disposal practices and strengthening the perception of shared responsibility. A study by Branco *et al.*, (2024), concluded that the main challenges of the system lie in the lack of continuous information on good practices to farmers and, primarily, in the great distances that producers need to travel to authorized collection points. However, isolated educational campaigns tend to be insufficient when they do not articulate the infrastructure of receiving, effective inspection, accessible communication and traceability mechanisms. Thus, environmental education needs to be part of a broader strategy of reverse chain governance, in line with the principles of shared responsibility and prevention of environmental damage provided for in the National Solid Waste Policy (Brasil, 2010; Noskoski *et al.*, 2024).

Public inspection and institutional monitoring are also essential to ensure the effectiveness of reverse logistics systems. In chains associated with hazardous waste, such as pesticide packaging, institutional control must allow the monitoring of the commercialization, return, receipt, destination and compliance of the agents involved. The construction of documentary bases and performance indicators makes it possible to identify territorial gaps, assess the degree of user adherence, monitor the operational efficiency of the receiving units and verify the system's adherence to the principles of circular economy and environmental sustainability (Brasil, 2010; Brazil, 2024).

In Rondônia, pesticide legislation underwent an important modernization with the publication of Law No. 5,567, of June 22, 2023, regulated by Decree No. 30,027, of 2025, which establishes strict criteria for shared responsibilities regarding the marketing, use, and disposal of empty packaging. This legislation innovated by making mandatory the use of a computerized system developed by the State itself through the Agrosilvopastoral Sanitary Defense Agency of the State of Rondônia – IDARON, for the purpose of inspection and control of the pesticide trade. Through this system, called Siafro, product inventory control, the issuance of agronomic prescriptions, authorizations for direct sale and the registration of returns of empty packages must be carried out. Siafro enables the traceability of pesticides in Rondônia by integrating information related to the commercialization by resellers and return of packaging to service stations and



collection centers.

Thus, the literature and the normative basis indicate that the reverse logistics of empty pesticide packaging should be understood through three articulated dimensions. The first is the legal-institutional dimension, which defines responsibilities, deadlines, obligations and competencies of the different agents in the chain. The second is the operational-logistical dimension, related to the infrastructure for receiving, transporting, sorting, storing and environmentally appropriate disposal. The third is the socio-environmental dimension, which involves environmental education, inspection, risk reduction, public health, conservation of natural resources, and transition to the circular economy (Brasil, 2010; Brazil, 2023; Brazil, 2024; Noskoski *et al.*, 2024).

Thus, the effectiveness of reverse logistics of empty pesticide packaging depends on the articulation between regulation, infrastructure, user participation, institutional monitoring, and environmentally appropriate disposal. In regions of agricultural expansion, as occurs in different areas of the Brazilian productive frontier, these factors become even more relevant, as the increase in the use of agrochemical inputs tends to increase the pressure on environmental control systems. By articulating reverse logistics, circular economy, and environmental sustainability, the literature allows us to understand how agribusiness can reduce negative externalities and advance more responsible production models, especially in territories marked by agricultural intensification and the need to strengthen environmental governance (Balbinot Junior *et al.*, 2022; Brazil, 2024; Noskoski *et al.*, 2024; inpEV, 2026;).

3 Methodology

For the elaboration of this study, applied research was carried out, nature quali-quantitative and exploratory-descriptive character. The study was structured in two main technical procedures: bibliographic review, carried out through a theoretical survey in academic databases, using the descriptors "reverse logistics", "empty pesticide packaging", "Campo Limpo System", "circular economy", "environmental sustainability" and "sustainable agribusiness"; and documentary survey of the relevant agri-environmental legislation, with emphasis on Law No. 14,785, of December 27, 2023, and Law No. 12,305, of August 2, 2010, referring, respectively, to the federal regulation of pesticides and the National Solid Waste Policy.

Finally, secondary data collection was carried out based on technical reports, newsletters and official databases of the National Institute for the Processing of Empty Packaging – inpEV and the Agrosilvopastoral Sanitary Defense Agency of the State of Rondônia – IDARON.

