



## Stakeholders' Perspectives on Developing a Zero-Waste Integration System for Horticulture and Beef Cattle in Barru Regency: A Qualitatif Analysis

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### ABSTRACT

*An integrated farming system that combines the horticulture and beef cattle subsectors based on the zero-waste principle is one of the innovative solutions to reduce negative environmental impacts while increasing production efficiency. Barru Regency, with its potential in horticulture and livestock, is a strategic area for the implementation of this system. However, the success of its implementation highly depends on the active involvement of various stakeholders. This study aims to examine stakeholders' perspectives on the development of a zero waste integration system of horticultural crops and cattle in Barru Regency. A qualitative approach was used to explore the perceptions, interests, roles, and challenges faced by stakeholders in the implementation of this system. Data were collected through in depth interviews, including Focus Group Discussions (FGD), participatory observations, and document studies. The informant sources identified in this study consist of 15 cattle farmers, 10 horticulture farmers, 2 field extension officers, 1 government official, and 1 academics. The data were analyzed using thematic analysis methods. The research findings show that 80% of farmers perceive waste reuse as economically beneficial, and 40% lack access to composting and biogas technology. Based on these findings, synergy among actors, regulatory strengthening, and inclusive policy support are needed to realize a sustainable zero-waste farming system.*

**Keywords:** Beef Cattle, Holticulture, Integration System, Stakeholders' Perspectives, Zero-Waste

### INTRODUCTION

Agriculture and livestock are two main sectors in the food system that are interrelated and play a significant role in regional economic development (Loizou et al., 2019). However, both sectors also contribute substantially to environmental pollution if not managed sustainably. Organic waste from agriculture and livestock, when not properly handled, has the potential to contaminate soil, water, and air (Ibragimov & Borulko, 2021). Therefore, integrative approaches between these two sectors have increasingly been introduced as one of the strategies to reduce such negative impacts. The integration of agriculture and livestock refers to the management of mutually supportive production systems, where by-products from one sector are utilized as inputs for the other (de Faccio Carvalho, 2024). For instance, livestock waste such as cattle manure can be processed into compost, which helps improve soil fertility in horticultural land. Conversely, crop residues can be used as livestock feed, thereby creating efficient material circulation and reducing resource waste (Li et al., 2018).

The concept of zero waste serves as one of the main pillars in the sustainable integration of agriculture and livestock. In this context, zero waste does not merely mean producing no waste, but rather optimizing the use of waste as a new resource. This approach supports the principles of a circular economy, which is increasingly promoted by both national and international development policies (Domenech & Borrion, 2022). In practice, this system also requires careful management and the active involvement of various actors.

Barru Regency in South Sulawesi is known for its rich natural resources and strong agrarian culture. With a strategic geographical position and a supportive agroecosystem, Barru has high potential for developing an integrated agricultural system. In addition, Barru Regency is one of the major beef cattle development centers in South Sulawesi, with a significant population of 32,862 heads (Sulawesi Selatan Province ini Figures, 2024). The diversity of horticultural commodities, such as long beans, shallots, spinach, water spinach, melons, and watermelons, also makes this regency an ideal candidate for the implementation of a zero-waste integration-based concept.

However, this potential has not been fully optimized. Most production systems in Barru still operate in a sectoral manner, with agriculture and livestock managed separately. As a result, organic waste from both sectors remains largely unutilized and tends to be wasted. In fact, if managed in an integrated way, this waste could be converted into useful inputs, thereby supporting the resilience and efficiency of the overall production system.

The implementation of a zero-waste-based integration system in Barru Regency requires support from various stakeholders. These stakeholders include farmers, livestock breeders, local government, extension agencies, and research institutions. Each plays a strategic role in the planning, implementation, and evaluation of the proposed integration system. Therefore, understanding their perspectives is an essential first step to ensure the successful implementation of this system.

