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The impacts of rice farming on multidimensional development in the municipality of Massaranduba (SC)

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Abstract
The general objective of the research is to analyze the impacts on the multidimensional development of the municipality of Massaranduba (SC) and its socioecological resilience from the management of the contamination of water resources due to the increasing use of pesticides in the production of irrigated rice. The methodology involves the collection of primary and secondary data and qualitative analysis to understand the relationship between man, nature and technology in rice farming and its impact on local development. The predicted results show that the region does not have efficient management of water resources, at least one that observes sustainability factors and resilience of water resources to the increasing use of pesticides. This directly interferes with the quality of life of the local population, as they are subject to various problems related to the contamination of water resources. This situation allows us to draw some predictions that a new development regime will be installed in the municipality, brought about by another scenario of transformation of the Socioecological System (SSE). The research aims to provide subsidies for the management of public policies in the promotion of sustainability and resilience of water resources.
Keywords: Regional Development. Ecodevelopment. Pesticides. Socioecological Resilience. Environmental Legislation.

Os impactos da rizicultura no desenvolvimento multidimensional no município de Massaranduba (SC)

Resumo
O objetivo geral da pesquisa é analisar os impactos ao desenvolvimento multidimensional do município de Massaranduba (SC) e sua resiliência socioecológica a partir da gestão da contaminação dos recursos hídricos devido a crescente utilização dos agrotóxicos na produção de arroz irrigado. A metodologia envolve a coleta de dados primários e secundários e a análise qualitativa para entender a relação entre o homem, a natureza e a tecnologia na

rizicultura e seu impacto no desenvolvimento local. Os resultados revelam que na região não existe uma gestão eficiente dos recursos hídricos, pelo menos uma que observe fatores de sustentabilidade e resiliência dos recursos hídricos ao uso crescente dos agrotóxicos. Isso interfere diretamente na qualidade de vida da população local, pois esta está submetida aos diversos problemas relacionados à contaminação das águas. Essa situação permite traçar alguns prognósticos de que um novo regime de desenvolvimento se instale no município, trazido por um outro cenário de transformação do Sistema Socioecológico (SSE). A pesquisa visa fornecer subsídios para a gestão de políticas públicas na promoção da sustentabilidade e da resiliência dos recursos hídricos.
Palavras–chave: Desenvolvimento Regional. Ecodesenvolvimento. Agrotóxicos. Resiliência Socioecológica. Legislação Ambiental.

Los Impactos de la Rizicultura en el Desarrollo Multidimensional en el Municipio de Massaranduba (SC)

Resumen
El objetivo general de la investigación es analizar los impactos en el desarrollo multidimensional del municipio de Massaranduba (SC) y su resiliencia socioecológica a partir de la gestión de la contaminación de los recursos hídricos debido al creciente uso de pesticidas en la producción de arroz irrigado. La metodología implica la recopilación de datos primarios y secundarios y el análisis cualitativo y cuantitativo para comprender la relación entre el hombre, la naturaleza y la tecnología en el cultivo del arroz y su impacto en el desarrollo local. Los resultados pronosticados muestran que la región no cuenta con una gestión eficiente de los recursos hídricos, al menos una que observe factores de sostenibilidad y resiliencia de los recursos hídricos ante el creciente uso de plaguicidas. Esto interfiere directamente en la calidad de vida de la población local, ya que están sujetos a diversos problemas relacionados con la contaminación de los recursos hídricos. Esta situación permite trazar algunos pronósticos de que se instalará un nuevo régimen de desarrollo en el municipio, propiciado por otro escenario de transformación del Sistema Socioecológico (SSE). La investigación tiene como objetivo brindar subsidios para la gestión de políticas públicas en la promoción de la sostenibilidad y resiliencia de los recursos hídricos.
Palabras clave: Desarrollo Regional. Ecodesarrollo. Agrotóxicos. Resiliencia Socioecológica. Legislación Ambiental.

1 Introduction

In the last decade, Brazil, in a deliberate manner, has considerably expanded the pesticide market, resulting in the country remaining as the world leader in consumption of these products since 2008 (INCA, 2022). According to the Pesticides Atlas (Heinrich Böll Foundation, 2021) in 2020, 770,393 tons of pesticides were consumed in the country, 119.4% more than in 1999. The atlas also demonstrates [...] 49% of pesticides sold in Brazil are extremely dangerous" for both human health and ecosystems. According to the Agricultural Census of the Brazilian Institute of Geography and Statistics (IBGE, 2017) between 2007 and 2017, around 40 thousand cases of acute poisoning caused by pesticides, culminating in around 1,900 direct deaths.

Among the Brazilian regions that most used pesticides in their agricultural production, the South region stands out, which is responsible for approximately 30% of national consumption (Cremonese, Freire; Meyer, 2012). In the South region, the state of Santa Catarina is among the ten largest consumers of pesticides in the country. Furthermore, the state increased consumption by 107% in the period

between 2009 and 2017 (IBGE, 2017). Among the agricultural activities that use the most pesticides in Santa Catarina, irrigated rice stands out. Rice contributed approximately 9% of the state's total agricultural production and around 70% of management is through irrigation (IBGE, 2017). In irrigated rice cultivation, a large application of pesticides and, mainly, herbicides were identified. Most pesticide residues, due to the irrigation process, go directly into water courses and rivers, worsening pollution upstream.

A significant part of the productive establishments in Santa Catarina that adopt irrigated rice cultivation are concentrated in the municipality of Massaranduba. There are 357 establishments in this region, making it the second largest concentration in the state. This concentration translates into an annual production of 41,916 tons of paddy rice, positioning Massaranduba as the seventh largest rice producer in Santa Catarina and the main producer in the Itapocu Basin, where it is located (IBGE, 2017). According to data from Epagri (2015), analyzes of water samples from the Itapocu River revealed a high concentration of toxic products residues, such as herbicides. Furthermore, there are flaws in the crop management system caused by farmers' lack of information regarding the use of pesticides.

In Massaranduba (SC) the situation regarding irrigated rice cultivation reflects in a similar way to the national and state reality. The presence of contaminants in irrigation water represents a significant concern, potentially compromising both the quality of agricultural products, human health, and the system's ability to resist and regenerate, affecting its balance. Given this scenario, it is imperative to address the challenges associated with this agricultural practice in a comprehensive and integrated manner. In this context, the intensification of the use of pesticides in irrigated rice cultivation in Massaranduba (SC) may be impacting regional socio-ecological resilience in a complex way. Increased application of agrochemicals, although it may result in temporary gains in agricultural productivity, raises concerns about long-term effects on human health, biodiversity, and the quality of water resources.

