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Analyzing Land Conversion Rate and Conversion Farmer Household Food Security in Bakalan Village, Pasuruan Regency

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Abstract: The conversion of agricultural land to non-agricultural uses presents significant challenges to food security, environmental sustainability, and economic progress in Bakalan Village. Food security categories for Bakalan Village conversion farmer families are assessed in this study using System Dynamic and Land Conversion Rate Analysis. A causal loop diagram illustrates the complex relationships between land conversion, food availability, affordability, and needs, crucial for understanding food security dynamics. Higher land conversion rates negatively impact food availability, risking local food security. System Dynamic integrates agricultural and non-agricultural income sources to model food affordability, a key food security determinant. Annual iterations capture fluctuations in land use, income, and food indicators, revealing the evolving impact on food security. This research emphasizes the need for sustainable land use practices, incentivizing land preservation, and promoting diversified incomes to ensure food security, environmental resilience, and socio-economic stability in Bakalan Village and similar agricultural communities globally. Adaptive policies informed by such models are essential for addressing these multifaceted challenges effectively.

Keywords: Conversion farmer household; Land conversion; System dynamic

Introduction

The transition from agricultural to non-agricultural land use is a pressing issue that reflects the increasing demands of a growing human population. This phenomenon is particularly evident in regions experiencing rapid urbanization, where the need for residential and industrial development drives significant land conversion. Tokula & Adekiya (2018) emphasizes that population growth is a primary catalyst for this shift, as it intensifies the demand for land to accommodate housing, infrastructure, and economic activities. The economic expansion associated with urbanization further exacerbates this demand, leading to the conversion of agricultural land into urban and industrial uses. This trend is corroborated by research indicating that urban expansion often results in the loss of agricultural land, which can adversely affect water quality and contribute to environmental degradation (Tokula & Adekiya, 2018).

Location factors, such as proximity to urban centers, significantly influence land conversion trends. For instance, data reveals that Pasuruan Regency has experienced higher land conversion rates compared to neighboring regions like Blitar, Nganjuk, and Jember in East Java. The well-developed infrastructure in Pasuruan Regency supports these land use changes, facilitating the transition from agricultural to urban land use. Historical data indicates a dramatic increase in land conversion rates, with annual conversions rising from

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approximately 30,000 hectares in the 1990s to around 150,000 hectares by 2019. This trend underscores the critical interplay between economic development, population growth, and land use dynamics (Maitlo et al., 2023).

A case study of Pasuruan Regency illustrates the stark differences in land conversion rates across neighboring districts. Between 2019 and 2022, Blitar District recorded a conversion of 1,135.36 hectares, while Nganjuk and Jember Regencies experienced conversions of 678.65 hectares and 1,033.80 hectares, respectively. The unique characteristics of Pasuruan Regency, particularly its robust infrastructure, facilitate rapid land use development and transformation. This evolution from agricultural to non-agricultural land use is a complex process influenced by various factors, including demographic changes, economic conditions, and locational advantages. Understanding these dynamics is essential for effective land use planning and sustainable development practices (Zubair et al., 2019).

In Pasuruan Regency, the most significant land conversion has occurred in Bakalan Village, located within the Purwosari Subdistrict and part of the Malang-Surabaya Metropolitan Corridor. Over the past five years (2019 to 2023), approximately 33.53 hectares of paddy fields in Bakalan Village have been converted to accommodate a growing number of industries. The area is home to various industries, including wood, precious materials, woven fabric, and food and beverage sectors, with major companies such as PT Emjebe Pharma and PT Mayora Indah TBK operating along the strategically located Malang-Pasuruan Highway. This concentration of industrial activity has significantly contributed to the conversion of agricultural land to industrial zones, highlighting the urgent need for research focused on Bakalan Village as a critical site for understanding land use changes (Wahab et al., 2018).