With regard to inpEV data, sustainability reports and performance data from the Campo



Limpo System were analyzed, focusing on the amount of packaging received and disposed of by the central stations and receiving stations in Rondônia. In the IDARON database, the survey considered inspection data, pesticide use control reports, and statistics related to the amount of packaging returned to receiving stations.

Based on the data obtained, the amount of pesticide packaging sold in Rondônia in the period from 2022 to the first four months of 2026 was analyzed, comparing it with the amount of packaging returned to the receiving units. To avoid distortions resulting from the legal lag of up to one year between the acquisition of the product and the return of the packages, an adjusted return index was also calculated, relating the amount of packaging returned in the reference year with the amount of packaging sold in the previous year. The quantitative data extracted from the inpEV and IDARON reports were tabulated in electronic spreadsheets and submitted to descriptive statistical analysis, allowing the construction of graphs and tables on the historical series and the geographical distribution of reverse logistics in Rondônia. Such data allowed us to discuss the results in the light of the circular economy theory, in addition to enabling the identification of bottlenecks and contributing with relevant information with a view to the continuous improvement of the Campo Limpo System in Rondônia.

4 Results and discussion

The data provided by IDARON regarding the commercialization of pesticides in Rondônia, in the period from 2022 to April 2026, revealed the total amount of 11,165,115 packages sold. There is a progressive growth in the amount of packaging sold between 2022 and 2025, as detailed in Figure 1. The growth observed between 2022 and 2025 represents a positive change of 65.91%, calculated by expressing the simple percentage change:

$$PV = ((V_{\text{final}} - V_{\text{inicial}}) / V_{\text{inicial}}) \times 100$$

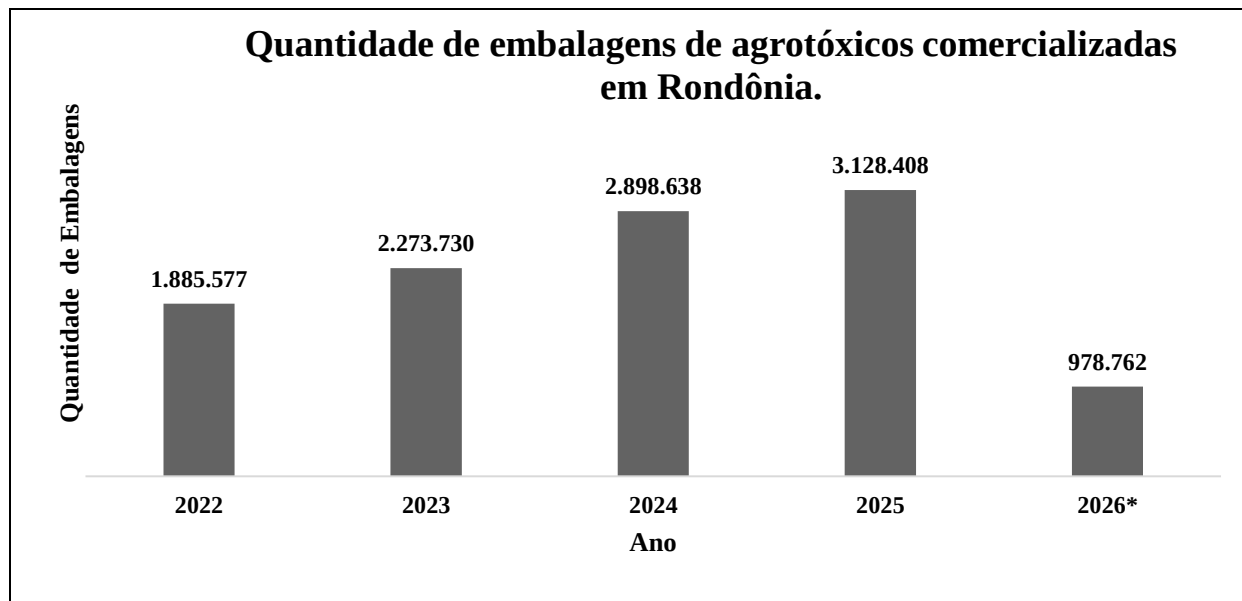
Where V_{final} represents the amount of packaging sold in 2025 and V_{inicial} the amount of packaging sold in 2022. Substituting the historical data, we have:

$$PV = ((3,128,408 - 1,885,577) / 1,885,577) \times 100 = (1,242,831 / 1,885,577) \times 100 \approx 65.91\%$$

This increase indicates a compound annual growth rate of approximately 18.39% per year in the consumption of these inputs in the state, associated with the expansion of grain-producing

areas, especially soybeans and corn in Rondônia (Embrapa, 2026).

