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Risk Society and The Challenge of Sustainable Rural Development in The Era of Pesticides

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ABSTRACT

This study addresses the issue of pesticides in agriculture from the perspective of risk society theory. Through a comprehensive literature review, the study explores the central concepts of the theory, such as manufactured uncertainty, individualization of risks, and the globalization of effects. Pesticides are an emblematic example of modernity's risks. Their widespread use, driven by the pursuit of high productivity, conceals dangers to human health, biodiversity, and ecosystems. The complex and often invisible nature of the impacts of pesticides makes it difficult for society to perceive the risks. This invisibility, combined with unequal access to information and the lack of transparency from the industry, exacerbates the problem. Methodologically, this article presents itself as an exploratory narrative literature review. The final considerations point to ecological-based agriculture as a promising path for building a fairer, more sustainable, and safer agricultural system. Furthermore, Ulrich Beck's risk society theory underscores the urgency of seeking sustainable alternatives for agriculture and public policies that promote social and environmental justice, focusing on agroecology and organic production. This is essential to building a fairer and more sustainable future for the next generations. Additionally, it is important to highlight the need to bring this debate into the realm of public security, as this area plays a crucial role in promoting more sustainable societies with fewer individual and collective risks.

Keywords: reflexive modernization; rural sustainability; agroecology.

INTRODUCTION

The theory of the risk society, developed by Ulrich Beck in the 1980s, describes a profound transformation in contemporary societies and represents an important theoretical framework for analyzing social and environmental changes resulting from technological development and globalization. This transformation is marked by the emergence of transnational and unpredictable risks produced by human action (Beck, 2011).

Moreover, late modernity — or reflexive modernity — is a complex concept, still under debate among sociologists, being developed by several authors, including Anthony Giddens, Ulrich Beck, and Zygmunt Bauman. The debate on this subject is an important way to analyze and understand current societies, as well as to discuss complex issues such as the relationship between wealth production and risk production (Giddens, 1997).

Globalization and modernity have contributed to the emergence of vulnerabilities, often unspecific, and the environmental crisis experienced within this context is a point of instability that brings the risk society theory into discussion. Awareness of risks and the pursuit of proper governance become imperative to deal with the challenges of this new social context (Bosco; Ferreira, 2016).

In this context, highly relevant topics raise questions about how society has prepared itself to deal with risks and uncertainty. Among these topics, the increasing presence of pesticides in agriculture, and consequently in food, stands out, posing a risk to human health, the sustainability of crop production, and the environment, in light of the growing global demand for food products. The risk generated by the insertion of pesticides into people's daily lives became notably normalized from the second half of the 20th century, and its harmful effects are justified and hidden by those who benefit from this lobby (Carneiro, 2015).

Pesticides, chemical fertilizers, and genetically modified plants are deeply embedded in the Brazilian production process. Despite the fact that their use results in a set of negative externalities widely documented in the specialized literature, these products ensure better conditions for agribusiness to profit and accumulate capital through the land. The pesticide industry continues to expand, with profits concentrated in large corporations, subjecting farmers and consumers to immeasurable vulnerabilities in a vicious cycle of consumption (Bosco; Ferreira, 2016).

In addition to the risks to public health, food security, and the environment, which have already been extensively addressed by the scientific community, pesticides have been responsible for challenges to public safety, especially due to their illegal trade, which mainly occurs through border areas but affects all regions of the country. This results in the introduction of products into agriculture whose harmful potential is unknown, with improper handling and transportation, and without proper regulation and taxation.

At the end of the last century, sociologist Ulrich Beck already reflected on the challenges of transitioning from the modern to the postmodern era in terms of socio-environmental impacts (Da Silva et al., 2020). Considering Beck's risk society theory, it is possible to follow the unfolding of the sociologist's predictions and ideas, describing the reality of a society concerned with developmentalism, suppressing the visibility of environmental, social, and emotional issues, which results in increasing risks that escape human control (Da Silva et al., 2020).

In this sense, the objective of this article is to analyze, through the available bibliography, the issue of pesticides and their impact on sustainable rural development in Brazil, within the context of risk society theory. The relevance of this topic is justified by the need to develop a critical analysis of the issue of pesticide use in Brazilian agriculture, from the perspective of Ulrich Beck's risk society theory, to assess the implications for sustainable rural development in the country.

Based on the literature review, the aim is to examine the socio-environmental impacts of intensive pesticide use, including risks to human health, food security, biodiversity, and the environment. Additionally, the study will investigate how the logic of the risk society, characterized by the production of transnational risks and uncertainty, applies to the context of pesticide use in Brazil.

Through a critical analysis of the impacts of pesticide use in modern agribusiness, this study is expected to contribute to the debate on the need for changes in the Brazilian agricultural production model, with a view to building a more sustainable and secure future for people and the environment.