In this context, the general objective of the research is to analyze the impacts on the multidimensional development of the municipality of Massaranduba (SC) and its socio-ecological resilience based on the management of contamination of water resources due to the increasing use of pesticides in the production of irrigated rice. The methodology involves collecting primary and secondary data with qualitative analysis. In addition to this introduction, the structure of this article pursues a theoretical foundation, characterization of the study scope, methodology, results and discussion and conclusions. The justification lies in promoting the perception of public authorities and the community so that they can organize themselves in proposals for future interventions, covering aspects of development and socio-ecological resilience. In other words, it is proposed to bring the academic theoretical debate closer to public managers, in order to they glimpse the need to think about socio-ecological resilience actions to the problem of the increasing use of pesticides.

2 Theoretical foundations

The inadequate management of water resources in Brazil represents a significant challenge and this is reflected in the poor distribution of water, scarcity, floods and disasters, pollution, and contamination of waterways, etc. The agricultural sector, fundamental to the Brazilian economy, often uses agrochemicals to increase productivity, resulting in the contamination of water resources. The indiscriminate use of pesticides contributes to water pollution, damaging not only the quality of the resource, but also human health and the balance of ecosystems.

The term "pesticides" was made official in Brazil through Federal Law No. 7,802, of 1989, later regulated by Decree No. 4,074, of 2002, which defines pesticides as compounds of chemical substances intended for the control, destruction, or prevention, directly or indirectly, of pathogens to plants, useful animals, and humans. The legislation allows states and municipalities to create their own regulations related to pesticides in their territories, and may, in some cases, establish stricter warnings than federal laws (Rigotto; Vasconscelos; Rocha, 2014).

In the state of Santa Catarina (SC), Law No. 11,069, enacted in 1998, addresses the control of production, trade, use, consumption, transportation and storage of pesticides and their components. Although it is based on the federal law on pesticides nº 7,802/89, state legislation highlights specific prohibitions, such as the import or commercialization of pesticides and biocides whose country of origin does not meet the established criteria, considering the producer or registration holder.

Later decrees, such as nº 3,657 of 2005 (ESTADO DE SANTA CATARINA, 2005), complemented the legislation, establishing specific conditions for carrying out activities related to pesticides. In this context, prior obtaining environmental licensing from Environment Foundation (FATMA) and registration with the competent body have become mandatory requirements, aiming to regulate and control practices associated with pesticides in the state.

Decree No. 1,331 of 2017 addresses the review of the register of pesticides, their components and related products intended for agriculture, with special attention to identifying signs that advise against their use in the territory of Santa Catarina. The reassessment is triggered both by the detection of potential risks and by alerts coming from national and international organizations dedicated to health, food, or the environment. However, the indiscriminate use of highly toxic agents, such as fungicides and herbicides, persists, raising concerns regarding environmental impacts and public health.

Irrigated rice cultivation stands out as one of the most impactful agricultural practices in the pollution of water resources in Brazil. In the irrigated rice system, crops are submerged to control weeds and to create the anaerobic conditions essential for rice development. Pesticides, such as herbicides, applied in this context, have the potential to be carried away by irrigation water, being carried to adjacent bodies of water, such as rivers and streams. In Brazil there are 1,716,600 hectares of irrigated rice, with the State of Santa Catarina occupying around 126,411 hectares, third place in the national ranking (IBGE, 2017). Rice is cultivated in environments with variable temperatures and different textures, drainage, and soil topography, which can be dry or flooded, as well as water regimes. The main negative environmental impacts arising from rice farming activities can be highlighted (Freitas et al., 2014): Reduction of natural ecosystems due to the opening of new areas; Decrease in the

productive capacity of the soil, as a result of inappropriate cultural practices; Lowering of atmospheric conditions due to the emission of methane gas (greenhouse gas); Reduction in the quantity and quality of water due to processes such as siltation, eutrophication and the use of pesticides.

"Development" is often intrinsically linked to agricultural expansion, but the sustainability of this development requires a balanced approach that considers the impacts of pesticides on soil quality, water, and biodiversity, in addition to the risks to human health. Thus, the search for more sustainable agricultural solutions began in the mid-1960s, with the outbreak of problems related to current development models.

Maurice Strong and Ignacy Sachs coined the term Ecodevelopment in 1973, aiming for solutions for development in each ecoregion (Sachs, 1993). Ecodevelopment emerges as one of the main concepts in opposition to economic rationalization. Ecodevelopment designates: A new style of development and a new (participatory) approach to planning and management, guided by an interdependent set of ethical postulates (Sachs, 2009, p. 12). Ecodevelopment demonstrates a concern with economic aspects, however, not dissociated from social, environmental, and cultural problems. Based on this configuration, the five dimensions of eco-development are created: i) Social dimension – seeks to reduce inequalities and substantially improve the rights and conditions of the mass of the population; ii) economic – aims to increase production and social wealth, without external dependence; iii) ecological – advocates improving the quality of the environment and preserving sources of energy and natural resources for future generations; iv) spatial – aimed at a more balanced configuration and better territorial distribution of human settlements and economic activities and; v) cultural – seeks to avoid cultural conflicts with regressive potential (Sachs, 1993).

In the famous "Bruntdland Report" in 1987, sustainable development was defined as [...] "development that responds to the needs of the present without compromising the possibilities of future generations to satisfy their own needs" (BRUNDTLAND REPORT; 1988; Raynaut; Zanoni, 1993, p.8). Sustainable development is a consequence of social, economic development and environmental preservation. Therefore, sustainable development aims at elements such as socio-environmental justice, social inclusion, and eco-efficiency (Nóbrega; Musse, 2019).

Through the 2030 Agenda, understood as an action plan that proposes global strategies for sustainable development, in 2016 the UN launched 17 Sustainable Development Goals (SDGs), which cover the social, environmental, and economic dimensions in an integrated and indivisible way throughout of all its 169 goals (UN, n.d.). In this article, SDG 6 stands out, which aims to governance water resources, clean water, and basic sanitation – Ensure availability and sustainable management of water and sanitation for all. Sustainable Development Goal 11 (SDG 11), of the UN 2030 Agenda, seeks to make cities inclusive, safe, resilient, and sustainable. In this context, the concept of resilience emerges.

The concept of resilience is the ability to easily recover from or adapt to bad luck or change. The term studied in this article concerns socio-ecological resilience, which became known in the 1970s, thanks to the work of Canadian ecologist C.S. Holling, with the publication of the article Resilience and Stability of Ecological Systems (1973). Holling's (1973) great contribution was to show that the idea of balance in ecological systems is valid only on limited scales of time and space and to

draw attention to non-linear changes that also occur in socio-ecological systems (Buschbacher, 2014).