Figure 1 – Quantity of pesticide packages sold in Rondônia from 2022 to April 2026.



Source: Prepared by the authors based on data from IDARON, 2026.

*Data up to April 2026.

Regarding the amount of pesticide packages returned by users at the receiving units, there is a behavior similar to that observed in the amount of packages sold, with an increasing increase in the amount returned over the period, except in 2024, when there was a punctual retraction compared to 2023, as shown in Chart 1.

The retraction recorded in 2024, although punctual, deserves analytical attention. Possible explanatory factors include: the time lapse between marketing and return provided for in Law No. 14,785/2023, which allows the user to return the packaging within one year after purchase, being able to shift returns of packaging purchased in 2024 to the following year; possible climatic variations that affected the agricultural calendar and, consequently, the cycle of use and return of inputs in the state; and the transition period to the Siafro computerized system, whose implementation may have generated temporary inconsistencies in the return records by IDARON. The absence of complementary qualitative data prevents a definitive conclusion about the causes of this retraction, which points to the need for future studies with triangulation of primary sources with the agents of the reverse chain.

Table 1 – Number of pesticide packages returned in Rondônia, by municipality and by receiving unit, in the period from 2022 to April 2026.

Municipalities and their receiving	2022	2023	2024	2025	2026*	Total Sum



units						
Alta Floresta do Oeste (ALTA)	15.061	25.272	25.077	34.392	16.750	116.552
Ariquemes (ARPAJAV)	181.205	381.284	477.921	470.085	192.089	1.702.584
Buritis (ARPABUR)	28.075	42.887	36.041	51.194	20.700	178.897
Cacoal (INPEV)	14.731	478.162	260.173	372.453	182.429	1.307.948
Espigão do Oeste (ARPA)	19.117	21.152	23.647	29.166	7.802	100.884
Jaru (ASCOPAGRO)	52.459	56.563	72.672	93.442	26.782	301.918
Ji-Paraná (ARPARO)	57.786	69.007	120.196	199.352	442.060	888.401
Machadinho D'Oeste (ARPARO)	39.115	58.896	57.837	55.844	21.970	233.662
Nova Brasilândia D'Oeste (ACOPANEM)	25.024	9.672	9.240	9.408	3.293	56.637
Ouro Preto do Oeste (ARPARO)	4.046	154	39	31.771	10.739	46.749
Porto Velho (ARAPEV)	58.726	199.152	191.782	282.902	89.182	821.744
Rolim de Moura (ARGROROM)	38.010	36.929	34.602	49.014	9.157	167.712
São Miguel do Guaporé (ARPA)	87.647	164.247	124.113	171.695	86.035	633.737
Vilhena (ARPAVI)	408.289	649.475	670.444	836.129	81.758	2.646.095
TOTAL	1.029.291	2.192.852	2.103.784	2.686.847	1.190.746	9.203.520

Source: Prepared by the authors based on data from IDARON, 2026.

*Data up to April 2026.

By analyzing the data in chart 1, it is verified that only 14 municipalities in Rondônia have receiving units, corresponding to 26.92% of the total of 52 (fifty-two) municipalities, a severe logistical and territorial bottleneck for the consolidation and completion of the circular economy in Rondônia is evident.

The low territorial coverage of the receiving units has direct implications on the logistical efficiency of the return system, as it increases the distance between rural properties, the municipalities where the products are purchased and the formal points of receipt of empty packages. In agricultural frontier regions, such as Rondônia, marked by territorial dispersion of properties, differences in road infrastructure and long commutes between productive areas and



urban centers, the concentration of receiving units can increase the private cost of return for users. This cost is not limited to transportation, but involves travel time, operational organization of the property, temporary storage of packages and the need to make the return compatible with the agricultural calendar. Thus, territorial coverage becomes a critical variable for the effectiveness of reverse logistics, because the greater the distance to the receiving points, the greater the risk of postponement, prolonged storage or non-return of the packages to the formal flow of destination.