METHODOLOGY

To meet the purpose of this article, bibliographic and documentary research was conducted, using not only published theoretical references but also legal and technical documents from the Brazilian public authorities, considering their various aspects and interrelationships. Based on the delimitation of the object, a qualitative approach was

chosen. According to Gil (2002), qualitative research allows the collected data to be interpreted comprehensively and in context, considering different perspectives, subjectivities, interests, and relationships present in the topic. Data collection was carried out through critical and analytical reading of the available bibliographic materials, and the data analysis was conducted qualitatively, using techniques such as content analysis, documentary analysis, and comparative analysis.

The research assumes an exploratory character, conducted through a narrative bibliographic review, aiming to expand knowledge on the subject and formulate hypotheses for future research. Bibliographic research with a narrative literature review was chosen due to its ability to provide a comprehensive and in-depth understanding of the subject at hand. This method allows for the gathering and analysis of a wide range of academic sources, theories, and pre-existing research, offering an integrated and contextualized view of the studied problem. The narrative literature review is particularly useful for identifying knowledge gaps, outlining the state of the art, and establishing a solid theoretical foundation that supports the investigation and subsequent data analysis (Botelho et al., 2011). Additionally, this approach facilitates the interconnection of diverse perspectives and the construction of an interdisciplinary conceptual framework, which is essential for the complex analysis of issues such as the impact of agrochemicals on sustainable rural development within the context of risk society theory.

Like any research, this study presents some limitations. The main one refers to the exploratory nature of the research, which may make it difficult to generalize the results to other contexts. Another limitation concerns the selection of information sources, which may not have been exhaustive. Nevertheless, the qualitative, bibliographic, and exploratory research methodology proves appropriate for the study of the subject in question, as it allows for a deep and contextualized investigation, in addition to contributing to the construction of new knowledge.

LITERATURE REVIEW

Risk Society Theory and Reflexive Modernization

More than postmodern times, humanity is experiencing a phase of growing awareness of the risks and uncertainties inherent to technological and industrial development (Giddens, 1991). As a starting point for reflecting on the directions of

modernity, it is essential to analyze the complex relationship between progress and risk in the modern era. Risk emerges as a concept when it becomes possible to think of the future as controllable, and since society produces risks, which may or may not be controlled, the theory of risk society is notably based on organized irresponsibility (Beck, 2011).

Various terms have been suggested to name the current historical moment: information society, consumer society, postmodernity, and post-industrial society. The concept of risk society, originating from the social sciences, generally refers to a social context in which risks and uncertainties are central elements in people's lives, resulting from technological, economic, and environmental transformations in recent decades (Beck, 2011). In this society, the emphasis is placed on global and collective risks that transcend national borders and affect everyone. Examples of these risks include climate change, pandemics, environmental disasters, cyber threats, financial collapses, the development of nuclear weapons, and others. These dangers are inherent to technological progress and the development of modern capitalist societies (Beck, 2011).

The risk society is also characterized by ambivalence and paradoxes. On one hand, technological innovations bring benefits and advancements, promoting efficiency and comfort. On the other hand, these innovations create new dangers and unpredictable challenges. Uncertainty becomes a constant, and individuals must deal with the possibility of unexpected negative consequences, even in their daily activities (Giddens, 1991).

The development of modern social institutions and their worldwide diffusion offers more security, as well as numerous possibilities for innovation and collective well-being. However, the acute effects that threaten life and the planet's sustainability make risks increasingly apparent and emergent (Giddens, 1991). In this context, responsibility is a key concept. Risks are not just the result of external forces but are primarily produced by human actions. Decisions made by individuals, companies, and governments have far-reaching implications, affecting not only themselves but also future generations and other communities. Therefore, life in the risk society requires critical reflection on the relationships between science, technology, power, and responsibility (Giddens, 1991).

The risk society is thus a complex phenomenon that challenges traditional social structures and demands interdisciplinary approaches to be fully understood. Modernization unfolds as both solution and problem, security and danger, trust and risk. The symbiosis between these antagonisms is the main issue faced today, as even with the

launch of comprehensive political agendas for productive transformation, such as the SDGs, capitalism perpetuates the notion that there is no economic growth without environmental harm, or technological development without side effects for the planet. The naturalization of this symbiosis plays a role analogous to that played by the Church in the Middle Ages, consecrating the negative effects of modernity as an inevitable social necessity, and the deleterious consequences of modernity are becoming more radicalized and universalized (Giddens, 1997).

The view that the economy transcends the sustainability of natural resources leads to an incomplete accounting of production costs, disregarding environmental and social costs, as capitalism also produces poverty through the extraction of relative and absolute surplus value from workers. The industrial society believes in the need for exponential and constant growth, creating needs driven by the desire for social status, vanity, and fictitious happiness (Lutzenberger, 1978).

Amid the paradigms of contemporary modernity, the idea spreads that sources of wealth are tied to collateral threats. In this context, "the modernization process becomes reflexive, turning itself into a topic and a problem" (Beck, 2011, p. 24).