The implications of land conversion extend beyond mere statistics; they encompass broader socio-economic and environmental concerns. Urbanization, driven by population growth and economic development, often leads to the displacement of agricultural activities and the degradation of natural landscapes. Studies indicate that urban sprawl can result in the fragmentation of agricultural lands, negatively impacting biodiversity and ecosystem services (Yang et al., 2024). Moreover, as cities expand, they tend to encroach upon prime agricultural lands, forcing agricultural activities to relocate to less productive areas, which can threaten food security (Martellozzo et al., 2014). The loss of agricultural land not only affects local food production but also has far-reaching consequences for rural livelihoods and community resilience (Suwarlan et al., 2022).

The relationship between urbanization and agricultural land conversion is further complicated by policy decisions and planning practices. In many cases, urban planners prioritize development over the preservation of agricultural lands, leading to conflicts between urban expansion and agricultural sustainability. Research has shown that effective land use planning must consider the competing demands for land while also addressing the needs of local communities (Kraemer et al., 2015; Alamsyar et al., 2018). This requires a comprehensive understanding of the socio-economic dynamics at play, as well as the environmental implications of land use changes. The conversion of agricultural land to non-agricultural uses has significant implications for food security, as evidenced by various studies that explore the intricate relationship between land use changes and food availability.

According to Government Regulation (PP) No. 17/2015, food security is defined as the availability of sufficient, safe, and nutritious food that is accessible to all individuals. This regulation emphasizes the importance of food availability, accessibility, and consumption as fundamental components of food security, which directly influence family nutritional status. Law No. 7/1996 on Food further reinforces the idea that food development is a collective responsibility, involving both governmental and community efforts to ensure household food security. The implications of these regulations are critical, as they frame the context within which land conversion occurs and its potential impact on food security.

In the context of Pasuruan Regency, the food security ranking is notably low, positioned at 187th nationally according to the National Food Security Index compiled by the National Food Agency in 2022 (Kraemer et al., 2015). This ranking reflects the challenges faced by the region in maintaining food security, particularly in comparison to neighboring districts that rank higher. To further investigate the relationship between land conversion and food security, a study will be conducted in Bakalan Village, employing System Dynamics and Land Conversion Rate Analysis to assess the food security categories of farming households affected by land conversion. This research aims to provide insights into how changes in land use impact food security dynamics at the local level.

The need for effective land-use policies is further highlighted by Kamil & Romadhan (2020), who discuss the role of local governance in enhancing urban food resilience. Their findings suggest that integrating food security initiatives within local policies can mitigate the adverse effects of land conversion on food availability. Additionally, Hanspach et al. (2017) argue that equitable

access to land for smallholder farmers is crucial for achieving food security, as social inequities can exacerbate food insecurity. This perspective aligns with the findings of Nzabuheraheza & Nyiramugwera (2017), who emphasize the importance of sustainable land use practices in improving food security in developing regions.

The intersection of food security and biodiversity conservation is explored by Glamann et al. (2015), who highlight the need for a holistic approach to land use that considers both agricultural productivity and ecological sustainability. This is particularly relevant in the context of Indonesia, where land use changes driven by economic development pose significant threats to food security and environmental integrity (Ivanka et al., 2024). The urgency of addressing these challenges is underscored by the findings of Hidayana et al. (2021), who note that agricultural land conversion disrupts national food security and nutrient availability.

Method

This study aims to understand the relationship between land conversion and food security in Bakalan Village, Pasuruan Regency. The research method used was a primary survey involving respondents from the farmer with land conversion household. The survey was conducted to obtain data directly from the field on perceptions, practices and conditions related to land conversion and food security.

The analytical tools used in this research are Land Conversion Rate Analysis and System Dynamic. Analyzing land conversion involves employing descriptive analysis alongside mapping techniques. Descriptive analysis provides insights into the area and spatial distribution of land that has undergone changes in land use, as depicted through mapping techniques. The outcomes of such land use change analysis include identifying the extent and distribution of converted paddy fields, along with their current usage status.