From the perspective of regional development, the reverse logistics of empty pesticide packaging goes beyond the environmental dimension and assumes a strategic role in the territorial governance of agribusiness. The existence of a capillary, inspected and accessible return system contributes to reducing environmental risks, protecting water resources and soils, preserving the health of rural workers and local communities and strengthening the institutional image of Rondônia's agribusiness in markets that are increasingly sensitive to socio-environmental criteria. On the other hand, barriers to access to receiving units can compromise the effectiveness of environmental public policies, especially when small and medium-sized producers face higher relative costs to comply with legal requirements. In this way, the expansion of the receiving infrastructure and the strengthening of technical guidance can contribute to a more balanced regional development model, in which productive expansion, environmental responsibility and territorial inclusion advance in an articulated way.

This asymmetry of access tends to affect producers differently according to their production scale. Large producers, with a higher volume of purchases and, consequently, a greater volume of packages to be returned, have economic incentives and operational capacity to organize periodic trips to distant receiving units, diluting the unit cost of transportation between multiple packages. Small and medium-sized producers, in turn, tend to face a proportionally higher unit cost of return, which can discourage full compliance with the legal obligation, especially in municipalities classified as "territorial voids" of collection. This dynamic reveals a tension between the principle of shared responsibility, provided for in Law No. 12,305/2010, and the operational reality of a public policy whose effectiveness depends, to a large extent, on the individual ability of each user to bear the costs of compliance. In addition, the effectiveness of environmental public policies applied to the sector — such as the inspection carried out by IDARON and the requirements of the Campo Limpo System — is conditioned by the existence of accessible infrastructure; Strict rules without corresponding capillarity tend to generate unintentional non-compliance, resulting from a logistical barrier, and not necessarily from user omission. This scenario reinforces the need for the sustainable regional development of Rondônia — inserted in the broader context of the Amazonian bioeconomy mentioned in the introduction of



this study — to contemplate mechanisms that reduce the inequality of access between different sizes of producers to the reverse logistics system.

This relationship between distance and system performance can be illustrated in a more concrete way when considering the distribution of receiving units presented in Chart 1. Municipalities such as Vilhena and Ariquemes concentrate significant volumes of returns (2,646,095 and 1,702,584 packages, respectively, in the period analyzed), which suggests that physical proximity to a receiving unit is positively correlated with the volume of formalized returns. On the other hand, the 38 municipalities without their own receiving unit (73.08% of the total) depend on the displacement of their users to neighboring municipalities, often tens or hundreds of kilometers away, which increases the private cost of legal compliance. This cost, although not directly measured in the available official data, can be estimated indirectly based on variables such as road distance, fuel consumption, and travel time — information that constitutes a data gap to be filled in future studies, preferably through a primary survey of rural producers or spatial analysis (GIS) that correlates the location of the properties with the location of the receiving units. The absence of this precise measurement does not invalidate, however, the inference that the concentration of receiving units in only 14 municipalities (26.92% of the total) constitutes, in itself, a structural barrier that penalizes more intensely producers located in the 38 municipalities without their own coverage.

It is believed that the low number of municipalities with receiving units is due to the flexibility of the pesticide legislation that allows the creation of these units through pesticide reseller associations from different municipalities, making certain units truly regional, as observed in figure 2, making access difficult for users who often purchase pesticides in their municipalities and need to travel long distances to carry out the return, that is, 73.08% of the municipalities are characterized as "territorial voids" of collection, depending entirely on intermunicipal transport routes for legalized disposal. These bottlenecks and difficulties are evidenced by Câmara *et al.* (2023) in a study carried out with melon producers in producing regions of Rio Grande do Norte and Ceará, as well as the one presented by Lara & Silva (2024) when analyzing the reverse logistics of crop protection packaging in the municipality of Campos de Júlio – MT.