The emergence of environmental issues in current decades and the recent debate about the Environmental Code in Santa Catarina and the Forest Code that involved farmers, unions, public authorities, and environmental movements have brought about the need to rethink the roles of different actors in the relationship between technology, society, and nature. As production growth is seen, it is also possible to observe the need for a sustainable alternative in rice farming in Santa Catarina, resulting in a balance of environmental and economic gains. In this context, there are new irrigation techniques that may be more sustainable and resilient than those currently practiced:

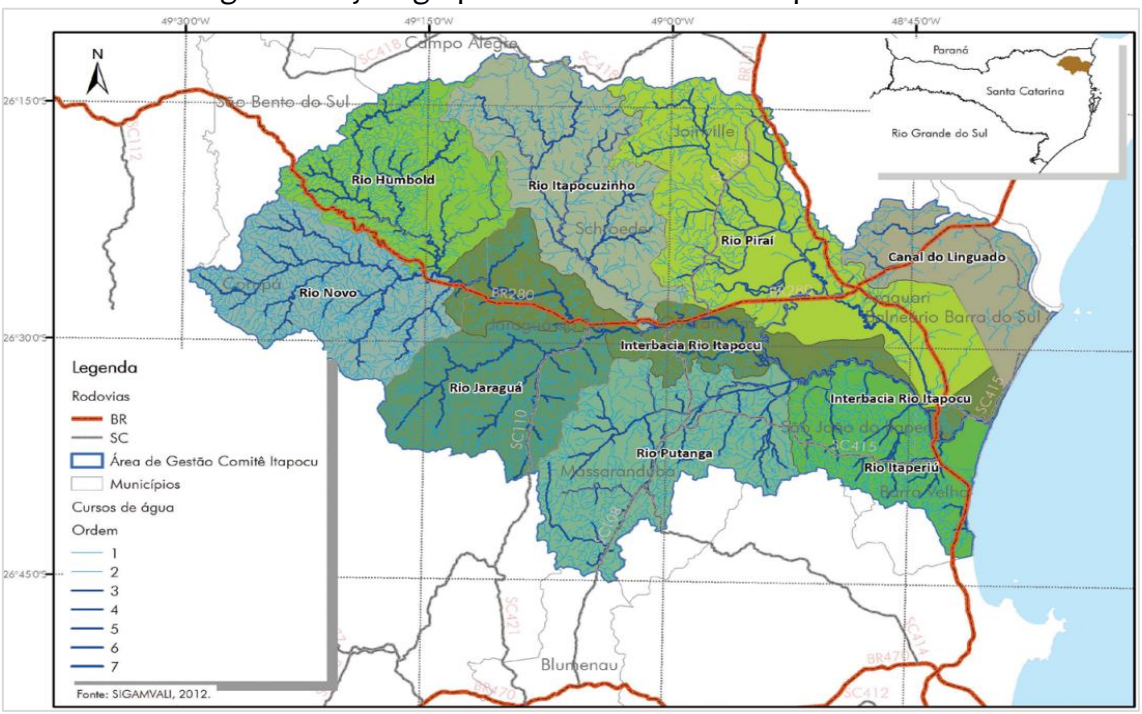
The drip system is an irrigation method in which water circulates through polyethylene tubes under pressure so that the drops fall precisely towards the roots of the plants, causing the percentage of water use to be around 95%. The micro sprinkler system is used for sustainable irrigation of plantations in which small mechanisms called micro sprinklers squirt water in nearby and specific areas. The fertigation system generally accompanies drip irrigation, as it combines both methods when fertilizing plants. This system uses the addition of nutrients, such as salts or mineral fertilizers, so that the soil and plants absorb water more efficiently.

In this sense, it is important to understand farmers' perception of technological innovations in agriculture that have been increasingly important for increasing productivity and efficiency in the agricultural sector (GARAY, 2021). The potential benefits for farmers in using technologies that aim for sustainable production go beyond better quality of water available to communities. The main gains for producers and the community are local economic development, job creation, biodiversity protection and socio-ecological resilience.

3 Socioeconomic aspects and environmental space of Massaranduba

The Itapocu River Basin has its sources in the Serra do Mar and drains its waters into the Atlantic Ocean. The basin's total area of contribution is 2,920 km², but it has coastal basins that are contiguous (STEINBACH; TOMASELLI; REFOSCO, 2015). The population of the basin is 311,716 inhabitants, which corresponds to approximately 6% of the population of the State of Santa Catarina concentrated in 3.3% of its area (IBGE, 2022). The Itapocu drainage area encompasses the entire municipalities of Corupá, Jaraguá do Sul, Schroeder, Guaramirim and Massaranduba; and part of the municipalities of Barra Velha, São João do Itaperiú, São Bento do Sul, Campo Alegre, Blumenau, Araquari and Joinville. Regarding to the management of water resources in the Itapocu Basin, in 2001 the "Itapocu River Hydrographic Basin Management Committee" was launched, covering 9 municipalities including Massaranduba. Figure 1 - Hydrographic sub-basins of the Itapocu River

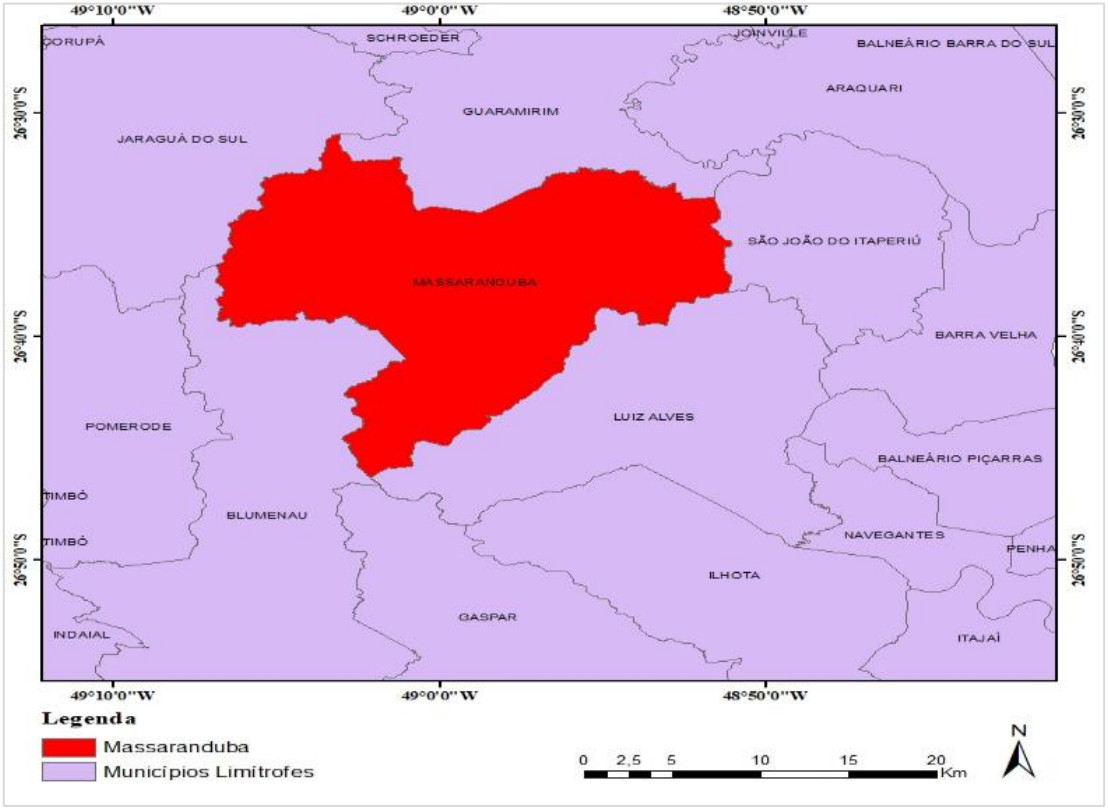
Figure 1 – Hydrographic sub-basins of the Itapocu River