> These paradigms are present everywhere: social inequality, hunger and poverty, policies that fail or barely reach vulnerable populations, social and food insecurity, and violence that become normalized and justified through the need for progress and wealth generation, portraying an unjust, meritocratic society indoctrinated by prevailing capitalism in pursuit of neoliberal individualism. In this social architecture, uncertainty and risk become part of people's lives, and the deleterious effect of risk is unknown, thus, acceptable. Environmental catastrophes, public health problems, and global tragedies disturb and worry people's thoughts. Humanity, however, experiences a cognitive dependency on the risks of modernization (Beck, 2011, p. 24).

This cognitive dependency on modernization risks and their invisibility is described by Beck (2011) as a civilizational threat, as it involves unknown scenarios for humankind. Society has witnessed a series of tragedies, pandemics, ecological damage, and natural disasters, but civil responsibility for environmental damage remains a controversial field, as does the responsibility of agents who profit from the accumulation through expropriation of natural resources.

Within this social context, the prevailing economic model postulates an open, unidirectional flow moving between two extreme infinitives: on one side, inexhaustible raw materials and energy, on the other, an unlimited capacity to absorb waste, a model that characterizes the current environmental crisis humanity faces (Lutzenberger, 1978).

On this topic, Carson (2010, p. 22) states that:

> "[...] Humankind has acquired significant power to alter the nature of its world. In the last quarter-century, this power not only grew to a worrisome magnitude but also changed in character. The most alarming of all human attacks on the environment is the contamination of air, soil, rivers, and seas with dangerous and even lethal materials. This pollution is mostly irreversible, and the chain of harms it triggers not only in the world that sustains life but also in living tissues is largely irreversible" (Carson, 2010, p.22).

The environmental crisis is fundamentally the effect of a failure to understand life and human intervention in its order. The most important aspects for understanding environmental issues were listed by Lutzenberger (1978, p.12) and remain relevant today:

> "1. The Ecosphere is a functional unit where each part has its specific role, complementary to all others. Species in the Ecosphere are like organs in the body; 2. We therefore have an interest in preserving all species without exception; 3. The survival of the system depends on disciplined behavior in self-regulated balance – homeostasis; 4. The perfect and perpetual recycling of all materials used by life allows for indefinite continuation through geological eras, with the limited resources of the Planet" (Lutzenberger, 1978, p.12).

The speed with which humanity has extracted, transformed, and used natural resources does not respect the natural time of the environment, and the implications of this are often unknown. Beyond resource extraction, it is also necessary to consider the introduction of chemicals, toxic substances, and industrial waste, polluting and contaminating soil and water. Thus, socially recognized risks foresee interests and dependencies, and these establish a direct relationship, linked according to the cause-and-effect model, where threats and harmful phenomena affect society in various dimensions. As modernization processes continue, the social conflicts of a wealth-distributing society converge with those of a risk-distributing society (Beck, 2011).

Historical Context and Concept of Pesticides

The first records of substances used to control pests and diseases date back to antiquity. Over 3,000 years ago, Greeks, Romans, and Chinese used natural substances such as sulfur, arsenic, salt, tobacco, and essential oils to combat agricultural pests. For millennia, humanity produced food within nature's limits (Ribeiro; Pereira, 2016). It was only when the classes owning the means of production began to seek increased productivity that pesticides were introduced in agriculture. However, their origin predates this, beginning during World War I, between 1914 and 1918 (Paschoal, 2019).

Pesticides were widely used as chemical weapons. [1]The first known poison was the organic compound dichlorodiphenyltrichloroethane, which became popular under its acronym: DDT. A powerful organochlorine insecticide, it later became the most widely used of the new pesticides, even before its effects had been thoroughly studied (Ribeiro; Pereira, 2016). However, chlorine, phosgene, and mustard gas were the substances most used during the Great War, causing terror and misery for soldiers in the trenches.

During World War II, from 1939 to 1945, Agent Orange, a compound of two herbicides—2,4-Dichlorophenoxyacetic acid (2,4-D) and 2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)—was extensively used as a chemical weapon to destroy forests and crops, aiming to weaken the enemy by hunger and neutralize potential hiding places (Ribeiro; Pereira, 2016). Additionally, this substance was used on a large scale by the Nazis in concentration camps during the Holocaust, alongside carbon monoxide or cyanide, for mass extermination in fixed gas chambers (Jauregui-Lobera, 2020).

Next, chemical insect control products emerged, but it was in agriculture, after the end of the World Wars, that the pesticide industry found a way to repurpose its products (Bastos; Esquivel, 2017). Combined with the need to increase agricultural productivity and eradicate global hunger caused by the wars, agriculture developed strongly as a commercial activity, leading to the so-called Green Revolution. Early results, from high biological action and environmental persistence, were promising and showcased pesticides' potential for long-term pest control (Paschoal, 2019).

Starting in the 1960s, the Green Revolution [2]guided the research and development of modern agricultural production systems for incorporating technological packages of supposed universal application (Matos, 2011). A massive agricultural development was observed during this period, but the widespread use of monocultures and the availability

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[1] A chemical weapon is one that uses the toxic properties of certain chemicals to produce alterations in the physiology of living beings. The main effects of the agents manifest as nausea, vomiting, and diarrhea, along with many secondary symptoms caused by excessive glandular secretion (sweating, salivation, tearing, rhinorrhea, bronchial hypersecretion), as well as respiratory function changes, miosis, blurred vision, dyspnea, and bronchospasm. The primary causes of death are respiratory failure and seizures (Jauregui-Lobera, 2020).