To mitigate the severe territorial limitations resulting from the fact that 73.08% of the municipalities do not have physical receiving units, the legislation of Rondônia institutionalized the mandatory Itinerant Receipt. According to Normative Instruction No. 10, made available on December 1, 2025 by IDARON, individuals and legal entities that sell pesticides and related products in the state are required to structure, finance, and execute the itinerant receipt of post-consumption packaging of the products sold by them when the recipient agricultural



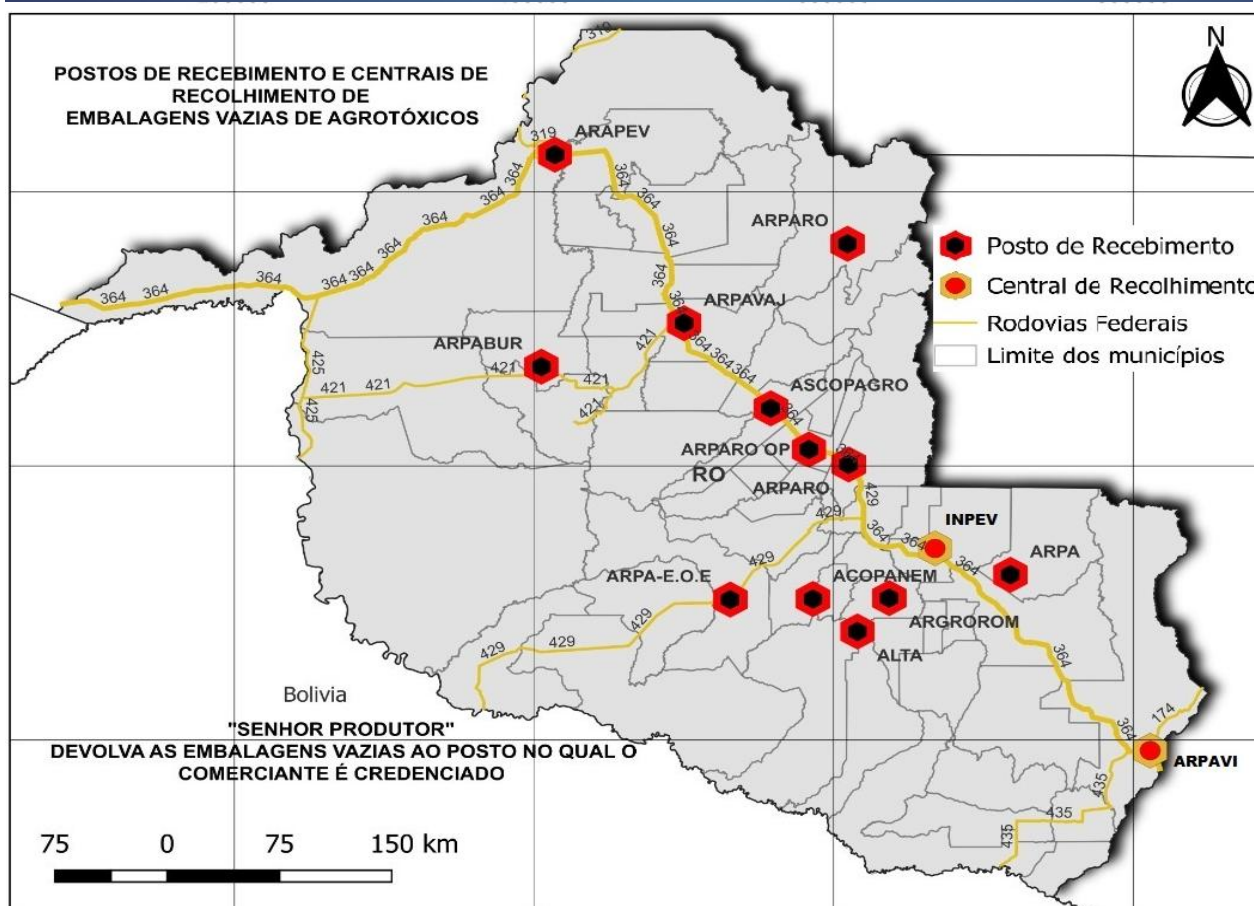
establishments or resellers are located at distances greater than 100 kilometers from any receiving unit. Such merchants must plan and submit to IDARON the annual calendar of the itinerant receipt, which will depend on the approval of the Agency. However, it is premature to assess the effectiveness of this standard as it has been implemented recently. On the other hand, it is pertinent for the state to develop mechanisms capable of encouraging the reseller sector to expand the territorial coverage of the receiving units and to increase the amount of returned packaging, in order to meet the growing demand evidenced in this study.