Source: SIGMAVALI, 2012

The Itapocu River basin comprises eight hydrographic sub-basins, formed by the main tributaries of the Itapocu River (Figure 1): basins of Rio Novo, Rio Vermelho, Rio Itapocuzinho, Rio Piraí, Rio Jaraguá, Rio Putanga (where Massaranduba is located), Coastal Basin and Middle Itapocu Basin. In this article, the Putanga River Sub-basin stands out, which has an area of 410.93 km² that includes parts of the areas of the municipalities of Blumenau, Luiz Alves, Guaramirim and São João do Itaperiú and the study section, Massaranduba.

Figure 2 - Geolocation position of Massaranduba (SC)



Source: Produced by the Authors.

The municipality of Massaranduba is in the Putanga River Sub-basin (Figure 1), bordering the West with Blumenau and Jaraguá do Sul. On the North border of Massaranduba is Guaramirim, to the East it borders the municipality of São João do Itaperiú and to the south is the municipality of Luiz Alves (Figure 2). According to the latest Demographic Census, the municipality of Massaranduba has 17,162 inhabitants in a territorial area of 374,459 km², with a demographic density of 45.83 inhabitants/km² (IBGE, 2022). It is part of AMVALI – Association of Municipalities of Vale do Itapocu in partnership with six other municipalities in the region. Regarding to the economy, the population has an average monthly salary of 2.3 minimum wages (IBGE, 2021). The Gross Domestic Product per capita is R$ 37,956.66 (IBGE, 2020), and of the total GDP, the services sector contributed 32%, industry 30% and agricultural activities 38% (IBGE, 2020). Currently, the main agricultural activity in Massaranduba is irrigated rice, representing around 20% of the area dedicated to agriculture in the municipality (Mapbiomas, 2022) (Table 1).

Table 1 - Land cover in Massaranduba (Hectares)

Class	2000	2010	2022
Forests	21.402 ha	20.606 ha	19.417 ha
Agriculture	15.790 ha	16.411 ha	17.383 ha
Urban area	198 ha	340 ha	491 ha
Irrigated rice	4.861 ha	3.715 ha	3.772 ha

Source: Mapbiomas (2022).

Historically, rice cultivation in Massaranduba corresponds to the colonization of the municipality in the early 1870s, when it was recently separated from Blumenau, until the 1920s. The first settlers were of German and Italian origin who were looking for a manual activity to start in the municipality's virgin lands. The settlers established their homes on fertile land, using it as a subsistence product. The alternative found was to start cultivation in steeper areas with upland rice and other food sources, such as bananas, initially planted for personal consumption. In 1920, when the areas were already pre-defined, farmers began a practice that would predominate in the flat part, the planting of irrigated rice. Until the 1950s, all rice harvesting was carried out manually (Ranguetti, 1992).

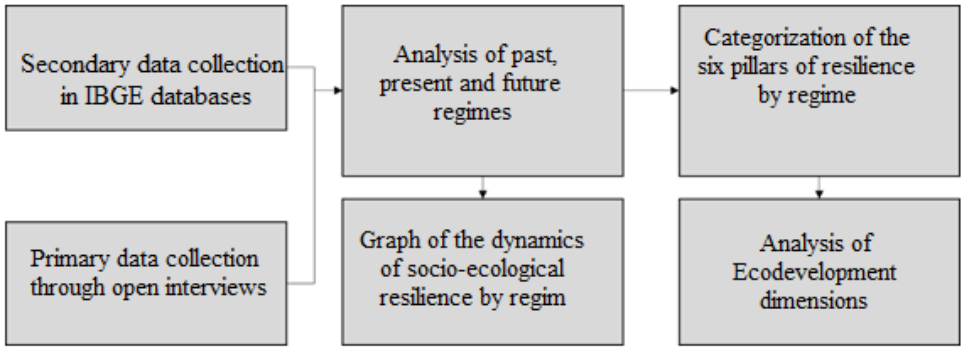
Over the years, several techniques were implemented that helped rice production, in addition to the use of instruments made manually with stone, iron and other raw materials. The creation of Cooperativa Juriti in 1969 in Massaranduba significantly changed the lives of farmers in the region. The cooperative represents a milestone in rice production, as it provides full assistance to producers, whether small, medium, or large, and monitors proposed agreements. When the cooperative emerged, little was known about what a cooperative represented, formed by a group of settlers from the municipality who were looking for significant changes to improve life in the countryside, especially for rice farmers.

Despite this productive scenario in the municipality of Massaranduba, an intervening factor that represents a complication for the development process is the contamination of water resources by pesticides. The municipality still lacks more precise data on the use of pesticides in irrigated rice cultivation, however, in conversations with the local population and researchers from the Regional University of Blumenau - FURB who are analyzing the case of the Putanga river, it is preliminarily recorded that the Waste from agrochemicals such as herbicides and fungicides in the Putanga River is high.

4 Methodology

The methodological approach adopted in this study is qualitative, seeking to identify the state of resilience and development in Massaranduba. The methodology is outlined in three sequential steps (Figure 3): i) Data Collection: Initially, a comprehensive data collection was conducted, covering both secondary sources and primary data. The bibliographic and documentary review was used to support the understanding of the historical and current context of Massaranduba; ii) Establishment of the Dynamics and Six Pillars of Resilience: Next, the research focused on identifying the development dynamics of the municipality, considering the past and present regimes and a prospect for the future. The analysis was based on the six fundamental pillars of socio-ecological resilience, exploring diversity, redundancy, capital reserve, stakeholders, institutions, decentralization, and polycentric governance and iii) Analysis of the Dimensions of Ecodevelopment: The last stage focuses on the analysis of the dimensions of ecodevelopment. This multidimensional approach seeks to understand and integrate social, economic, ecological, spatial and cultural aspects. The objective is to develop guidelines that promote sustainable and balanced development in Massaranduba.

