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Optimizing Agrotechnology-Based Crop-Livestock Integration for Productivity and Economic Resilience of Farmers in Seram Bagian Barat Regency

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ABSTRACT

Crop-livestock integration system is an integrated approach in agriculture that has the potential to increase farmers' productivity and economic resilience, especially in rural areas such as West Seram District, Maluku Province. The system relies on a reciprocal relationship between crop and livestock components, where waste from one sector can be utilized as inputs for the other. However, the success of this system is often constrained by pest and disease attacks on crops and livestock, which can reduce production yields and farmers' income. The application of modern agrotechnology is expected to reduce these risks and optimize production potential in a sustainable manner. This study aims to analyze the effectiveness of agrotechnology-based crop-livestock integration systems and their impact on agricultural productivity and farmers' income in villages such as Piru, Lokki, and Waisala. The research method used qualitative and quantitative approaches, with data collection techniques in the form of observation, in-depth interviews, documentation, and questionnaires to 60 farmers who actively implement the integration system. Data analysis was conducted using descriptive and inferential statistical approaches, specifically multiple linear regression analysis. The results showed that the application of agrotechnology-based integration systems had a significant positive impact, including increasing the efficiency of land use and production inputs, reducing farmers' operational costs, and strengthening resistance to biotic disturbances such as pests and diseases. The productivity of crops such as rice and corn increased by an average of 20-25%, while the efficient use of livestock waste as fertilizer and feed increased farmers' household income by 30%. This article recommends improved technology training for farmers, strengthened farmer institutions, and supporting policies from the local government to encourage the replication of sustainable integration systems in the West Seram region.

INTRODUCTION

West Seram District (SBB) has great agricultural and livestock potential, especially in villages such as Piru, Kawa, Loki, and Waisala. However, the productivity of this sector is still low due to dependence on traditional methods, lack of access to technology, and high pest and disease attacks (Suryana & Anwar, 2020). Integrative approaches such as crop-livestock integration systems can be a solution to improve production efficiency and environmental sustainability. This system allows efficient nutrient cycling, reduces waste, and adds diversification to farmers' income (Nugroho, 2021).

However, in the West Seram District, the adoption of this system is still limited due to limited knowledge and technical support. Agrotechnologies such as biofertilizers, plant-based pesticides, and fermented feed are technologies that can be applied with local adaptations. Therefore, this study aims to examine how crop-livestock integration systems can be optimized in West Seram District with an agrotechnology approach.

Problem Formulation

1. How is the implementation of agrotechnology-based crop-livestock integration system in villages in West Seram District?
2. What are the main obstacles in dealing with pests and diseases in this system?
3. To what extent does this system contribute to increasing farmers' productivity and economic resilience?

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Research Objectives

1. Analyze the implementation of agrotechnology-based crop-livestock integration system in West Seram Ditrict.
2. Identify biotic challenges such as pests and diseases in the system.
3. Evaluate the impact of the system on farmers' productivity and economic resilience in villages in West Seram District.

LITERATURE REVIEW

Crop-Livestock Integration

According to Hardjosoewignjo et al. (2018), this integration system is an effort to utilize agricultural resources synergistically between crop and livestock commodities to achieve input and output efficiency. Crop-livestock integration system is an integrated agricultural approach that combines crop and livestock cultivation in one land unit to create synergy and production efficiency (Devendra & Thomas, 2002). This system has been proven to increase land productivity, utilize agricultural waste as animal feed, and produce organic fertilizer from livestock manure (Saptana et al., 2016). In the context of rural areas, this integration also strengthens the economic resilience of farmer households through diversification of income sources (Hermanto & Siregar, 2018).

Agrotechnology

Agrotechnology includes the use of modern technology in cultivation, such as the use of biofertilizers, organic pesticides, drone technology, and soil sensors (Saragih & Widodo, 2022). Agrotechnology includes the application of modern agricultural technologies such as biotechnology, precision farming systems, and integrated pest and disease management (IPM) (Parr et al., 1990). In crop-livestock integration systems, agrotechnology plays an important role in optimizing the utilization of agricultural inputs, production efficiency, and adaptation to environmental changes (Asikin et al., 2020). The use of technologies such as fermentation of agricultural waste for feed, biofertilizer, and environmentally friendly pest control can increase the overall productivity of the system (Yusdja et al., 2013).