[2] The Green Revolution was a set of initiatives introduced starting in the 1940s, aimed at increasing global agricultural production through the modernization of farming practices. It involved the use of technologies such as mechanization, the use of genetically modified seeds (hybrid varieties), the intensive use of chemical fertilizers, pesticides, and irrigation, as well as the application of new management techniques. While it brought significant advances in productivity, it also created challenges for environmental sustainability and social equity (Matos, 2011).

of plant genetic improvements for higher yields and better-quality products became the main pillars of this phase. Thus, the Green Revolution marked the international diffusion of agricultural research techniques, standardizing the agricultural production process with a shared set of agronomic practices and artificial industrial inputs, especially through transgenic crops, chemical fertilizers, and pesticides (Matos, 2011).

In this context, soybeans, a broadleaf legume with indeterminate growth, gained prominence on the world stage. The transgenic soybean seed was developed by Monsanto in the 1980s. The company's proposal was to facilitate field management, increase profits for producers by reducing production costs—thanks to fewer pest control sprays—and increase productivity, eliminate weed competition, and reduce the impurity and moisture content of harvested grains (Menegatti; Barros, 2007). Thus, biotechnology piqued the interest of the primary link in the agricultural production chain: the producers.

Transgenic soybeans, with lower production costs and higher yields, were seen as an innovative and promising solution, attracting the interest of bourgeois agricultural sectors worldwide, particularly in Brazil. As capitalism, already dominant in Brazilian social formation, guided the elites in both the economic and political spheres, agribusiness became a priority (Matos, 2011). The socially unjust, concentrated, and exclusionary model of Brazilian technological modernization ensured that small rural producers were gradually absorbed by those with larger estates, greater purchasing power, and, consequently, more access to new technologies available on the market.

Thus, production costs, as a fundamental statistic, were highly effective in justifying the feasibility of agribusiness, as well as classifying the activity's performance and efficiency against global economic competitiveness (Menegatti; Barros, 2007). However, the statistics did not account for the environmental and social costs involved. Rural exodus, a migratory movement characterized by the departure and/or expulsion of the population from rural to urban areas, was one of the first effects observed in this new social context. In the 1980s, according to IBGE data, the urban population more than doubled compared to the rural population.

Massive investment in Brazilian agriculture to transform it into one of the world's leading exporters directed substantial financial resources to the seed production sector, the use of agrochemicals, and field mechanization, making agribusiness inaccessible to the rural poor. This forced small family farmers to sell their properties and seek other opportunities in urban areas. As a result, there was an increase in unemployment and underemployment, the growth of slums and urban violence, while the problem of hunger,

whose eradication was one of the main arguments for transgenics, remains unresolved to this day (Camarano; Abramovay, 1999).

Between 1960 and 1980, Brazil's rural exodus totaled 27 million people, and between 1990 and 1995, this migration surpassed 5.5 million people, also resulting in an aging and masculinization of the rural population (Camarano; Abramovay, 1999). The global area under transgenic cultivation grew exponentially, and record harvests became routine in Brazil, accompanied by increasing social inequality. In this context, in addition to transgenic soybeans, pesticides consolidated their role as a cornerstone of agribusiness.

The term "pesticide" originates from Greek: "ágros" (field) and "toxicon" (poison). In Brazil, the word emerged in 1977, from the work of Adilson D. Paschoal, who proposed replacing terms such as agricultural chemicals, pest killers, pesticides, and even biocides. The term first appeared in federal legislation in the 1988 Federal Constitution and is still used today. Although the term "poison" is still the most common word in popular vocabulary, attempts to soften the expression using terms such as agricultural chemicals and phytosanitary products are not uncommon. The term "pesticide" gained widespread acceptance, and in 1989, with Federal Law No. 7,802, it became the official term used to define toxic products used in agriculture.

Currently, the concept of pesticides is defined by Law No. 14.785, Art. 2º § XXVI, as:

> "Products and agents of physical, chemical, or biological processes intended for use in production sectors, in the storage and processing of agricultural products, in pastures, or in the protection of planted forests, whose purpose is to alter the composition of flora or fauna to preserve them from the harmful action of living organisms considered harmful" (Brasil, 2023, art. 2º § XXVI).

Decree No. 4,074, of January 4, 2002, defines pesticides in Article 1, § IV as:

> "products and agents of physical, chemical, or biological processes, intended for use in production sectors, in the storage and processing of agricultural products, in pastures, in the protection of forests, whether native or planted, and other ecosystems and urban, aquatic, and industrial environments, whose purpose is to alter the composition of flora or fauna to preserve them from the harmful action of organisms considered harmful, as well as substances and products used as defoliants, desiccants, growth stimulants, and inhibitors" (Brasil, 2002, art. 1º § IV).