To quantify the rate of land use change, a partial and continuous approach is employed, as outlined by Sutandi (2019). In this study, the partial approach is adopted, focusing on the conversion rate of land over the past five years. This rate is calculated using the following formula:

$$V = \frac{(L_t - L_{t-1})}{L_t} \quad (1)$$

Description:
V : Retrieved
L_t : Current land area/year t (ha)
L_{t-1} : Previous year's land area (ha)

This method allows researchers to quantify and understand the pace and extent of land conversion, providing valuable insights for land management and policy planning. On the other hand, The System Dynamic Model plays a pivotal role in the policy formulation process by establishing causal relationships and encompassing all relevant entities within the main causal effect relationships, as highlighted by Andhika (2019). This model serves as a versatile tool for evaluating the effectiveness of various policy scenarios, thereby supporting informed decision-making, as noted by Rashedi & Hegazy (2015) and Bérard et al. (2016). By considering the ripple effects of policies across different sectors, the system dynamic model enhances the likelihood of producing high-quality policies that address multifaceted challenges. During the policy formulation stage, this model identifies causal relationships among various sectors, concepts, and theories, shedding light on significant factors that influence outcomes.

Furthermore, system dynamic characterized by continuous temporal changes, are indispensable for analyzing complex patterns and behaviors. They leverage tools such as management flight simulators and computer simulations to comprehend feedback loops, anticipate future trends, and devise effective policies, as described by Sterman (2000) and Forrester (1994). Key to constructing system dynamic models is the utilization of platforms like STELLA, offering user-friendly interfaces and analytical functionalities such as dynamic graphs and sensitivity analysis. These features empower decision-makers to explore system behaviors comprehensively and make well-informed policy decisions.

In constructing a system dynamic model of food security and its connection to land conversion, the researchers undertook a comprehensive approach that involved several critical steps. Initially, they identified the specific challenges related to food security in Bakalan Village, Purwosari District, Pasuruan Regency. This identification process highlighted the significant impact of paddy field conversion on the livelihoods of farming households, a concern echoed in the literature which notes that rural areas in Indonesia face persistent food security challenges despite their agricultural potential (Venna & Romulo, 2024). The urban-rural divide exacerbates these issues, as rural regions often lack the necessary resources and infrastructure to enhance agricultural productivity, leading to increased food insecurity (Venna & Romulo, 2024).

Following the identification of the problem, the researchers formulated hypotheses regarding the factors influencing food security. These factors were categorized into three main areas: food availability,

affordability, and utilization. This categorization aligns with existing frameworks that emphasize the multifaceted nature of food security, where availability is influenced by agricultural productivity, affordability is affected by income levels and market access, and utilization is linked to dietary diversity and nutritional standards (Pawlak & Kołodziejczak, 2020; Firdaus & Cahyono, 2017). The literature further supports the notion that socio-economic factors, such as household income and education levels, play a crucial role in determining food security status (Hastuti et al., 2022).

The next step involved the creation of a system dynamic simulation model using the STELLA 10.0 application. The validation of this model was critical, as it ensured that the simulation outcomes were accurate, with an error variance maintained below 5%. This rigorous validation process is essential in system dynamics modeling, as it enhances the reliability of the model's predictions and scenarios (Ciccullo et al., 2020). The use of simulation models in food security research has been documented as a valuable tool for understanding complex interactions between various factors, including land use changes and agricultural practices (Ciccullo et al., 2020).

Finally, the researchers developed potential scenarios aimed at improving food security in Bakalan Village, taking into account the dynamic factors associated with paddy field conversion. This scenario planning is crucial, as it allows for the exploration of various interventions and their potential impacts on food security outcomes. The literature emphasizes the importance of scenario analysis in agricultural policy-making, particularly in the context of sustainable food production and food security (Pawlak & Kołodziejczak, 2020; Pakerti et al., 2021). By considering the implications of land conversion and agricultural practices, the researchers can propose informed strategies that address the root causes of food insecurity in the region.