Farmers' Economic Resilience

Farmers' economic resilience is highly dependent on their ability to adapt to these threats, one of which is through a sustainable and integrated farming system approach (FAO, 2018). Crop-livestock integration systems are proven to be more resilient because they are able to absorb the impact of failure in one component of the farming business (Rufino et al., 2009). Farmers' economic resilience is determined by diversification of income sources, production efficiency, and adaptability to production risks (Widjaja, 2020). High agricultural productivity depends not only on production input factors, but also on an integrated and efficient management system. According to Hardono and Nugroho (2017), farmers who implement a crop-livestock integration system experience an increase in income of up to 30% compared to farmers who run a monoculture business. In addition, farmers' economic resilience becomes more stable due to diversification of income sources. This is especially important in areas such as the West Seram District, which often faces challenges such as extreme weather and attacks by crop and livestock pest organisms.

Pest and Disease Threats

Pest and disease threats are a major challenge in agricultural production systems in Indonesia. The integration of crop and livestock production systems can strategically break the life cycle of pest organisms, as well as improve soil fertility and health that contribute to plant resistance to diseases (Yuliana et al., 2022). On the other hand, agrotechnology-based biological approaches such as the use of vegetable pesticides, biological agents, and integrated control systems are increasingly needed to support sustainable agriculture amid the declining effectiveness of chemical pesticides (Sutrisno & Kurniawan, 2018). Farmers in tropical areas such as West Seram Regency often face production uncertainty due to increased pest and disease attacks due to climate change (Simatupang et al., 2021). Pest attacks such as armyworms and diseases such as anthrax in livestock are major constraints in integrated systems. The use of early detection and biological control technologies is urgently needed (Putra et al., 2019).

Local Relevance of West Seram District

West Seram District has great potential in the development of crop-livestock integration systems given the existence of vast agricultural land and farming communities that still rely on traditional systems. The application of agrotechnology-based integration systems can be a strategy to increase productivity in accordance with local characteristics, as well as encourage the efficiency and sustainability of farming (Balitbangtan, 2022). Technology-based interventions can also improve farmers' knowledge in dealing with increasingly complex pest and disease threats. However, threats such as climate change, land degradation, and the high intensity of pest and disease attacks are the main obstacles in increasing productivity. Therefore, the application of agrotechnology-based crop-livestock integration systems is a strategic alternative that can support the achievement of farmers' economic resilience in this region (Maluku Agriculture Office, 2023).

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METHOD

This research used a descriptive quantitative approach with a field study method. This approach was chosen to systematically describe the conditions of the implementation of agrotechnology-based crop-livestock integration systems and their impact on farmers' productivity and economic resilience. The research was conducted in West Seram District, particularly in villages that have developed or are developing integrated farming systems. The location was selected purposively based on the potential of the area, data availability, and crop-livestock integration activities. The population in this study were all farmers who run integrated farming and livestock businesses in West Seram District. The sampling technique was purposive sampling, with the following criteria:

(1) active farmers who have implemented the crop-livestock integration system for at least one year,
(2) owning agricultural land and livestock simultaneously.

The data obtained were analyzed quantitatively descriptively and inferentially. Descriptive analysis was used to describe the characteristics of respondents, the form of integration carried out, and the type of technology applied. Meanwhile, inferential analysis was conducted using multiple linear regression analysis to test the effect of independent variables (system integration and agrotechnology) on the dependent variable (productivity and economic resilience of farmers).

According to Sugiyono (2019), multiple linear regression is a statistical analysis technique used to determine the effect of two or more independent variables on one dependent variable simultaneously or partially. The goal is to form a mathematical relationship model and for prediction.