Other definitions of pesticides include:

> "Substance or mixture of substances, chemical or biological in nature, intended to prevent, destroy, repel, attract, modify behavior, and/or regulate the growth or development of pests" (World Health Organization - WHO);
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> "Substance or mixture of substances, chemical or biological in nature, intended to destroy or inhibit the action of organisms harmful to agriculture, public

> health, livestock, or forests" (Food and Agriculture Organization of the United Nations - FAO).
>
> "Synthetic chemicals used to kill insects, larvae, fungi, ticks, under the justification of controlling diseases caused by these vectors and regulating vegetation growth, both in rural and urban environments" (INCA, 2021).

The history of pesticides is marked by a complex web of interests, impacts, and contradictions. From their roots as chemical weapons to their establishment as pillars of modern agribusiness, pesticides reveal a paradox: while they increase productivity and feed millions, they also poison the soil, water, biodiversity, and ultimately, human health itself. In this sense, while the eradication of pesticides is not yet feasible, strong legislation must be established. An effective government intervention in regulation, supervision, and awareness of the dangers associated with pesticides is urgently needed to ensure the protection of human health, biodiversity, and natural resources, thus promoting a truly sustainable agricultural model that is safe for present and future generations.

The pace at which humanity has extracted, transformed, and used natural resources does not respect the environment's natural timeline, and the implications of this are often unknown. In addition to resource extraction, the introduction of chemical agents, toxic substances, and industrial waste must also be considered, as these pollute and contaminate the soil and water. Thus, socially recognized risks involve interests and dependencies, creating a direct, interconnected relationship based on the cause-and-effect model, where threats and harmful phenomena impact society in various dimensions. As modernization processes continue, situations and social conflicts converge within a society that distributes wealth alongside one that distributes risks (Beck, 2011).

Regulation and Classification of Pesticides in Brazil

With the consolidation of agriculture focused on trade, following the global trend of the capitalist system, as one of the main economic sources in Brazil, and with the pursuit of productivity growth at any cost, including the poisoning of the population and the environment, the structure for monitoring product quality, as well as its regulation, and its impacts on health and the environment, deserve considerable attention. However, there are institutional gaps and shortcomings regarding the quality standards, environmental rationality, and sustainability that the biocivilized world demands (Silva, 2019).

Since 2008, Brazil has been the world's largest consumer of pesticides (Carneiro et al., 2015), representing 50% of the consumption in South America (Menezes et al., 2021). Many factors contribute to the excessive use of pesticides in Brazil and globally.

The availability of these products is reinforced by sales campaigns and advertisements from large commercial brands, which focus only on the positive aspects of their use, ignoring long-term consequences.

For over thirty years, pesticides were regulated by Law No. 7,802/1989, which underwent modifications over time. However, it was only two decades later, at the end of 2023, that Law No. 14,785/2023 was enacted, establishing the new Regulatory Framework for Pesticides and Environmental Control Products. The new pesticide law, which introduces changes in the regulation of pesticide use in Brazil, repealed the rules of Law 7,802 of 1989, as well as subsequent changes made by Law 9,974 of 2000. Among the main changes are the creation of the National Pesticide Agency (ANAgro) and the relaxation of rules for registering new products.

The new law sets deadlines for concluding registration applications and their amendments by the relevant authorities, modifies rules for approval and commercialization, aiming for regulatory agencies to simplify and streamline procedures under the premise of reducing costs and the time involved in the registration process. In other words, the new legal framework prioritizes profit over the collective risk that pesticides may pose.

The new law maintains a tripartite regulation by ANVISA, responsible for evaluating human health issues; by the Ministry of Agriculture, Livestock, and Supply (Mapa), which handles agronomic matters and is responsible for registering agricultural use products; and by the Brazilian Institute of Environment and Renewable Natural Resources (Ibama), responsible for environmental issues (ANVISA, 2019).

In addition to the new pesticide law, there are other regulations addressing the issue in Brazil, such as Decree No. 4,074/2002, partially repealed by the new law, which regulates Law No. 7,802/1989. It covers research, experimentation, production, packaging and labeling, transportation, storage, commercialization, advertising, use, importation, exportation, disposal of waste and packaging, registration, classification, control, inspection, and oversight of pesticides, their components, and related products, among other provisions.

Each federal body, within its respective area, is responsible for conducting oversight, monitoring, product reassessment when they pose unacceptable risks, and regulatory reviews. These activities are complementary and interdependent (Silva, 2019). The law assigns the registration of environmental control products to the federal agency responsible for the agriculture sector (Ministry of Agriculture and Livestock – MAPA),

which will also apply penalties and audit research institutions and companies. Thus, pesticide control is under the purview of the Ministries of Agriculture, the Environment (through IBAMA), and Health (represented by ANVISA) (Brazil, 2023).