Data Collection

Data collection for this study focuses on farmers who are experiencing land conversion while still retaining some agricultural land. The primary survey involved direct interviews with these respondents using a standardized questionnaire designed to gather insights into their perspectives and experiences regarding land conversion, as well as the status of household food security in Bakalan Village. This methodological approach is supported by the findings of Cheng et al. (2021), who emphasize that land use change significantly impacts regional food production, thereby affecting food security. Their research highlights the critical link between land use dynamics and food availability, reinforcing the necessity of understanding these relationships in the context of local agricultural practices.

The questionnaire utilized in this study aims to assess various dimensions of food security, which is a multifaceted issue influenced by numerous factors, including agricultural productivity and land management practices. Szabo (2015) discusses the risks of food insecurity associated with urbanization, noting that rapid changes in land use can lead to negative outcomes for food availability and accessibility. This perspective is crucial for understanding the implications of land conversion in Bakalan Village, where agricultural land is being transformed for industrial purposes.

The study's focus on the experiences of farmers aligns with the findings of Hidayana et al. (2021) who argue that agricultural land conversion poses a serious threat to national food security and nutrient availability. Their research indicates that decreased food productivity due to land conversion can disrupt the entire food system, highlighting the importance of investigating the local impacts of such changes. This is particularly relevant in the context of Pasuruan Regency, where food security is already a concern.

To enhance the understanding of the relationship between land use change and food security, the study will employ System Dynamics and Land Conversion Rate Analysis. This analytical framework is supported by the work of Daioglou et al. (2019) who emphasize the importance of integrated assessments in understanding the implications of land use changes on food production and environmental sustainability. Their findings suggest that effective management of land resources is essential for maintaining food security, particularly in regions facing significant agricultural land loss.

The research will draw on the insights of Martanto et al. (2023) who utilized a mixed-methods approach to assess food security levels in relation to land use conversion. Their study underscores the value of combining qualitative and quantitative data to provide a comprehensive understanding of the dynamics at play in agricultural communities. This approach will facilitate a nuanced analysis of how land conversion affects food security in Bakalan Village, contributing to the broader discourse on sustainable land management practices.

Results and Discussion

In today's rapidly changing global landscape, the conversion of agricultural land into non-agricultural uses such as residential areas, industrial zones, tourist sites, or infrastructure development has emerged as a

significant concern impacting the delicate balance between food production, environmental integrity, and economic progress. This shift, while often indicative of economic growth, presents critical challenges regarding food security, environmental preservation, and social sustainability. The reduction of agricultural land due to conversion can severely harm food availability, thereby threatening the food security of the population (Syakirotin et al., 2023). Their findings emphasize that the macro impact of land conversion leads to diminished food availability, which is a pressing concern in many regions, including Bakalan Village.

Moreover, Hidayana et al. (2021) discuss the serious threats posed by agricultural land conversion to national food security and nutrient availability. They argue that decreased food productivity resulting from land conversion can disrupt the entire food system. This aligns with the observations in Bakalan Village, where significant portions of agricultural land have been allocated for industrial purposes, potentially exacerbating food insecurity in the area.

The relationship between urbanization and food security is further explored by Szabo (2015), who notes that rapid urban growth often leads to negative impacts on food security. The study emphasizes the need for disaggregated indicators to measure progress in food security across urban, peri-urban, and rural areas, suggesting that urbanization can create challenges for food accessibility and availability. This perspective is particularly relevant in the context of Bakalan Village, where the conversion of agricultural land for industrial use may limit local food production capabilities.

The implications of land use conversion on food security are underscored by the findings of Wirapradeksa (2024), who highlights that land conversion can lead to adverse effects such as declining food security, reduced agricultural employment, and the marginalization of agricultural land. This research suggests that the ongoing conversion processes in Bakalan Village could have similar detrimental impacts on local communities, affecting their livelihoods and food security.

The work of Mulyani et al. (2023) illustrates the broader implications of agricultural land conversion on food security in Indonesia. They argue that as the population grows, the demand for food and land increases, leading to a decrease in productive agricultural land due to conversion. This trend poses significant challenges for future food security, necessitating effective land management strategies to balance agricultural and non-agricultural needs.