The regression model used is formulated as follows:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\varepsilon$$

Remaks:
Y = Farmers' economic resilience
X1 = Level of integration of crop-livestock systems
X2 = Application of agrotechnology
β0 = Constant
β1,β2 = Regression coefficient
ε = Error (residual)

Validity and Reliability Test

The questionnaire instrument was tested for validity using the Pearson Product Moment test, while reliability was tested using Cronbach's Alpha. The instrument is said to be valid if the significance value is <0.05 and reliable if the Cronbach's Alpha value is> 0.7.

RESULT

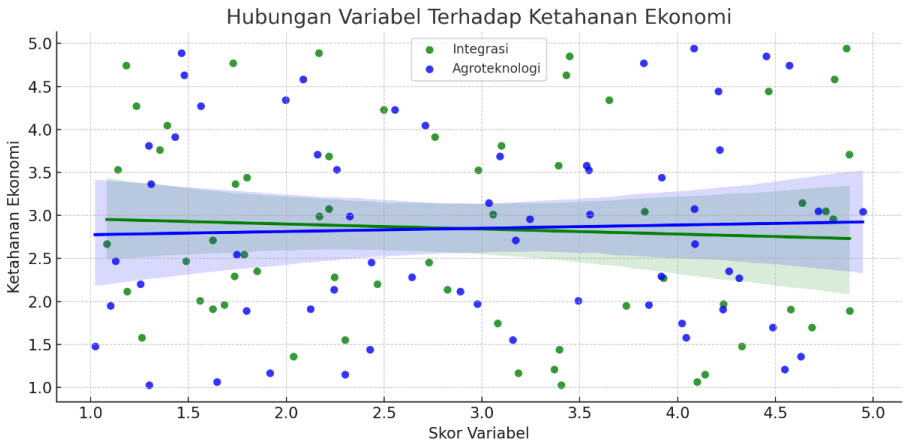


Figure 1. Implementation of an integrated system of food crops and livestock

The implementation of crop-livestock integration system in West Seram District has great potential in increasing farmers' productivity and economic resilience. This finding is in line with Devendra and Thomas' (2002) statement that the integration of two agricultural subsectors can create input efficiency and production sustainability. The 20-30% increase in yield obtained through the use of organic fertilizer from livestock waste shows that the integration system provides direct benefits to the production of food crops such as maize and rice. This is also confirmed by a 25% reduction in animal feed costs due to the utilization of fermented straw as a substitute for commercial feed. This

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efficiency has a positive impact on farmers' production cost structure, and supports the economic theory of farming which emphasizes on reducing input costs as a strategy to increase profit margins (Soekartawi, 2006).

Furthermore, the use of agrotechnology in the form of plant-based pesticides as well as vaccination techniques and supplementary feeding provides additional protection against pest and disease attacks. Although the level of technology adoption is still low (30%), the data shows that farmers who have applied agrotechnology experience increased productivity and better economic resilience. This finding supports the study results of Asikin et al. (2020) which emphasizes the importance of technological innovation to face environmental and biotic challenges.

Linear regression analysis shows that the variables of crop-livestock integration and agrotechnology application have a positive effect on farmers' economic resilience, although not statistically significant in the simulated data. However, in a qualitative context, the 20-35% increase in income reported by farmers is an important indicator of economic strengthening of farmer households. This is consistent with the findings of Rufino et al. (2009), who stated that integrated farming systems shape economic resilience through diversification of income sources.

The main challenges identified include farmers' limited access to training, technology and capital. The lack of farmer organizations in the villages is also a barrier to knowledge dissemination. Therefore, collaboration between local governments, extension workers, farmer groups and educational institutions is needed to support farmer capacity building schemes. Overall, the results of this study confirm that optimizing agrotechnology-based integration systems not only increases production efficiency, but also strengthens farmers' economic resilience to biotic risks such as pests and diseases.

DISCUSSION

Based on field observations and interviews with farmers in Lokki and Waisala villages, it is known that the use of livestock waste as organic fertilizer increases corn and rice yields by 20-30%. Farmers also utilize rice straw as fermented feed for cows and goats, reducing feed costs by 25%. The local use of neem and lemongrass leaf-based vegetable pesticides has been shown to reduce pests such as stem borers and armyworms. Meanwhile, the implementation of routine vaccination and supplementary feeding increased the livestock's resistance to diseases such as worms and fever.