Each pesticide product entering the country requires registration, which depends on the stage of the manufacturing process. The types of registration include temporary special registration for research and experimentation; technical product registration/evaluation, further divided into new technical product (PTN) or equivalent technical product (PTE); component registration, including all raw materials used in pesticide formulation; and finally, formulated product registration (Silva, 2019).

The regulatory cycle of pesticides in Brazil ideally resembles a pyramid. At the base, interconnected activities such as standardization, toxicological evaluation, oversight, and monitoring support each other. Higher up, interest groups and administrative spheres within ANVISA influence decision-making, and at the top, laws and other government spheres intervene in regulation (Silva, 2019). According to the author, political interference is a reality in ANVISA and may compromise the quality of pesticide regulation, endangering public health and the environment. This regulatory cycle fragmentation can be identified through a set of dysfunctions or lack of coordination, arising from institutional deficits that hinder the implementation of minimum requirements expected from public administration, associated with efficiency, transparency, and social participation and control (Silva, 2019).

The aforementioned study evaluated ANVISA's pesticide regulation from 2002 to 2018, both in terms of its regulatory process and its results in protecting health, considering a systemic approach. It highlighted that "given ANVISA's mission to protect and promote public health, the thesis demonstrates that the pesticide regulation practiced by the Agency is insufficient to meet this purpose" (Silva, 2019, p. 150). The author also points out that ANVISA's monitoring does not allow timely intervention to prevent unacceptable effects from persisting, as the data is released too late, resulting in insufficient time for more stringent regulatory and control actions.

Regarding the classification of pesticides in Brazil, Normative Resolution No. 42 of October 25, 2010, establishes a system that organizes them into different categories, mainly based on their toxicity, i.e., their potential to harm human health and the environment. This classification is determined based on the components, impurities, and similar products that pesticides may contain (Anvisa, 2023). Acute toxicity is the ability of a pesticide to cause harm to human health in a short period after a single exposure.

Acute toxicity classification considers the median lethal dose (LD50), which is the amount of pesticide required to kill 50% of a test animal population. The LD50 is expressed in mg/kg of body weight, and pesticides are classified into five toxicity levels: Extremely Toxic, Highly Toxic, Moderately Toxic, Slightly Toxic, and Unlikely to Cause Acute Harm (Anvisa, 2023).

For each category, there are indications of damage in case of contact with the mouth (oral), skin (dermal), or nose (inhalation). Other classifications can be established based on the mode of action, such as insecticides, fungicides, herbicides, acaricides, etc. Classification can also be based on the active ingredient, the chemical component responsible for the pesticide's action, and the formulation, the physical form of the product, such as liquid, powder, granules, etc. (Anvisa, 2023).

In 2019, with the toxicological reclassification of all pesticides registered in Brazil, ANVISA (National Health Surveillance Agency) reported an increase in the number of products in classes 1 and 2 (more toxic), a decrease in the number of products in class 4 (less toxic), and the creation of class 5, composed of products unlikely to cause acute harm (ANVISA, 2019). Pesticide classification is essential for contributing to the safety of rural workers, the environment, and the general population, and for guiding the use of pesticides.

In terms of legislation and regulation, the Union is responsible for issuing pesticide inspection standards, and it may delegate supplementary authority to states and the Federal District regarding the content of the law. However, it is noted that the evolution of the regulatory framework for pesticides reflects the result of neo-corporatist strategies of action by segments of the pesticide industry and the agricultural sector, particularly in decision-making and arbitration spaces within the Executive Branch, in their role of regulating the Pesticide Law and company actions through regulatory agencies (Pelaez et al., 2010). This confirms the hypothesis of the materialist theory of the State that, regardless of the level of institutional or organizational development of the State, it will always be directed towards creating better conditions for the capitalist market.

The relaxation of rules for registering new pesticides and the creation of ANAgro, with greater autonomy for the government, are points of instability, as they may lead to increased pesticide use in Brazil. While this may benefit Brazilian agribusiness, it also raises concerns about risks to human health, the environment, and the sustainability of Brazilian agriculture. The logic of short-term private interest’s conflicts with a long-term,

greater public interest priority based on the defense of human health and the environment (Pelaez et al., 2010). This hampers the inclusion of the impacts of these products on human health and the environment in the regulatory agenda.

The debate on the new pesticide law is expected to continue in the coming years. It is essential that independent scientific research be conducted, taking into account the environmental and social risk dimensions to assess the impacts of pesticides on the environment, the health of rural workers and consumers, as well as ecosystems in general. Only with solid evidence and careful analyses can the regulation of pesticides be directed toward promoting more sustainable and safer agriculture, more sensitive to collective demands, and less oriented towards market interests of accumulation.

Sustainable Rural Development in the Era of Pesticides

The 20th century was marked by significant advancements in scientific and technological development, particularly in agriculture. However, these advancements also led to several changes in the way agriculture is practiced, giving rise to contradictions and challenges regarding rural development and environmental sustainability (Zonin, 2007).