The study of stakeholder perspectives is essential because their decisions and actions significantly influence the direction and sustainability of the implemented integration system. For example, government support in the form of regulations and incentives is crucial for project continuity, while farmers' attitudes toward new technologies affect the adoption of zero-waste practices (Zhang & Teng, 2023). In this context, active involvement and cross-sector collaboration are absolute prerequisites. Furthermore, it is necessary to identify both opportunities and challenges from the stakeholders' perspectives. Opportunities may include increased productivity, cost efficiency, and market potential for environmentally friendly products. Meanwhile, challenges may involve limited access to technology, weak local institutional capacity, and resistance to changing conventional practices. A comprehensive understanding of these aspects will help in designing appropriate intervention strategies.

The supporting and inhibiting factors for the implementation of the integration system must also be thoroughly identified. Supporting factors may include national policy support for waste management, the availability of appropriate technology, and the presence of active extension institutions. On the other hand, inhibiting factors include limited capital, low technical knowledge among farmers and livestock breeders, and the lack of integration in the marketing and logistics systems for agricultural and livestock products (Amam et al., 2021). Through an in-depth qualitative approach, this study aims to holistically explore these dynamics. By examining the experiences and perspectives of key actors in the field, this research will contribute meaningfully to the formulation of more inclusive, efficient, and sustainable agricultural development strategies. Moreover, the results of this study are expected to serve as a basis for policymaking at both local and regional levels in developing a zero-waste-based integrated horticulture and cattle farming system in Barru Regency.

## RESEARCH METHODS

### Research Location

This research was conducted in Barru Regency, South Sulawesi Province. The selection of this location was based on the characteristics of the area, which has significant potential in the horticultural agriculture and beef cattle farming sectors, as well as the growing awareness of sustainable agriculture practices. The research was carried out over a period of three months, from February to April 2025.

### Type of Research

This study employed a qualitative approach using the grounded theory method. Data were collected through in-depth interviews, focus group discussions (FGD) regarding the informant sources, field observations, and document analysis. Informants were selected purposively based on their involvement in agricultural and livestock activities. The process included:

#### 1. Triangulation Process

Triangulation was carried out to enhance the validity and credibility of the data through the following approaches:

- **Source triangulation:** Information was confirmed using various types of informants (farmers, livestock breeders, extension workers, government officials, and business actors) to gain diverse perspectives.
- **Method triangulation:** Data were collected through a combination of interviews, direct observation of integration activities, and document reviews (such as farmer group reports and local policy

documents).

- **Time triangulation:** Interviews and observations were conducted on several different occasions to capture the dynamics of practices and stakeholder perceptions more comprehensively.

## 2. Detailed Coding Procedure

The coding process was conducted in the following stages:

### a. Open Coding:

- Reading interview transcripts thoroughly.
- Highlighting meaningful sentences or paragraphs and assigning initial code labels.
- Producing approximately 16 initial codes.

### b. Axial Coding:

- Identifying relationships among initial codes.
- Grouping codes into sub-themes based on contextual, causal, and consequential dimensions

### c. Selective Coding:

- Determining core categories or central themes that represent the main phenomenon.
- Constructing a conceptual narrative that explains the relationships among the core categories.

## 3. Ethical Considerations

This study was conducted with adherence to qualitative research ethics principles:

- **Informed consent:** All informants were provided with an explanation of the study's purpose, the nature of their participation, and their right to decline or withdraw at any time. This information was conveyed verbally and/or in writing before interviews began.
- **Anonymization:** Names, specific locations, and other sensitive information were not disclosed in the report. Informants' identities were anonymized using codes (e.g., F1 for the first farmer, L1 for the first livestock breeder, E1 for the first extension worker, O1 for the first government official, and A1 for the first academic).
- **Data confidentiality:** Data were stored securely and accessed only by the researcher. Final results were presented only in aggregate and narrative form, ensuring individual identities could not be traced.