Figure 3 – Analysis Model

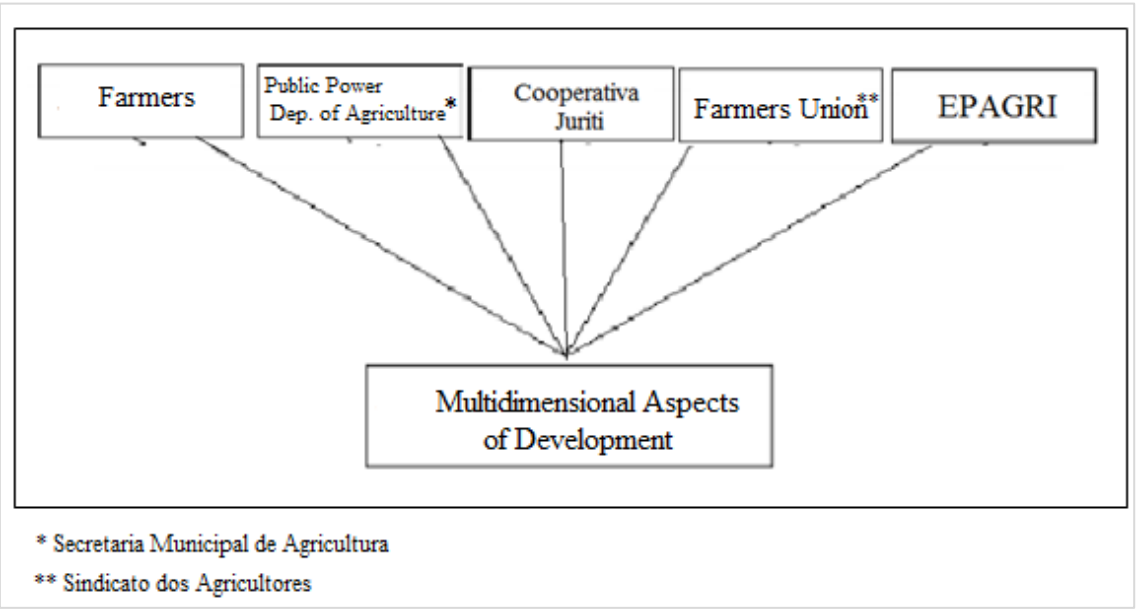


Source: Produced by the Authors.

First Stage: Collection of secondary data through bibliographic and documentary review of the spatial, environmental, and socioeconomic aspects of the territory, aiming to highlight the current stage of development that has formed and is in force in the territory of Massaranduba. Regarding spatial and environmental aspects, the historical and geographic contextualization of its location, relief, climate, vegetation, and geomorphology will be presented. These factors helped to understand how geographic space enables anthropogenic relationships linked to territory. In turn, the socioeconomic data verified are demographic aspects (population and demographic density); economic/productive (productive activities and GDP) and human development (education, health and income). These socioeconomic factors in line with spatial and environmental factors allow us to outline the current development profile of the municipality.

Subsequently, primary data collection was carried out, using semi-structured exploratory interviews (interviewee speaks freely about questions regarding a given topic) with different key actors (triangulation of key informants) involved in the agricultural segment of Massaranduba (SC) (farmers, municipal agriculture department, representative of the Farmers Union, Epagri and Cooperativa Juriti) (Figure 4). This survey aims to collect as much information as possible to understand the current stage of development of the Municipality in relation to its rice production.

Figure 4 – Key Informant Triangulation



Source: Adapted from Mc-Arthur, 1994 apud (SEIXAS, 2005).

Stage 2: In order to analyze the incidence of pesticide use (intervening variable) in Massaranduba, the theoretical and methodological approach of Environmental History was used, dividing the past development regime. The analysis model shows the process of transformation of three development regimes (past, present, and future) (Chart 1) triggering socio-ecological resilience according to the incidence of the intervening variable, use of pesticides.

Chart 1 – regimes as an analysis framework

Regime	Description
Past	The past regime covers the period between 1870 and 1950
Present	The present regime covers the period between the 1950s and the present day.
Future	The future regime comprises a future prospection of resilience

Source: Produced by the Authors.

Therefore, it was possible to develop graphics in relation to the dynamics of development and socio-ecological resilience in Massaranduba. The graphs were constructed in a Cartesian representation in which the vertical axis represents development (multidimensional aspect, growing from the vertex to the end, and the horizontal axis represents the passage of time in an increasing chronological progression from the vertex to the end. The red arrow pointing to above represents the increase in the intervening variable (use of pesticides) and its impact on the resilience capacity of the regimes and consequently on their development. Furthermore, it was possible to establish the situation of Massaranduba through the six fundamental pillars, or principles of resilience Walker et al. (2006) and Biggs, Schluter, Schoon, (2014) (Chart 2).

Chart 2 – pillars of resilience

Pillars	Description
1 - Systems with diversity and redundancy	have greater resilience than systems that maximize the productivity of just one benefit;
2 – Capital reserve	Resource reserves and accumulation of capital - financial, natural, human, social and manufactured - allow the system to recover after small disturbances;
3 - Stakeholders	social capital, leadership and trust contribute to resilience;
4 - Institutions	Institutions have a fundamental role in resilience;
5 - Decentralization	systems with a modular structure (for example, decentralized networks) have greater resilience than centralized systems;
6 – Polycentric governance	for polycentric governance systems is consistent with the previous two points.

Source: Buscbascher, 2014.

Stage 3: analysis of the data collected in the previous stages from the perspective of regional development theory, specifically on Ecodevelopment and its multidimensional approach. From this configuration, it aims at the five dimensions of ecodevelopment: i) Social dimension; ii) economic; iii) ecological; iv) spatial and; v) cultural (Sachs, 1993).

5 Results

The results, as discussed in the methodology, will be presented following the division into past, present, and future regimes.

5.1 Past Regime

According to the pillars of resilience, one can observe the maxim that the **first pillar (Systems with diversity and redundancy):** Although rice production was the main activity in Massaranduba during this period, family polyculture was always present in the territory, being necessary to meet the needs of the families who lived there. Soil exhaustion was postponed, not only due to lower productivity (compared to today), but also due to crop rotation, which was a common practice at that time for farmers.

The **second pillar (Capital Reserve):** when resources (financial, natural, human, social and manufactured) are accumulated, it provides a "reserve" so that the SSE can rebuild itself even in the face of disturbances. An example of this overcoming occurs in the continuity of rice farming, even after events such as flooding, drought and frost that compromised entire harvests. However, the accumulated capital meant that new harvests could guarantee the continuity of this culture over time. In other words, the accumulation of these resources allowed the system to rebuild itself after small disturbances over the years.