The urgency of addressing these challenges is also reflected in the research by Rondhi et al. (2018), who identify urbanization as a leading cause of rapid and irreversible agricultural land change. Their study emphasizes the need for sustainable agricultural practices and policies to mitigate the impacts of land conversion on food security and environmental sustainability.

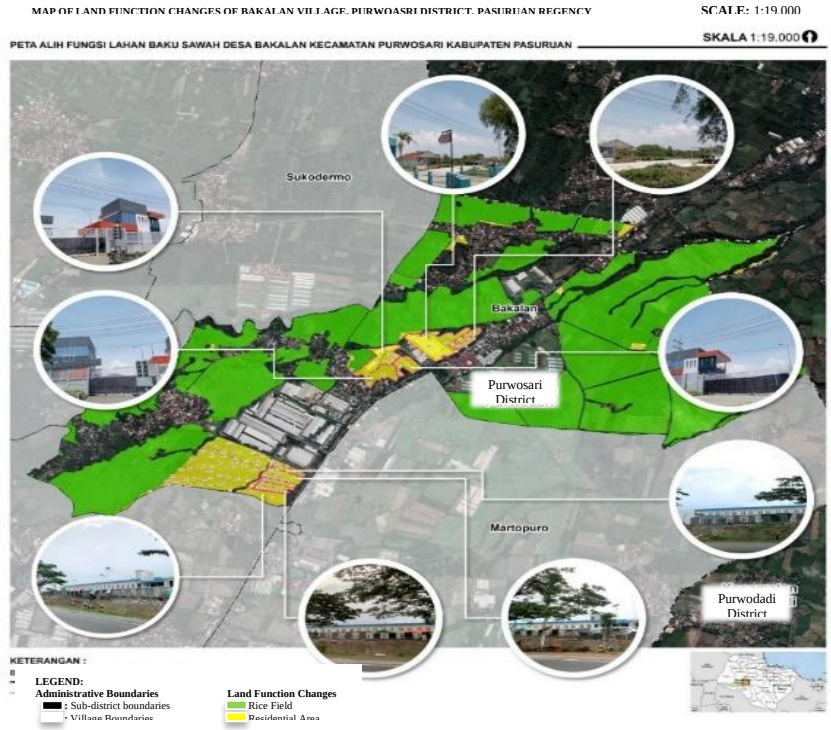

Figure 1. Map of rice field conversion in Bakalan Village, Purwosari Sub-district, Pasuruan Regency