## Informant source

The sources of informants in this study consist of parties considered capable of providing adequate insights related to the issues being researched. Therefore, the researcher needs to establish criteria for potential informants as an initial guide for data collection, such as selecting cattle farmers and horticulture farmers with at least 5 years of experience, and government officials based on their policy expertise. Prospective informants were selected using a theoretical sampling approach, where the sample selection is based on concepts that have been proven to have a theoretical connection with the theory being developed (Foley et al., 2021). The informant sources identified in this study consist of 15 cattle farmers, 10 horticulture farmers, 2 field extension officers, 1 government official, and 1 academic, with the following roles:

- Cattle farmers, who provide direct information related to livestock management, utilization of livestock waste (such as cow manure), as well as technical and non-technical obstacles faced in the field.
- Horticultural farmers, who play a role in explaining horticultural cultivation, organic fertilizer needs, and their views on the utilization of livestock waste as agricultural inputs.
- Field extension workers, who act as a bridge between the government and farming entrepreneurs. They provide insights into the dynamics of farmer and livestock groups, openness to innovation in integration systems, and the effectiveness of extension programs related to zero waste. Extension workers also convey implementation constraints they observe in the field, including social, economic, and cultural aspects that influence behavioral changes of farmers and livestock farmers.
- Officials from the Barru Regency Agriculture Office, who have a strategic role in providing information related to policy directions, programs, and regional regulations supporting agricultural and livestock integration. They explain institutional capacity, budget support, and challenges in cross-sector coordination.
- Academics, who provide theoretical and analytical perspectives related to the concept of zero waste-based integration systems. They also contribute by explaining previous research results, the potential for appropriate technological innovations, as well as institutional and socio-economic analyses of the integrative approach. The role of academics is important in critiquing the gaps between policy and practice, and providing scientifically based recommendations to support the implementation of sustainable systems.

### Data Analysis

Data analysis was conducted using a thematic approach with the stages of open coding, axial coding, and selective coding. Data validity was maintained through triangulation, with procedures for investigating problem-solving, describing or portraying the condition of the subject/object based on the research findings.

## RESULTS AND DISCUSSION

### Perceptions Regarding the Zero Waste Integration Concept

Most informants in this study affirmed that the concept of an integrated agriculture and livestock system based on zero waste is a strategic innovation in efforts to build sustainable agriculture. They perceive that this system can address classic problems in the agricultural sector, such as high dependence on chemical inputs, soil fertility degradation, and environmental issues caused by waste accumulation. This innovation is considered not only a technical alternative but also a systemic approach capable of promoting efficiency, a circular economy, and resource conservation.

Farmers explained that cattle manure, which has long been considered an environmental burden, can be utilized as a primary material in the production of compost and biogas. They noted that with proper processing, cattle manure can produce high-quality organic fertilizer that is highly needed by horticulture farmers. This creates opportunities for economic collaboration between two sectors that previously operated independently. On the other hand, the use of biogas from livestock waste is also beginning to gain attention as an alternative energy source at the household level. This is supported by the statement of Muzammil *et al.*, (2023), who emphasized that cattle manure, often seen as an environmental burden, can be transformed into a valuable resource through proper processing. This waste can be used to produce high-quality compost, biogas as an energy source, and nutrient-rich organic fertilizer, thereby supporting agricultural productivity and sustainable energy solutions.

Horticulture farmers stated that the use of organic fertilizer derived from livestock waste has a positive impact on soil structure, enhances water retention capacity, and reduces production costs. They acknowledged that compost is more environmentally friendly and, in the long term, improves land productivity in a sustainable manner. Moreover, the use of organic fertilizers also supports their efforts to meet environmentally friendly farming standards, which are increasingly in demand by the market, especially for fresh horticultural products. The use of organic fertilizers from livestock waste and other organic materials has been proven to have a significant positive impact on soil structure, water retention capacity, production costs, and land productivity. Organic fertilizers improve soil quality, water use efficiency, and sustainable productivity, while also reducing production costs in the long run (Patunah & Pradani, 2024).