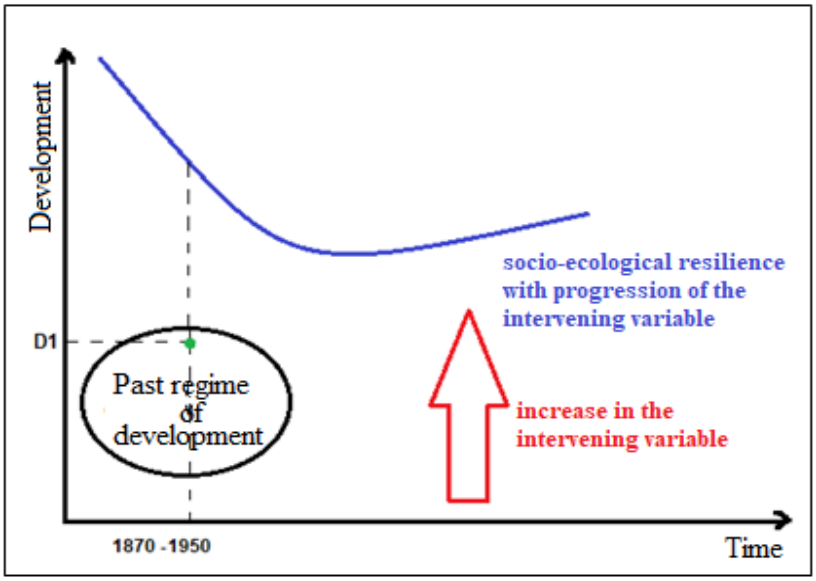
The **third pillar (Stakeholders):** As in this period (1870 to 1950) the changes in the SSE were minimal (here we are dealing with the transformation of cultivation techniques and the use of technologies that significantly impacted the SSE), the management of slow variables, i.e., of natural and behavioral resources occurred smoothly, practically preserving, and maintaining existing ecosystem services. This was a factor that meant that socio-ecological resilience could be configured with few changes until the green revolution.

The **fourth pillar (Institutions):** it can be understood that in the past development regime this pillar was little explored due to the separate and less institutionalized actions in the SSE. However, this principle did not compromise socio-ecological resilience, as the way of life and techniques used in rice production were still within acceptable limits in carrying capacity in the socio-ecological cycle. This principle developed and took greater shape from 1950 onwards, and with the advent of the institutionalization of relations in the SSE.

The **fifth pillar (Decentralization):** This situation can be seen during the past regime, in which the production process was more decentralized and actions on a given property did not directly reflect on another. Over time, the modular structure weakened and gave way to increasingly stronger connections that, on the one hand, could bring benefits to the entire SSE, or, equally, damage of gigantic proportions, such as, for example, the proliferation of pests.

The **sixth pillar (Polycentric Governance):** At this moment, despite there being a direction towards the institutionalization of power representations in the SSE, it cannot yet be said that there is a strong incidence of this pillar. What we have is a rapprochement between farmers in the search for solutions that strengthen production and the maturation of the public sector in the territory.

Figure 5 – Past Regime of Development



Source: Produced by the Authors.

According to (Figure 5), it is important to realize that although development in the past regime is lower in the graph, due to the analysis carried out previously, socio-ecological resilience at this moment is high, mainly due to the maintenance of

SSE due to the absence of polluting techniques such as the exacerbated use of pesticides.

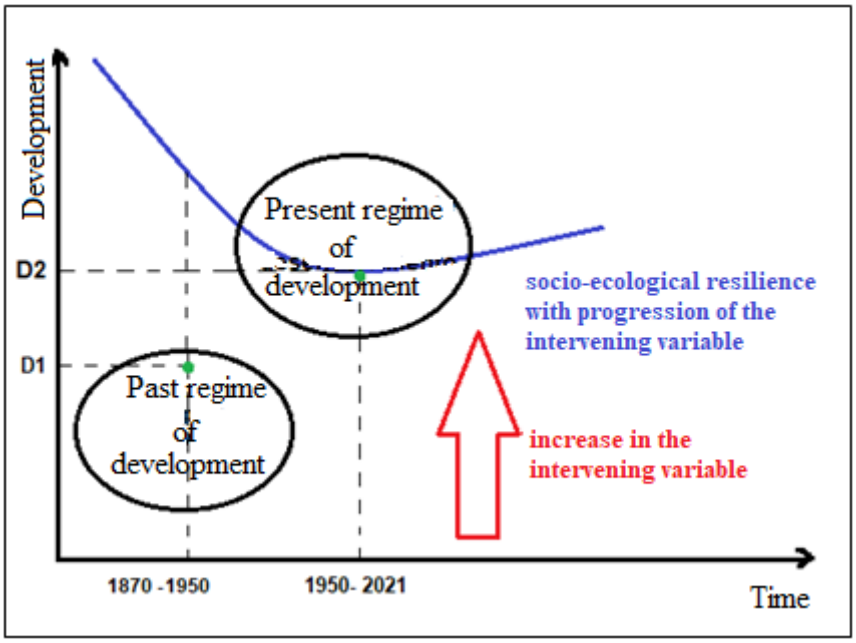
Furthermore, the line that corresponds to resilience in the SSE with the progression of the use of pesticides, in the past development regime, it is much higher. This is due to the production quantity and exploitation factors and the level of pesticides being still low. Over time, we have a new configuration of development aspects based on a new amount of production and use of pesticides.

After verifying how the past development regime occurred in Massaranduba, through the perspective of environmental history, we begin to investigate the construction of the model of the present development regime according to the same sustainability dimensions of eco-development and socio-ecological resilience. To this end, we continue to investigate the development aspects arising from the perceptions of key informants and secondary sources from institutions that provide data that support this study.

5.2 Present Regime

After verifying how the past development regime occurred in Massaranduba, through the perspective of environmental history, as shown in (Figure 6), we begin to investigate the construction of the model of the present development regime according to the same sustainability dimensions of eco-development and of socio-ecological resilience.

Figure 6 - Passage from the Past Regime to the Present Regime of Development



Source: Produced by the Authors.

Furthermore, the line that corresponds to resilience in the SSE with the progression of the use of pesticides, in the current development regime, it remains constant and tends to fall progressively, gradually, and not abruptly, as it takes a time for the release phase to be completed and the reorganization phase of the future regime to arrive. This occurs due to the production quantity and exploitation factors

and the level of pesticides increasing progressively. Over time, there is a new configuration of development aspects based on a new amount of production and use of pesticides. It can also be observed that during the future development regime the resilience line will tend to a new constant situation.

As in the transformation from the past regime to the present regime of development, there will be significant changes in technologies that, simultaneously, boosted rice farming and worsened SSE, mainly in the spatial and environmental components.

According to the **first pillar (Systems with diversity and redundancy):** Despite the latent diversification of production, mainly with the processing industry, agricultural activity will continue to be the focus of production in the municipality, with rice production expected to continue to be essential for the economic sector of Massaranduba. This diversification, which can be a positive principle of resilience, requires, however, a greater occupation of the space and natural resources of the SSE, reducing its carrying capacity and exposing the population to greater levels of pollution. Furthermore, other activities that make up the entire production chain, including commerce and urban densification, tend to have a positive impact (income generation, employment, and access to infrastructure benefits) and negatively (pollution, increased cost of living, shortage of services public) in the resilience of SSE. Soil exhaustion will become a factor that will limit resilience, requiring an intervention plan from public authorities to mitigate such effects.

The **second pillar (Capital reserve):** As in the current regime, technology and cooperativism have the capacity to ensure that resources can be accumulated for times of scarcity or crises in the productive sector. New technologies, grain selection and technical support from technical institutions tend to continue to guarantee productivity in the SSE. The institutional security brought by the cooperative will be a great help in maintaining resilience. However, the increasing use of pesticides and the artificial process of grain selection and pest control will further inhibit the naturalness of SSE, making it fragile due to the exclusion of natural organisms necessary for SSE.