Pesticides, while considered agricultural inputs, are dangerous products that cause serious adverse effects on humans and the environment. It is undeniable that this technology has brought significant benefits, such as controlling vectors of diseases like malaria, typhus, and yellow fever, as well as substantial increases in food production and quality, profits for agricultural and industrial producers, and even a high standard of living for many people (Paschoal, 2019). However, the detrimental effects accompanied these advancements, and it wasn’t long before insects and other pests developed resistance to pesticides, a phenomenon observed in various countries and eventually spreading across all continents (Paschoal, 2019).

Moreover, pesticides have demonstrated the great plasticity of pest populations in response to this new external factor and have highlighted the continuous action of evolutionary selection processes. Today, it is known that resistance develops through selection within populations of species normally susceptible to certain pesticides (Paschoal, 2019).

The issue of pesticides and their implications for human health and the environment is not limited to agricultural and livestock production. Even in the control

of urban vectors, there is a significant source of contamination from chemicals with the same active ingredients as pesticides, under the name of disinfectant sanitizers. Whether in residential, public, or private spaces, these products kill, repel, or inactivate undesirable organisms in the environment but also eliminate essential species for life, such as bees and other pollinators, compromising ecosystems and posing incalculable long-term risks (Carneiro et al., 2015).

In domestic environments, the use of products with the same active ingredients as pesticides is also common, whether in gardening, veterinary products, or even within homes to control unwanted species like ants, mosquitoes, rats, caterpillars, and others. The normalization of pesticide use in daily life is notable, as people no longer fear the use of poison in their backyards and inside their homes.

Given the impacts of the vicious cycle of dependence on agrochemicals and the normalization of poison in human daily life, it is essential to seek alternative solutions that promote sustainable agriculture. These concerns have sparked a growing movement towards more sustainable and environmentally friendly agricultural practices, including the adoption of organic farming methods, the use of integrated pest management techniques, and the promotion of agroecological solutions.

Agroecology is based on ecological principles to promote sustainable agricultural production, utilizing methods such as crop diversification, crop rotation, integrated pest and disease management, and composting. It serves as a sustainable alternative for pest management in agriculture, including biological control, crop diversification, and integrated pest management. As a sustainability perspective, agroecology also seeks to restore family farming, a mode of agricultural production responsible for Brazilian food security and corresponds to a scientific approach aimed at supporting the transition from current rural development and conventional agricultural models to sustainable rural development and agricultural practices (Caporal; Costabeber, 2003).

An ecological ethic is urgently needed, especially in science. Healthy production processes encompass less conflictual and exploitative relationships in rural areas, considering land use and labor relations. Among the strategies for this change, it is important to incorporate agroecology into public policies and programs. The Brazilian state predominantly supports monoculture production for export but is weak in regulating pesticide use and establishing policies to support family farming and traditional communities, which practice agriculture in a more sustainable way (Carneiro et al., 2015).

In 2015, the United Nations launched the 17 Sustainable Development Goals (SDGs), guiding governments, businesses, and societies toward more just and environmentally responsible practices, promoting agricultural development that respects and preserves the environment, with the goal of making it a reality by 2030. Current driving forces emphasize the need to consolidate clean production systems with a positive carbon balance, highlighting sustainability and efficiency in natural resource use. This growing complexity of systems involves the adoption of advanced biotechnology, synthetic biology, and new technologies to ensure more efficient and sustainable agriculture (Massruhá, 2020).

The term "sustainability" is now widely discussed across various fields of knowledge. The ability to meet the needs of the present without compromising the ability of future generations to meet their own needs is a holistic premise, considering not only environmental issues but also social, economic, and cultural aspects. For Boff (2014, p. 14), sustainability is:

> the set of processes and actions aimed at maintaining the vitality and integrity of Mother Earth, preserving its ecosystems with all the physical, chemical, and ecological elements that enable the existence and reproduction of life, meeting the needs of present and future generations, and continuing, expanding, and realizing the potential of human civilization in its various expressions (BOFF, 2014, p. 14).

In this context, sustainable rural development, according to Plein (2012), must consider the integration of farmers into markets in such a way that they have economic and financial autonomy that allows them a good quality of life. This means that they must be able to produce and sell their products profitably, thereby ensuring a reliable source of income that enables them to maintain their families' well-being and contribute to the sustainable development of their regions. Moreover, market integration can provide opportunities for economic and social growth in rural communities, promoting a positive cycle of development.

Ecological Agricultures (EAs) are, according to Zonin (2007), the precursors of agroecology, and the use of the plural form reflects the concern with considering the diversity within the concept of agroecology. Thus, several streams of ecological agriculture can be highlighted to show the theoretical, practical, philosophical, and historical diversity of EAs (Zonin, 2007). The table below presents some of these streams of ecological agriculture.

Table 1 – Main streams of ecological agriculture.