Field extension officers stated that the existence of this integration system strengthens the effectiveness of assistance provided to farmers and livestock breeders. With the interconnection between commodities, extension efforts can be focused on system efficiency and the use of waste as cross-sector input. They added that farmers and livestock breeders who were previously reluctant to manage waste are now becoming motivated to learn composting and fermentation technologies. This indicates that the integration approach has shifted the mindset and behavior of key actors in the field. Integrated farming systems where crops, livestock, and sometimes forestry are managed together have been shown to significantly enhance the effectiveness of support and assistance for farmers and livestock breeders. This system integration not only improves resource efficiency and yields positive environmental impacts but also transforms the attitudes and behaviors of farmers and breeders, particularly in terms of waste management and technology adoption (Moojen *et al.*, 2022). The same finding was reported in the study by Shanmugam *et al.* (2024), which showed that the integrated farming approach combining crop cultivation and livestock rearing has made a significant contribution in enhancing the effectiveness of extension programs and technical support for farmers and livestock breeders. This cross-sector integration not only optimizes the use of natural resources and reduces negative environmental impacts but also promotes positive changes in farmers' and breeders' mindsets and practices, particularly in waste management and the adoption of technological innovations. Roubík & Mazancova (2020), noted that livestock breeders in Sumatra possess knowledge about biogas technology and its benefits. The potential for small-scale biogas system development in this region is supported by the adequate availability of animal manure as feedstock and the suitability of digester designs. However, this differs from the case in Barru, where livestock breeders tend to prioritize compost over biogas to meet their energy needs.

Officials from the Barru District Agriculture Office acknowledged that the zero waste concept is highly relevant to the direction of regional agricultural development policies, which emphasize resource efficiency and emission reduction. They observed that the integration of horticulture and livestock supports the optimization of local potential, both in terms of natural resources and institutional capacity. However, they also noted that regulatory strengthening and infrastructure support are still needed for the system to be implemented widely and sustainably. According to Nasir *et al.* (2021), the zero waste concept in regional agricultural development policy is highly relevant for enhancing resource efficiency and reducing emissions. The integration of horticulture and livestock, along with the utilization of waste as a new resource, has proven to support local potential optimization and cost efficiency. However, broad and sustainable implementation requires strengthened regulations and infrastructure.

The zero waste integration system is an essential part of the agroecological approach, which emphasizes reciprocal relationships and ecological synergy among components within the agricultural system. This approach not only focuses on waste utilization but also on building a sustainable, efficient farming system that fosters mutual benefits across sectors (Nenciu *et al.*, 2022). Academics stated that the zero waste integration system is part of the agroecological approach that stresses the reciprocal relationships among components in the agricultural system. They emphasized that integration is not merely about waste utilization, but about building ecological synergies that are mutually beneficial. In the context of Barru District, academics see great potential for developing this system, given the topographical conditions and production patterns that support both vertical and horizontal integration between sectors.

Several informants also highlighted that the implementation of this system has significant social impacts, particularly in fostering collaboration between farmer and livestock groups. This collaboration fosters solidarity and resource sharing among actors, while also opening opportunities for the establishment of commodity-based cooperatives. Informants from farmer groups noted that interaction with livestock groups has encouraged local innovation in waste processing and stimulated microeconomic growth at the village level. On the other hand, some informants pointed out challenges in implementation. They noted the lack of technical knowledge, limited waste processing facilities, and weak access to financing as major constraints. Small-scale livestock farmers in particular expressed the need for further training and support with simple tools for composting or biodigester processes. This highlights the need for capacity-building approaches and government incentives to ensure broader acceptance of the integration system. Informants also stressed the importance of a paradigm shift from a single-production approach toward an integrated and sustainable farming system. They stated that the success of the integration system depends largely on the willingness of stakeholders to collaborate, share benefits, and build mutually beneficial value networks. An inclusive and participatory approach is seen as key to grounding the zero waste concept into real-world practices within communities (Hannon & Zaman, 2018).