The **third pillar (Stakeholders):** The interference caused by the increasing use of pesticides tends to manifest itself in the near future, as the current regime already has an accumulative burden on the SSE. The saturation of these components in the soil, groundwater and deposition in different socio-ecological destinations will have a negative influence on environmental and human health in the SSE. Transformations in the local landscape will reflect changes in SSE in a constant and progressive manner, without abrupt changes. Many of the ecosystem services will be transformed, reduced, or even cease to exist because there will not be the same SSE configuration as in the current development regime. Water shortages must be one of the services that will bring the greatest challenges to regional development managers.

The **fourth pillar (Institutions):** The legislation pertinent to the use of pesticides must be observed by local managers. These will need to strengthen control, inspection, and technical support institutions to shape farmers' thinking and action towards a strategy of adjustments in local production and recovery of SSE. The Juriti cooperative will continue to have great influence in directing local production management, establishing guarantees, benefits and restrictions for the actors' cooperation and decision-making process. This principle must be the one that will

best be coordinated in the SSE, due to the need for answers to the problems that will arise.

The **fifth pillar (Decentralization):** the process of centralizing structures in the SSE replaced the modular and decentralized structures that existed in the past regime. This situation should be even more evident due to the process of interconnection and interdependence of the SSE with the outside world. The cooperation process converged with actions between properties and the logistics and production chain is increasingly strengthened. In other words, actions on a given property, with increased interdependence between actors, can yield good results for everyone or a generalized crisis for everyone (in the event of an undesirable situation, such as a drought, devaluation of production, etc.).

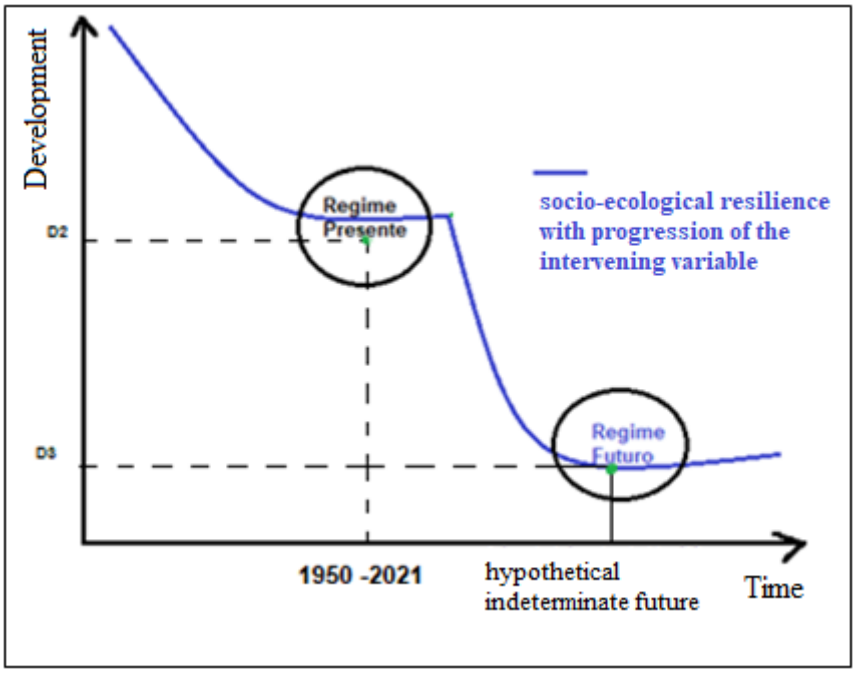
Finally, **the sixth pillar (Polycentric Governance):** As in the past regime, the maturity of organizations that encompass different types of leadership and knowledge within the SSE must continue to grow. However, the exclusive role of the cooperative and public authorities is not sufficient in the process of empowering farmers and other members of the community. Representatives from all sectors must be able to assume responsibilities and participate in the decision-making process within the SSE. The fragmentation in the perception of environmental and health problems caused by the current production system in the SSE continues to be an obstacle to the complete strengthening of this principle.

Therefore, it can be understood that the principles of resilience, no matter how mature they have been, will encounter other challenges due to a new configuration in the SSE. Some principles linked to the maturation of actions within the SSE are very important for thinking about an alternative for a better future regime that has greater development and resilience. This model will be presented below with proposals for an agenda that aims to strengthen the components of development and modify the resilience curve in the face of the incidence of the intervening variable, exhaustive use of pesticides.

5.3 Future Regime

As in the previous one, this section aims to prospect a future scenario for Massaranduba. In this way, the perspective remains that the municipality is an SSE that must be analyzed from the perspective of the dimensions of eco-development and the principles of resilience. After verifying, through the perspective of environmental history, the past and present development regimes with a focus on socio-ecological resilience, (Figure 7) we move on to the last stage of this thesis, that of projections of future scenarios and propositions of guidelines to achieve an alternative response from a desired development regime.

Figure 7 – Prospecting the transition from present to future development regimes following the socio-ecological resilience curve



Source: Produced by the Authors.

Therefore, in relation to the pillars of resilience in the face of the proposed interventions, some results can be expected. The **first pillar (Systems with diversity and redundancy):** one can have the following prospection. Despite the latent diversification of production, mainly with the processing industry, agricultural activity will continue to be the focus of production in the municipality, with rice production expected to remain the main economic activity in Massaranduba. This diversification, which can be a positive principle of resilience, requires, however, a greater occupation of the space and natural resources of the SSE, reducing its carrying capacity and exposing the population to greater levels of pollution.

The **second pillar (Capital reserve):** As in the current regime, technology and cooperativism have the capacity to ensure that resources can be accumulated for times of scarcity or crises in the productive sector. New technologies, grain selection and technical support from technical institutions tend to continue to guarantee productivity in the SSE. The institutional security brought by the cooperative will be a great help in maintaining resilience. However, the increasing use of pesticides and the artificial process of grain selection and pest control will further inhibit the naturalness of SSE, making it fragile due to the exclusion of natural organisms necessary for SSE.

Regarding the **third pillar (Stakeholders):** it is expected that this will continue to be the principle of resilience that is most impacted on SSE in the future regime. The interference caused by the increasing use of pesticides tends to manifest itself soon, as the current regime already has an accumulative burden on the SSE. The saturation of these components in the soil, groundwater and deposition in different socio-ecological destinations will have a negative influence on environmental and human health in the SSE. Transformations in the local landscape will reflect changes in SSE in a constant and progressive manner, without abrupt changes. Many of the

ecosystem services will be transformed, reduced, or even cease to exist because there will not be the same SSE configuration as in the current development regime. Water shortages must be one of the services that will bring the greatest challenges to regional development managers.