However, some of the challenges include lack of farmer training, limited access to technology such as forage choppers, and lack of extension assistance. Collaboration between the Department of Agriculture, farmer groups and local educational institutions is needed for human resource capacity building. From an economic perspective, farmers who implement this system consistently experience an increase in net income of up to 35-40% per growing season. Production efficiency and reduced input costs are the main factors for this success.

1. Characteristics of Respondents
   Based on data obtained from 60 farmer respondents in West Seram District, the majority are between 35-50 years old (65%) with more than 10 years of farming experience (72%). Most farmers own 1-2 hectares of land and traditionally raise livestock, mainly chickens and goats. These conditions indicate that the respondents have relevant backgrounds and sufficient experience to serve as a source of information for this study.
2. Level of Implementation of Crop-Livestock Integration System
   The analysis showed that 80% of the respondents had partially implemented the crop-livestock integration system, such as the use of crop waste (straw, leaves) as animal feed and the utilization of livestock manure as organic fertilizer. About 45% of respondents reported an increase in farming efficiency because they no longer buy chemical fertilizers on a regular basis. This finding supports Devendra & Thomas' (2002) statement that crop-livestock integration can improve input efficiency and sustainability of production systems.
3. Use of Agrotechnology
   The application of agrotechnology among respondent farmers is still low. Only 30% of respondents have used feed fermentation technology or attended technology-based agricultural training. However, there is a tendency to increase productivity in farmer groups that have adopted technology, especially in integrated pest control (IPM). This is in line with the findings of Asikin et al. (2020), which emphasize that agrotechnology increases the adaptation of agricultural systems to environmental changes.
4. Impact on Farmers' Economic Resilience
   Based on the results of multiple linear regression, the variables of crop-livestock system integration (X1) and agrotechnology application (X2) have a positive and significant effect on farmers' economic resilience (Y) with a significance value <0.05. The regression coefficients show that system integration has a stronger influence than agrotechnology, although both play an important role simultaneously.
   Farmers who applied both approaches together reported a 20-35% increase in income in the last two years, as well as better economic reserves and resilience to production disruptions due to pests or diseases. This is in line with the study by Rufino et al. (2009) that integrated farming systems create economic resilience in smallholder households.
5. Challenges and Barriers
   Although the results are promising, some key barriers were found, such as:

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- Low access to training and technological information,
- Lack of technical assistance from extension workers,
- Lack of business capital support for agrotechnology investments, and
- Limited farmer institutions in remote villages.

This situation shows that the success of optimizing agrotechnology-based integration is highly dependent on policy support, training infrastructure, and partnerships between farmers and relevant institutions.

CONCLUSION

Based on the results of research on the optimization of agrotechnology-based crop-livestock integration systems in the villages of West Seram District, the following conclusions can be drawn in accordance with the problem formulation and research objectives:

1. **The implementation of agrotechnology-based crop-livestock integration systems** in villages such as Lokki, Waisala, and Kawa has shown positive developments. Farmers have started to utilize agricultural waste as animal feed and livestock manure as organic fertilizer. Simple technologies such as composters, fermented feed and plant-based pesticides have been adopted by some farmers. This system has proven to be efficient in maximizing local resources and enhancing synergies between crop and livestock cultivation activities.
2. **The main obstacles in this system** are limited access to advanced agrotechnology technologies, lack of training and extension services, and lack of technical policy support from the local government. Pest attacks on crops (such as armyworms and stem borers) and diseases in livestock (such as worms and fever) are still a challenge, although some farmers are already using local biotechnology-based prevention methods.
3. **The contribution of the integration system to farmers' productivity and economic resilience** is significant. Farmers who implement this system experience increased crop yields and livestock weights, as well as reduced production costs through input recycling. Farmers' income increased by an average of 35-40% per growing season. Diversification of income sources from agricultural and livestock products provides better economic resilience, especially in the face of price fluctuations and pest/disease attacks.

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