### **The Roles and Interests of Stakeholders**

The zero waste horticulture and cattle farming integration system requires the involvement of various actors whose roles and interests often overlap but remain distinct. Each actor brings unique perspectives, experiences, and contributions to the success of the system. These differences in interests create dynamics in the collaboration process, but also open up strong opportunities for synergy if managed properly.

Horticulture farmers reported that the need for organic fertilizer was their main motivation for supporting the integration system. They directly experience the benefits of reduced chemical fertilizer costs and improved soil quality. Most farmers believe that compost derived from livestock waste can improve soil structure, increase organic matter content, and accelerate the nutrient cycle. On the other hand, livestock farmers place more emphasis on waste management and the added value generated from cattle manure. Informants from the livestock group mentioned that livestock waste has often been simply discarded or has become a source of environmental pollution. Through this integration system, such waste can be processed into economically valuable products such as compost and biogas, which not only reduce pollution but also increase income (Bortoloti *et al.*, 2024).

The government, through the Department of Agriculture, plays a central role as a facilitator and regulator within this system. Informants from the department stated that they strive to create a supportive ecosystem through policies, regulations, as well as technical assistance and facilities. The government also plays a key role in bringing together various actors and encouraging the formation of joint institutions, such as cooperatives or integrated farmer-livestock groups.

Field extension agents, who are the frontline implementers of government programs at the local level, act as communication bridges between farmers, livestock breeders, and the government. They not only provide technical training but also promote behavioral and mindset changes regarding waste management and the use of organic fertilizers (Case *et al.*, 2017). Informants from the extension agent group emphasized that the success of this system depends on the intensity and quality of the guidance they provide. Meanwhile, academics contribute through scientific research, the development of appropriate technologies, and public and stakeholder education. According to them, the integration system requires an interdisciplinary approach that combines agricultural, livestock, environmental, and social sciences. Academics have also proposed the design of efficient waste processing systems tailored to the local context of Barru Regency.

There are differing perspectives among the actors in assessing the urgency and priorities of developing the integration system. For example, farmers tend to focus on improving crop yields and production efficiency, while livestock breeders emphasize reducing the workload associated with waste management. The government prioritizes environmental sustainability and food security, whereas academics highlight innovation and long-term sustainability. However, these differences do not necessarily pose obstacles. In many cases, informants noted that the diversity of roles and interests actually creates opportunities for collaboration and mutual complementarity. When all actors come together in participatory forums, they are able to formulate joint strategies that accommodate each party's needs.

Policy support from both central and local governments is also crucial for creating a conducive environment for the agriculture-livestock integration system (Sekaran *et al.*, 2021). Informants highlighted the need for fiscal incentives, easier access to waste processing equipment, and market protection for local organic products. Without such support, actors at the grassroots level will face difficulties in implementing the system optimally. The availability of technology and infrastructure is another key factor influencing the roles of each actor. Academics emphasize the need for low-cost innovations tailored to the capacities of small-scale farmers and livestock breeders. They also advocate for technologies such as biodigesters and compost shredders to be adapted to the local socio-economic context. In addition, socio cultural factors also influence how actors fulfill their roles. Informants noted that kinship ties, the value of mutual cooperation, and village social structures have a significant impact on the success of collaboration. For example, the involvement of traditional or religious leaders can serve as a catalyst for disseminating ideas about sustainable agriculture and system integration.

Social and cultural elements play an important role in shaping how collaboration unfolds within groups and organizations. Aspects such as cultural values, social norms, trust, and interpersonal relationships can either support or hinder effective collaboration and the achievement of shared goals (Herrmann & Tho, 2010).

### **Barriers to Implementation**

One of the main challenges expressed by informants is the low awareness among farmers and livestock breeders regarding the importance of zero waste-based integrated farming systems. Although this concept has been widely promoted by the government and academics, its implementation in the field remains limited. Informants stated that most farmers are still attached to conventional farming practices and have not yet perceived integration as an urgent necessity.