The **fourth pillar (Institutions):** must be strengthened due to institutional maturity in the municipality. The challenges and problems in the SSE must force actors to converge their efforts in a natural way to resolve the disturbances within the SSE. Legislation pertaining to the use of pesticides must be observed by local managers. These will need to strengthen control, inspection, and technical support institutions to shape farmers' thinking and action towards a strategy of adjustments in local production and recovery of SSE. The Juriti cooperative will continue to have great influence in directing local production management, establishing guarantees, benefits and restrictions for the actors' cooperation and decision-making process. This principle must be the one that will best be coordinated in the SSE, due to the need for answers to the problems that will arise.

The **fifth pillar (Decentralization):** will continue to be a significant feature in the future development regime. In the current regime, the process of centralizing structures in the SSE replaced the modular and decentralized structures that existed in the past regime. This situation should be even more evident due to the process of interconnection and interdependence of the SSE with the outside world. The cooperation process converged with actions between properties and the logistics and production chain is increasingly strengthened. In other words, actions on a given property, with increased interdependence between actors, can yield good results for everyone or a generalized crisis for everyone (in the event of an undesirable situation, such as a drought, devaluation of production, etc.).

Finally, **sixth pillar (Polycentric Governance):** As is the case in the current regime, the maturity of organizations that encompass different types of leadership and knowledge within the SSE must continue to grow. However, the exclusive role of the cooperative and public authorities is not sufficient in the process of empowering farmers and other members of the community. Representatives from all sectors must be able to assume responsibilities and participate in the decision-making process within the SSE. The fragmentation in the perception of environmental and health problems caused by the current production system in the SSE continues to be an obstacle to the complete strengthening of this principle.

5.4 Eco-development Dimensions

In relation to the socioeconomic dimension, it was noticed that the farmers, despite rehearsing the first steps of what would be transformed into the currently existing cooperative, acted according to their own financial capabilities. Although farmers used their resources to expand their productive and economic capacity, they did so intuitively, without technical support that calculated the risks and potential and was constantly observing productive capacities. There was no awareness and direction for absorbing environmental costs, which were only directed at direct financial aspects, inputs, and economic profitability. The endogenization component was very present in the local reality since farmers only had their own productive capabilities. Production increased over the years, even without incentives from the public and private sectors.

The environmental dimension proved to be efficient in some points and inefficient in others. Agricultural activities aimed at productive management guided by traditional knowledge. Rice plantations followed the calendar known to rural producers and other crops on the properties were aligned with the aspect of producing for one's own consumption. The use of less modern techniques had a lower impact on ecosystems, which had the necessary time to reorganize themselves, thus ensuring that the resilience line was higher during the period. The use of pesticides during this period still had little impact on ecosystems due to the amount of use. The machinery available during this period was more rudimentary, not requiring inputs such as fossil fuels. The focus on biomass production in Massaranduba has always been present because of rice farming and other primary crops on a smaller scale. Regarding the reduction of energy intensity and increase in energy conservation, in the past regime, this component was glimpsed due to the low volume of production and the techniques used. In this sense, there was still a low level of waste within the SSE. There were no discussions about environmental care in Massaranduba, and the reflection of the environmental quality of life in this period is due to the way of life in conjunction with SSE.

The spatial or geographical aspect was also a factor that represented less development in Massaranduba under the past regime. Despite fully meeting the sustainability objective of this dimension, "avoiding crowds and occupations in risk areas", many of its components do not meet the sustainability character of development. The focus on agricultural activities meant that the population was always tied to certain spaces, not expanding their productive capabilities and potential. Families with greater productive capacities expanded their spatial use, reaffirming their current power capacities, without changes over time. In relation to the spatialization of the municipality, the balance between city and countryside was modest, with Massaranduba being characterized essentially by the rural way of life and the allocation of spaces to agricultural activities. This development factor is also responsible for placing the past regime at a level below the current one.

The cultural dimension of development is quite evident in the past regime. In the past there has always been great appreciation and respect for community cultural formation. The coexistence between the different ethnicities that characterized the rural producers of Massaranduba reflected in the harmonious way of life of the population at the time and this was evidenced by the exchange of parties that took place.

6 Conclusions

The challenge of reconciling economic growth with ecological prudence and the preservation of natural resources, through the concept of eco-development. This development model is based on the specific solution to the problems of each region, considering ecological and cultural data, and prioritizes a sustainable, fair, harmonious, and participatory society. The resilience perspective of Socio-Ecological Systems is incorporated into ecodevelopment to understand adaptive cycles and shock absorption capacity. A methodology is proposed to reduce vulnerabilities within the SSE, based on management, financial interventions, education, and governance. It is also important to highlight the contamination of pesticides in agricultural production and the environmental concern related to the quality of water

resources, which represents one of the main challenges in the municipality of Massaranduba.

Regarding aspects of economic development in Massaranduba, we have the following conclusions: The permanent flow of public and private investments with an emphasis on cooperativism should continue to grow. What can be improved in this component to achieve greater resilience is that, in terms of management, part of these investments is destined to strengthen the local productive structure, observing the deconcentration of land use. In terms of financial intervention, it is necessary to develop public/private partnership strategies with the aim of investing in projects for training and generating employment for the future population.

Regarding the limitations of this research, the unavailability of detailed economic data may impact the ability to carry out a comprehensive analysis of the economic aspects related to the use of pesticides in Massaranduba, limiting the understanding of the financial factors involved in agricultural practices. The lack of specific data on the exact number of pesticides used in irrigated rice crops can make it difficult to accurately assess the environmental and health impact associated with these agricultural practices, compromising the depth of the analysis. The research recognizes the importance of qualitative interviews to obtain detailed and contextualized insights into the use of pesticides in Massaranduba. Limiting the number of interviews may restrict the representativeness of the results, requiring a more comprehensive approach to capture diverse perspectives. Understanding resilience as a dynamic concept is crucial. The limitation lies in the non-static nature of socio-ecological resilience, which means that the analysis performed may capture a snapshot but does not fully reflect the continuous evolution of this phenomenon over time.

The contribution of this study is to identify specific points of vulnerability in a region, as well as factors that contribute to its resilience. This allows development strategies to focus on strengthening robust aspects and addressing weaker areas. Promote sustainable agricultural practices, conservation of natural resources and effective management of ecosystems, ensuring more balanced and lasting regional development. Addressing resilience and ecodevelopment often requires an interdisciplinary approach that integrates knowledge from diverse areas, including social sciences, natural sciences, and environmental management. This integration of knowledge can enrich regional development strategies.

Finally, external factors such as climate change and even the cumulative effects of pesticides cannot be predicted accurately, requiring intervention plans that consider such unpredictability. In relation to management, it is necessary to expand participatory monitoring and inspection of the resources applied, mainly the efficiency and costs linked to the use of pesticides and other techniques used in production. The next studies will focus on detailing this research with more recent data on the number of contaminants in the waters of the Itapocu River Basin, as well as exploring the concept of hydro social territories.

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