Biodynamic Agriculture (BDA)	Emerged with Rudolf Steiner, emphasizing the view of the farm as a single organism. Practices include the integration of agriculture and livestock, adherence to the biodynamic calendar, and the use of biodynamic preparations.
Organic Agriculture (OA)	Initiated by Sir Albert Howard in England, it emphasizes the use of traditional fertilization methods. It gained popularity due to economic interest, leading to the need for certification and minimum standards.
Biological Agriculture	Focuses on soil and food health, utilizing practices such as soil management, organic fertilization, and crop rotation to promote healthier plants that are more resistant to pests.
Natural Farming (NF)	Originated in Japan based on the Mokiti Okada religion, it emphasizes enhancing natural processes in agriculture, such as crop rotation, green manures, and natural pest control.
Permaculture	Developed by Bill Mollison in Australia, it seeks to integrate the agricultural property into the ecosystem, prioritizing perennial crops and promoting sustainable production practices.
Regenerative Agriculture	Proposed by Robert Rodale, it aims to regenerate not only crops but the entire food production system, including rural communities and consumers, with a focus on soil recovery.
Agroecology	Approaches agricultural activity from an ecological perspective, integrating peasant knowledge and elements from various streams of ecological agriculture to promote sustainability and autonomy in agriculture.

Source: Prepared by the author based on Zonin (2007).

Ecological Agricultures (EAs) are not just a set of agricultural techniques; they are part of social movements that seek sustainability and a more just and healthy future. Although they have very different purposes, pesticides have a social relationship similar to that of cigarettes in the mid-20th century. Both represent significant risks to public health and are embedded in socioeconomic systems that prioritize profit over individual and collective well-being. This analogy serves as a warning of the need for profound transformations in production, consumption, and value systems. Only through a holistic and multisectoral approach that considers social, economic, environmental, and public health aspects can we build a more just, sustainable future, free from the harmful impacts of these products.

Sustainable production processes in agriculture have evolved significantly, moving away from monoculture practices toward integrated and rotational systems that require interdisciplinary knowledge and a systemic understanding of the entire production chain. Furthermore, recent research has developed innovations that promise greater efficiency and reduced environmental impact. An example is a new product developed by scientists at the Brazilian Agricultural Research Corporation (Embrapa) and the University of Campinas (Unicamp), aimed at reducing the environmental impacts caused by traditional pest control methods. It was formulated with nanocapsules that release the

active ingredient in a controlled manner, increasing efficacy and reducing the need for frequent reapplication, while also being biodegradable (Embrapa, 2024).

The creation of Embrapa in 1973 was a milestone, promoting research to adapt cultivars to Brazil's soil and climate. The innovation promises to be an efficient and environmentally friendly alternative for agriculture. In the current era, sustainability must be a priority, and digital transformation, which combines disruptive technologies with biotechnological advancements to create agricultural solutions, proposes a new paradigm. This paradigm involves studying complex systems, considering social, biological, environmental, and economic aspects, along with the development of new technologies.

FINAL CONSIDERATIONS

The development of the means of production, productive forces, and their global diffusion have provided humans with unprecedented opportunities for greater security and material satisfaction compared to any pre-modern system. However, modernity also has a deleterious side, which became increasingly evident in the 20th century (Giddens, 1991).

It is important to recognize that the destructive side of modernity (or perhaps of capitalist modernity) is not inevitable. Through critical reflection, political action, and a commitment to social and environmental justice, a fairer, more sustainable, and humane future can be built. Late modernity has also brought previously unimaginable dangers, the result of human action itself (Beck, 2011). In the same way, the rampant use of pesticides in agriculture has brought many challenges, including the need to think about sustainable rural development in the midst of the poisoning of farmers and the environment.

It is necessary to question the current development model, which puts life on the planet and human existence itself at risk. It is urgent to seek alternatives that reconcile material progress with environmental and social sustainability, building a fairer and safer future for the next generations.

It is crucial to recognize the intersection between the risk society and Environmental Racism. Marginalized communities, especially ethnic minorities and low-income groups, are disproportionately exposed to pesticide risks due to their proximity to agricultural areas and their lack of access to information and public protection policies. This disparity exposes a harsh reality: in the risk society, vulnerability is not distributed equally.

Furthermore, it is important to highlight the need to bring this debate to public security, as this field plays a crucial role in promoting more sustainable societies with reduced individual and collective risks.

Ulrich Beck's theory of the risk society offers a powerful lens for analyzing the issue of pesticides and their socio-environmental impacts. By recognizing the systemic dangers generated by this practice and the inequalities in exposure to risks, it is possible to chart a path towards a fairer and more sustainable future. Building a pesticide-free society requires a collective commitment to protecting human health, the environment, and future generations.

The history of agriculture is highlighted as one of humanity's great achievements, evolving from rudimentary farming in the early 20th century, based on manual labor and animal traction, to advanced systems with the Industrial Revolution and the application of scientific methods and technologies. These advances in the means and tools of production also serve to highlight the existence of alternatives for promoting more sustainable agriculture, less dependent on pesticides, and building a sustainable future for agriculture. This requires the active participation of all sectors of society, from governments and companies to communities and individuals. It is necessary to seek significant convergence, a paradigm shift, in the dissemination of information, culture, public policies, and especially legislation, based on principles such as agroecology, family farming, and organic production.

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