The itinerant receipt is aimed at small rural producers, being limited to 50 (fifty) packages per producer, exceeding this limit, the producer is obliged to return them directly to the receiving station or collection center for empty pesticide packages. This decentralizing public policy is made possible by regionalized governance partnerships between IDARON, receiving units and pesticide resellers.

Considering that the legislation allows the user to return empty pesticide containers within one year after purchase, the direct comparison between the amount of packaging sold and the amount of packaging returned in the same year can generate interpretative distortions. For this reason, an adjusted index of return by the legal lag was adopted in this study, calculated by the ratio between the amount of packaging returned in the reference year and the quantity of packaging sold in the previous year. This strategy allows interpreting the performance of the reverse logistics system in a way that is more compatible with the legal cycle of returning packages.

It should be noted, however, that the D/C ratio calculated on an annual basis has an inherent methodological limitation: due to the legal deadline of up to one year for return, part of the packaging returned in a given year was sold in the previous year, and part of the packaging sold in a given year will be returned in the following year. This means that the annual indices are not entirely comparable to each other in isolation, and their reading is more appropriate as trend indicators than as accurate measures of adherence in each period. For future analyses, it is recommended to adopt a cut-off methodology, correlating the returns of each year with the sales of the previous year, in order to produce a rate of return indicator with greater temporal precision and greater adherence to the reality of the reverse cycle.

Figure 2 – Geographical distribution of units receiving empty pesticide containers in Rondônia.



Source: IDARON, 2026.

Chart 2 - Adjusted rate of return of empty pesticide containers in Rondônia, considering the legal lag of up to one year between commercialization and return

Return reference year	Quantity of packaging sold in the previous year C(t-1)	Quantity of packages returned in year D(t)	Adjusted return ratio D(t)/C(t-1)
2023	1.885.577	2.192.852	116,30%
2024	2.273.730	2.103.784	92,53%
2025	2.898.638	2.686.847	92,69%
2026*	3.128.408	1.190.746	38,06%

Source: Prepared by the authors based on data from IDARON and inpEV, 2026.

*Data up to April 2026.

The results presented in Table 2 indicate that, in 2023, the amount of returned packaging corresponded to 116.30% of the amount of packaging sold in 2022. This percentage higher than 100% may be associated with the return of packaging purchased in previous periods, the accumulated compliance with the legal deadline and the regularization of stocks temporarily held on rural properties. In 2024 and 2025, the adjusted ratios were 92.53% and 92.69%, respectively,



indicating stability in the performance of the reverse logistics system when considering the legal gap between purchase and return. The index of 38.06% observed in 2026 should be interpreted with caution, as it refers only to the first four months and does not represent the consolidated annual performance.

The adoption of the adjusted index allows a more accurate reading of the operationalization of the system, as it avoids attributing to the same calendar year an obligation whose fulfillment may occur in the following year. From this perspective, the results of 2024 and 2025 suggest that the system maintains a relevant capacity for the return of packaging to the formal flow of destination, with rates close to 93%. However, the residual difference between the quantity sold in the previous year and the quantity returned in the following year indicates the permanence of logistical, territorial and behavioral bottlenecks, which may be associated with the distance to the receiving units, prolonged storage on the properties, insufficient inspection or the low adherence of part of the users to the return procedures.

Such data suggest flaws in the reverse logistics process, evidencing the importance of the user's awareness and commitment to the proper disposal of the packages, as well as the need to create new receiving units in the state, in addition to more rigorous action by the agencies responsible for inspection, as pointed out by Aragos *et al.* (2021). From an environmental point of view, failure to return packaging increases the risk of inappropriate disposal practices, such as open burning, burial, improper reuse for water or food storage, and abandonment on rural properties or in permanent preservation areas — practices documented by Câmara *et al.* (2023) in producing regions of the Northeast and by Lara and Silva (2024) in the context of Mato Grosso. In agricultural frontier regions such as Rondônia, where production expansion occurs in areas adjacent to sensitive biomes, the improper disposal of this packaging represents a direct risk to the quality of water resources, the health of rural workers, and the integrity of local ecosystems, compromising the natural resources that sustain agricultural activity (Brasil, 2023; Noskoski *et al.*, 2024).