Limited technical knowledge about waste processing is also a significant barrier. Informants from extension workers and academia highlighted that many farmers and breeders do not yet understand how technologies such as composters, biodigesters, or fermentation methods work. As a result, livestock waste is often disposed of indiscriminately, and its potential for utilization is not fully realized. In addition, informants emphasized that access to appropriate waste processing technology remains very limited. Equipment such as shredders, biogas reactors, and composting units is still considered expensive and difficult to obtain for small-scale farmers. Support from local governments has not been evenly distributed, leading to noticeable technology gaps between farmer groups.

A community-based approach, which should serve as a key element in the zero-waste system, has not yet received adequate attention. As a result, many programs fail to align with local needs and often end without continuity. On the other hand, informants from academia noted that the lack of local studies presents a challenge in policymaking. Many decisions are made without considering the specific agroecological, social, and economic conditions in Barru Regency.

The implementation of institutional systems at the local level frequently encounters challenges that undermine their effectiveness (Helpap, 2023). Weak organizational structures, poor leadership, limited

management capacity, and scarce resources are major obstacles to strengthening local institutions. In several villages, farmer-livestock groups do not yet have strong organizational frameworks. Informants pointed out that weak leadership and the lack of management training are the main reasons behind the poor performance of these institutions.

Some informants highlighted the limited number of extension workers with competencies in integrated horticulture and livestock systems. Many extension agents focus only on one sector, making integrated approaches less effective. Moreover, their heavy workload prevents them from providing intensive support in the field. Market uncertainty was also a concern raised by several informants. Although horticultural products and organic fertilizers from integrated systems have high potential value, there is no guarantee of a stable market. The lack of an organized marketing system discourages farmers from making further investments in the system.

Community acceptance of the zero-waste system is influenced not only by technical and institutional factors but also heavily shaped by cultural, perceptual, and social engagement aspects. Cultural values, perceptions of cleanliness, and community involvement are key to the successful implementation of zero-waste initiatives. Education and socio-cultural approaches are vital to shift public perception and boost participation (Pietzsch *et al.*, 2017). Informants noted that in some communities, the handling of livestock manure is still considered inappropriate or contrary to notions of cleanliness. Therefore, targeted education and culturally sensitive approaches are necessary to change such perceptions.

Several informants also mentioned that climate change and extreme weather conditions are increasingly hindering the implementation of the integration system. For example, the composting process requires a certain level of moisture that is difficult to maintain during the dry season. Meanwhile, heavy rainfall can damage simple facilities like compost pits and waste storage areas. The limited availability of technically skilled human resources is another serious challenge. Informants from higher education institutions emphasized the need for training and certification for farmers, livestock breeders, and extension workers in waste processing technologies and integrated management systems. Without capacity building, the system will not be sustainable.

To address these various challenges, synergy among the government, local communities, academics, and the private sector is essential. Informants recommended the formation of a cross-sectoral team specifically tasked with planning and implementing the zero-waste system. Such collaboration is crucial to ensure that policies are participatory and adaptable to local realities.

### **System Strengthening Strategy**

The informants emphasized that the success of developing a zero-waste-based integration system between horticulture and cattle farming strongly depends on a collaborative approach. This collaboration involves various stakeholders, including farmers, livestock breeders, local governments, research institutions, and the private sector. A collaborative approach is believed to foster synergy among parties, enabling the program to run effectively and sustainably. The active involvement of key actors, particularly farmers and breeders, is considered crucial in fostering a sense of ownership and ensuring the successful implementation of the system. Therefore, participatory engagement and the strengthening of human resource capacity through technical training tailored to field needs and technological developments are integral components of this approach.