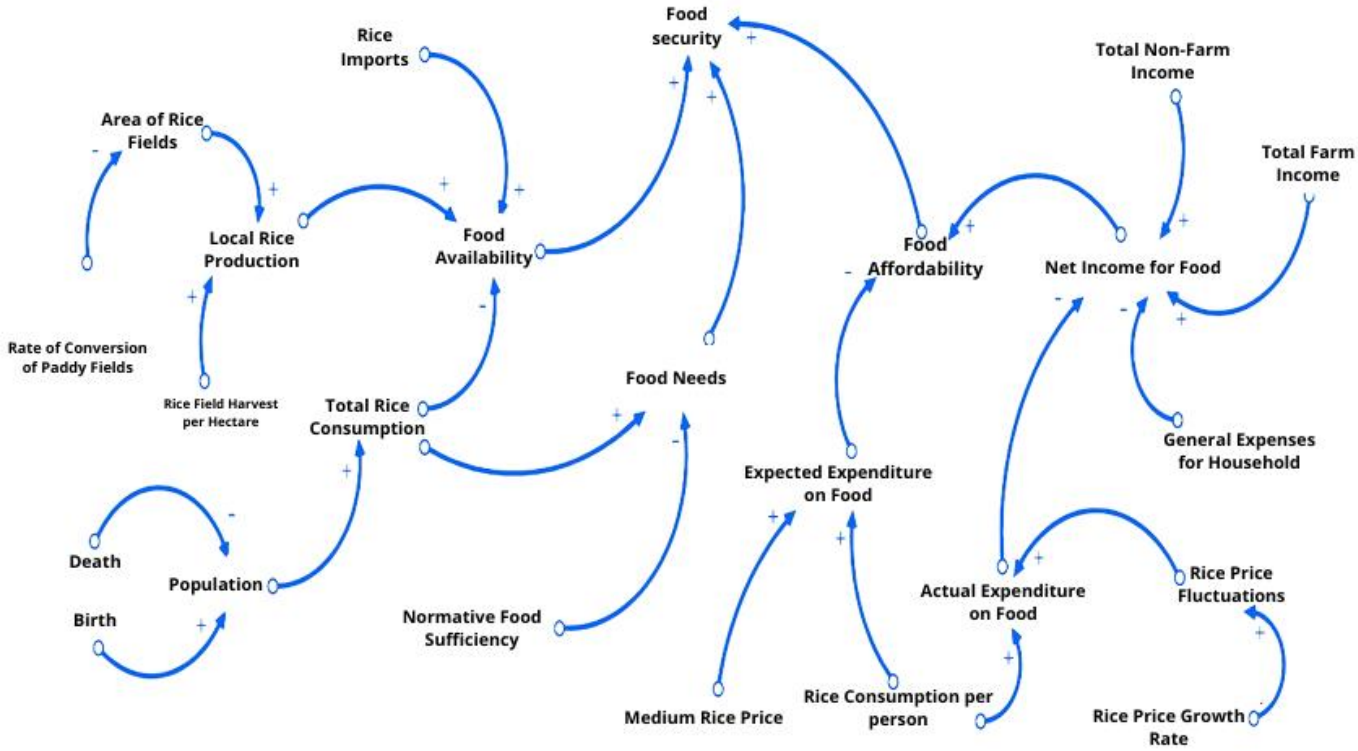

Figure 2. Causal loop

According to the 2023 analysis, agricultural land experienced widespread conversion, averaging a rate of 50.10%. The varied decisions made by farmers significantly influence this trend, with some opting to preserve their land (at a conversion rate of 8.63%), while others convert as much as 90.32% of their land. A lack of incentives for land preservation contributes to this phenomenon. However, extensive land conversion poses a substantial risk to food production, potentially endangering the food security of the populace.

In the research concerning the causal loop diagram that illustrates the interrelationships between food security and agricultural land conversion, the researchers employed a systematic approach to depict the complex dynamics at play. Causal loop diagrams (CLDs) are effective tools for visualizing the feedback loops and causal relationships among various factors influencing food security, such as food availability, food needs, and food affordability. The negative correlation between land conversion and food availability is particularly significant, as increased land conversion typically leads to reduced agricultural output, thereby compromising food security (Hidayana et al., 2021).

The CLD developed in this study encapsulates the multifaceted nature of food security, which is influenced by a variety of determinants. Friel et al. (2017) emphasize the importance of including multiple determinants and feedback loops in understanding food security dynamics, as this holistic approach allows for a more comprehensive analysis of the factors at play. Similarly, Isaac et al. (2023) highlights that ecological stability, particularly in the context of climate change and land-use changes, is crucial for maintaining food system stability, reinforcing the idea that agricultural productivity is directly linked to environmental factors. This connection is vital, as it illustrates how land conversion not only affects food availability but also impacts the broader ecological context that supports agricultural systems.

Moreover, the system dynamic model accounts for the income sources of conversion farmer households, which typically include both agricultural and non-agricultural income. This aspect is crucial, as it acknowledges that even amidst land conversion, many households retain productive land that contributes to their agricultural income (Picchioni et al., 2022). The integration of these income sources into the model reflects the complexity of food security, where economic stability and agricultural productivity are intertwined (Isaac et al., 2023).