The residual difference between the amount of packaging sold and the amount of packaging returned must be interpreted critically, as the non-return of packaging to the formal system weakens both environmental safety and the logic of the circular economy. Unreturned packaging can remain improperly stored on properties, be disposed of in open areas, burned, buried or improperly reused, increasing the risk of contamination of soil, water, animals and people exposed to chemical waste. In addition to the environmental and health risk, the non-return represents a loss of material value, since packaging that could be recycled or properly disposed of ceases to circulate in the formal system. Therefore, the non-return should not be understood only



as an operational failure, but as a partial rupture of the reverse cycle and concrete limitation to the circularity of materials in Rondônia's agribusiness.

In quantitative terms, the difference between the total sold (11,165,115 packages) and the total returned (9,203,520 packages) in the period from 2022 to April 2026 corresponds to 1,961,595 packages (17.57%) that, at least within the time window analyzed, did not return to the formal flow recorded by IDARON. Although a significant part of this difference is explained by the legal lag of up to one year between purchase and return — as shown by the adjusted rates of 92.53% and 92.69% in the full years of 2024 and 2025 —, a residue of approximately 7% to 8% per year remains outside the formal system even after this time adjustment. This waste ultimately represents packaging that potentially followed destinations not documented in the official data, such as burning, burial, improper reuse or indefinite storage on properties.

From the point of view of the circular economy, this unreturned waste represents a direct loss of material value, since the Campo Limpo System destines, on average, 95% of the packaging received for recycling (inpEV, 2026). Packaging that does not return to the system is no longer reincorporated as secondary raw material, which contradicts the principle of "retention or recovery of value" provided for in Decree No. 12,082/2024 as the foundation of the circular economy. In this sense, each percentage point of unreturned packaging represents not only an environmental risk, but also a concrete interruption of the circular flow that the system itself seeks to institutionalize — showing that, in Rondônia, circularity remains partial, and not full, even in the face of relatively high adjusted return rates.

In addition, it should be noted that the present study, as it is based on secondary data aggregated from inpEV and IDARON, does not allow for the precise identification of the specific destinations of unreturned packages or to directly quantify any episodes of environmental or sanitary contamination associated with this portion. This is a relevant methodological limitation, which points to the need for complementary field studies, with primary data collection from rural producers and environmental and health surveillance agencies, capable of qualifying the real consequences of non-return in Rondônia.

Comparatively, the challenges observed in Rondônia are close to those faced by other regions of agricultural expansion in Brazil, in which the expansion of agricultural production is not always accompanied, at the same speed, by the expansion of the infrastructure for receiving, inspection and technical guidance. Unlike more consolidated agricultural areas, which tend to have more structured logistics networks and greater proximity between producers, resellers and receiving units, productive frontier territories have greater access asymmetries, greater operational distances and greater dependence on regional receiving arrangements. In this sense, the case of



Rondônia highlights a challenge typical of expanding regions: ensuring that the growth in the commercialization of agrochemical inputs is accompanied by equally robust mechanisms for controlling, returning and disposing of post-consumption packaging. This comparison reinforces the need for differentiated territorial policies, capable of considering the logistical, environmental, and institutional specificities of the Legal Amazon.

This approximation can be detailed from the studies cited in this work. Câmara et al. (2023), when analyzing melon producers in Rio Grande do Norte and Ceará, identified the great distance between properties and authorized collection points as the main obstacle to return — a structural problem equivalent to that observed in Rondônia, where 73.08% of the municipalities do not have their own receiving unit. Similarly, Lara and Silva (2024), when studying the municipality of Campos de Júlio, in Mato Grosso — a territory also characterized by recent expansion of the agricultural frontier — reported operational difficulties similar to those described here, related to dependence on regional receiving arrangements and the insufficient capillarity of the infrastructure.