The researchers' approach to quantifying food security through an accumulation of the fulfillment values of its indicators—food availability, affordability, and needs—aligns with established methodologies in systems science. This method allows for a nuanced assessment of food security, converting qualitative indicators into quantifiable scores for evaluation (Sharma et al., 2021). The use of CLDs not only aids in visualizing these relationships but also facilitates the

identification of potential interventions that could enhance food security outcomes (Sawyer et al., 2021).

Based on the model, there is an income variable as a component forming Food Affordability. It is known that the Food Availability indicator is formed from the comparison between the total local rice production of Bakalan Village and the total rice consumption of Bakalan Village households; the Food Affordability indicator is formed from the comparison between net income for food and expected expenditure for food; and the Food Needs indicator is formed from the comparison between the total rice consumption of Bakalan Village households and expected rice consumption.

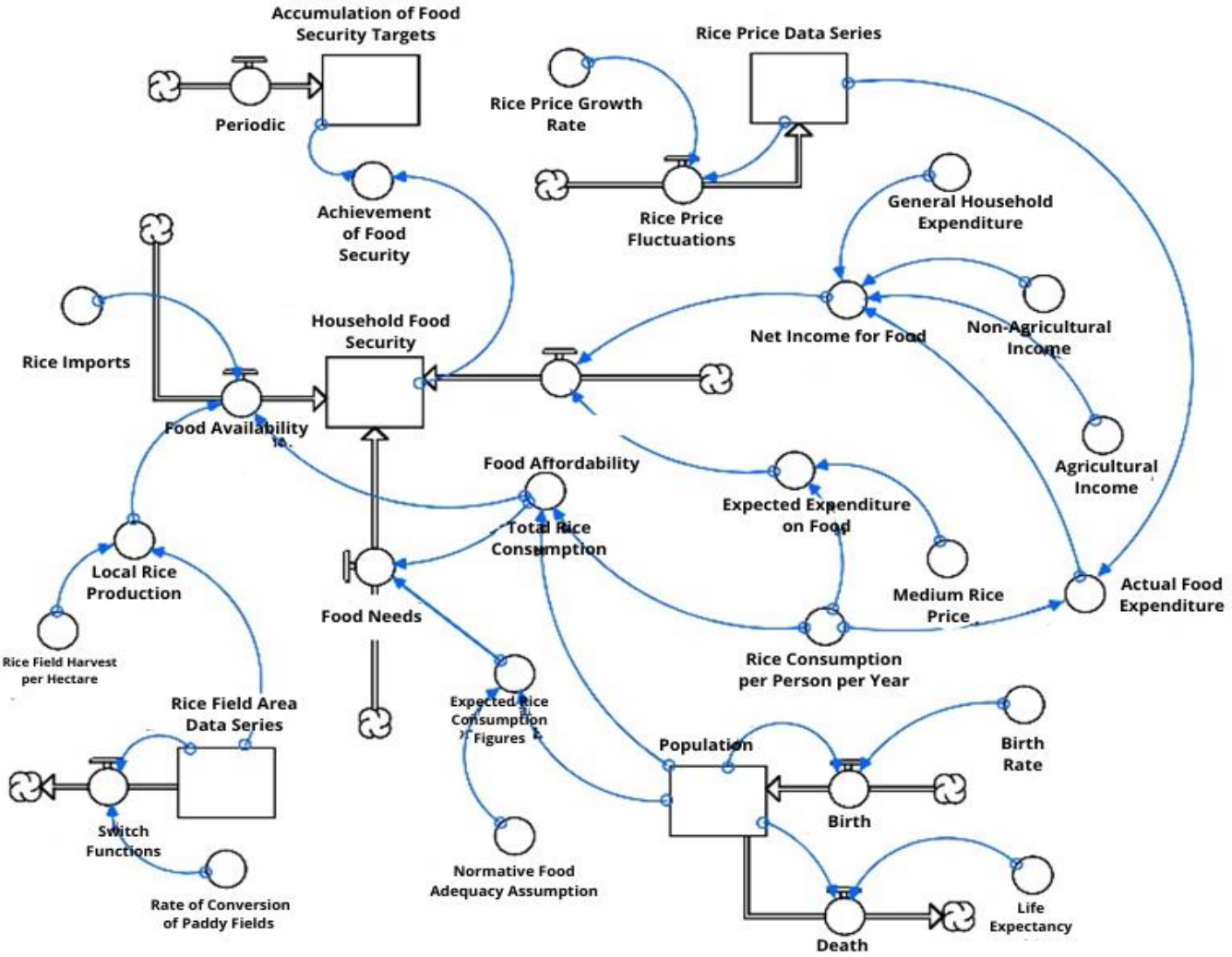

Figure 3. System dynamic model of conversion farmers household in Bakalan Village

The model developed for analyzing food security in Bakalan Village operates on an annual iteration basis, incorporating fluctuations in various variables that significantly impact food security. A critical aspect of this model is the land conversion analysis, which reveals a land conversion rate of 50.1%. This substantial rate of conversion leads to a reduction in agricultural land to 2.85 hectares by the fifth year of iteration, highlighting the pressing issue of diminishing agricultural land in the face of a growing population. The inverse relationship between agricultural land area and population growth underscores the urgent need for sustainable land management practices to mitigate food security risks (Azadi et al., 2015; Rondhi et al., 2018).

The dynamics of population growth are derived from the cumulative effects of birth and death rates. The birth rate, reported at 14.86 births per 1,000 individuals, and the death rate, based on a life expectancy of 70.55 years, contribute to a net population increase. The system dynamic model calculations indicate that Bakalan Village experiences a birth rate of 99 per 1,000 individuals annually, while the death rate fluctuates between 94 and 95 per 1,000 individuals. This demographic trend, characterized by a higher birth rate

than death rate, signifies a consistent annual growth in population, which in turn drives the demand for land and exacerbates the conversion of agricultural land to non-agricultural uses (Wulan et al., 2022; Rondhi et al., 2018).