This recurrence of challenges between geographically distinct regions, but with similar trajectories of recent agricultural expansion, suggests that the bottlenecks identified in Rondônia are not an isolated particularity of the state, but an expression of a broader pattern observed in productive frontier territories in Brazil. This reinforces the argument that the effectiveness of reverse logistics is less associated with the volume of natural resources or the productive potential of the region, and more with the speed with which the institutional infrastructure for receiving it keeps up with the pace of expansion of pesticide consumption. In terms of public policy, this finding indicates that solutions already tested in regions with similar challenges — such as the itinerant receipt mechanism itself, adopted by Rondônia through IDARON Normative Instruction No. 10/2025 — can offer relevant parameters of comparison for future evaluation of their effectiveness, since analogous instruments are already in operation. although with different degrees of maturity, in other agricultural frontier regions of the country.

The results show that the reverse logistics of empty pesticide packaging in Rondônia presents partial adherence to the principles of the circular economy, since it enables the return of a significant part of the post-consumption waste to the formal system of reception and environmentally appropriate disposal. When considering the legal lag of up to one year, the adjusted ratios for 2024 and 2025, close to 93%, indicate relevant operational performance of the system in the full years analyzed. However, the residual difference between the amount of packaging sold and the amount of packaging returned indicates a partial break in the reverse cycle, limiting the full circularity of materials and increasing the risks of improper disposal,



environmental contamination and loss of economic value of the waste. In this sense, the expansion of the territorial coverage of the receiving units, the strengthening of inspection, and the intensification of environmental education actions with users are strategic measures to consolidate the system as an effective instrument of circular economy in Rondônia's agribusiness.

In summary, the results indicate that the reverse logistics of empty pesticide packaging in Rondônia has a relevant performance, but still faces structural limits for its full consolidation as an instrument of circular economy. The existence of adjusted ratios close to 93% in the full years analyzed demonstrates a significant capacity for return; However, the restricted territorial coverage, the costs of travel, the dependence on the behavior of users and the permanence of packaging outside the formal flow indicate that the effectiveness of the system depends on logistical, institutional and educational improvements. Thus, the strengthening of reverse logistics in the state should be understood as a component of a broader agenda for sustainable regional development, capable of articulating agricultural productivity, environmental protection, public health, and governance of the agrochemical chain.

5 Final considerations

It is concluded that the reverse logistics system for empty pesticide packaging in Rondônia is structured based on the articulated action between users, resellers, receiving units, inspection agencies and the Campo Limpo System, in line with the determinations of the National Solid Waste Policy and the federal pesticide legislation.

The data analyzed show that, between 2022 and April 2026, a total of 11,165,115 packages of pesticides were sold in the state, of which 9,203,520 were returned, corresponding to a gross aggregate return rate of 82.43% in the period analyzed. However, considering the legal lag of up to one year between purchase and return, the adjusted rates for 2024 and 2025 were 92.53% and 92.69%, respectively, indicating stability in the return of packaging to the formal flow of disposal in the full years analyzed.

However, the residual difference observed between the amount of packages sold and the amount of packages returned, as well as the adjusted indices lower than the total in 2024 and 2025, reveal the permanence of bottlenecks in the reverse cycle, especially related to the territorial coverage of the receiving units, the distance traveled by users, temporary storage on properties, and the commitment of producers to return procedures. It was found that only 14 of the 52 municipalities in Rondônia have receiving units, which can limit users' access to the system and compromise the full circularity of materials. Thus, although the reverse logistics of empty pesticide packaging in Rondônia presents relevant adherence to the principles of the circular economy, its



environmental effectiveness depends on the expansion of the receiving infrastructure, the strengthening of inspection actions and the intensification of environmental education programs aimed at pesticide users.

Thus, the study demonstrates that the Campo Limpo System contributes to environmental sustainability in Rondônia's agribusiness by promoting the return of a significant part of the packaging to the formal disposal flow, reducing risks of improper disposal, environmental contamination and loss of waste value. However, the consolidation of the circular economy in this sector requires logistical, institutional, and educational improvements, capable of expanding the territorial coverage of the system, reducing costs and barriers to access for users, reducing the amount of unreturned packaging, and strengthening co-responsibility between the different links in the chain. These improvements are essential for reverse logistics to contribute not only to the environmentally appropriate disposal of waste, but also to sustainable regional development, the protection of natural resources and the effectiveness of agri-environmental public policies in Rondônia.

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