The competition for land use between agricultural and non-agricultural sectors is a critical factor in this analysis. As noted by Wulan et al. (2022) the limited availability of land resources, coupled with population growth and economic development, intensifies the competition for land, making agricultural land conversion increasingly inevitable. This competition is further compounded by urbanization and the rising economic value of land, which often leads to conflicts between agricultural and non-agricultural interests (Rondhi et al., 2018; Ardhana & Fithriya, 2023). The findings from this research align with the broader literature, which emphasizes that land conversion poses significant threats to food security, particularly in developing regions where agricultural land is under pressure from urban expansion and industrial development (Azadi et al., 2015; Rondhi et al., 2018).

The implications of land conversion extend beyond mere agricultural output; they also encompass environmental and socio-economic dimensions. The conversion of agricultural land can lead to a decline in soil quality and ecosystem services, which are vital for sustaining agricultural productivity (Don et al., 2010). Studies have shown that land-use changes can significantly impact soil organic carbon stocks, thereby affecting the long-term sustainability of agricultural practices (Don et al., 2010). The need for integrated land-use planning that considers both agricultural productivity and environmental conservation is paramount in addressing these challenges (Waqa et al., 2017; Kurniasari et al., 2020).

Conclusion

To address the challenges posed by agricultural land conversion on food security and sustainability, a multifaceted approach is needed. This includes implementing strict land use regulations and incentive programs to preserve agricultural land, promoting education and awareness about sustainable practices, supporting diversification of income for farmers, encouraging technology adoption in farming, and fostering collaborative governance among stakeholders. By combining these strategies, we can mitigate the negative impacts of land conversion while ensuring long-term food security, environmental integrity, and economic stability in affected areas.

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Author Contributions
Conceptualization, data curation, P.C.N. and S.; methodology, validation, supervision, S. and A.E.; software, formal analysis, investigation, resources, writing—original draft preparation, writing—review and editing, visualization, project administration, funding acquisition, P.C.N.

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Conflicts of Interest
The authors declare no conflict of interest.

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