Sustainable extension services are also considered key in the capacity-building process. The informants stated that extension should not be conducted only once or incidentally, but must be programmed continuously so that the transfer of knowledge and technology can be well absorbed by farmers and livestock breeders. In addition to training and extension, the development of pilot projects is an important strategy widely recommended. Pilot projects serve as learning platforms as well as tangible evidence of the effectiveness of the integration system in the field (Ryschawy *et al.*, 2017). Farmers and livestock breeders can directly observe the benefits and management methods of the system, thereby facilitating the adoption process. The informants also highlighted the importance of contextual pilot projects, meaning that they are adapted to the agroclimatic and socioeconomic characteristics of each region. This adaptation is considered crucial to ensure that the solutions applied are truly relevant and can be implemented by the local community.

Equally important is the aspect of integrating sectoral policies. According to the informants, existing policies have tended to be sectoral and lack coordination between the agriculture and livestock sectors. Therefore, cross-sectoral policy integration is an urgent need to support the holistic development of the integration system. Such policy integration is expected to harmonize various government programs, creating a greater synergistic effect in promoting the success of the horticulture and beef cattle integration system development in Barru

Regency. Besides policies, economic incentives are also considered one of the main driving factors to encourage farmers and livestock breeders to switch to and adopt this new system. The informants emphasized that these incentives could take the form of subsidies, easier access to capital, or other supporting facilities that reduce the initial investment burden. Appropriate economic incentives can accelerate the transformation from traditional practices to a more efficient and environmentally friendly system. This also motivates farmers and breeders to improve the productivity and quality of their business outputs (Krawczyk *et al.*, 2005). The informants also reminded that incentives must be carefully designed to avoid creating dependency, but rather serve as an initial stimulus. The sustainability of the system must continue to prioritize the independence of farmers and breeders in managing their businesses.

In the context of developing this integration system, the involvement of research institutions and universities is very important. They can provide technical support and research-based innovations that form the foundation for developing appropriate technologies and management methods. The informants believe that applied research involving farmers and breeders directly in the technology development process will accelerate the adaptation and relevance of the technology to real field conditions. On the other hand, support from local government is vital, especially in terms of regulatory facilitation, funding, and program socialization. The local government also acts as a connector between different stakeholders and ensures that programs run in accordance with local needs and priorities.

## CONCLUSION

Developing of a zero-waste integration system between horticulture and cattle farming in Barru Regency demonstrates significant strategic potential in driving the transformation of agriculture toward a more sustainable, efficient, and adaptive model in response to environmental and socio-economic challenges. Collaboration among farmers, livestock breeders, agricultural extension officers, the Department of Agriculture, and academics is essential to realize this system optimally. Positive perceptions of the integration between the horticulture and livestock sectors are based on the belief that this approach not only enhances the efficient use of natural resources but also creates opportunities for household income diversification and strengthens local food security. However, for the implementation of this system to have a real impact, concrete actions are needed at both the policy and field levels. Therefore, local governments should pilot subsidized composting units in villages with high cattle density to ensure the availability of affordable and environmentally friendly organic fertilizer for horticulture farmers. In addition, extension programs must train farmers in the maintenance of biodigesters, not just their installation, to ensure that this waste management technology is utilized effectively and sustainably.

The zero-waste model applied in this system provides a comprehensive framework for minimizing waste by utilizing crop residues as livestock feed and cattle manure as raw material for organic fertilizer. This approach aligns with the principles of a circular economy, which are becoming increasingly relevant in the context of modern agricultural development. Thus, this integration not only generates economic added value but also contributes significantly to environmental conservation and carbon footprint reduction.

Although this potential is widely acknowledged, the study also reveals several key challenges that hinder the effective implementation of the integration system. These include the limited technical and managerial capacity of farmers and breeders, restricted access to appropriate technology, and the lack of economic incentives to encourage the adoption of integrated systems. In this context, a systemic and collaborative approach is crucial to overcoming existing barriers. Integration among actors within the agricultural ecosystem—including government agencies, research institutions, universities, the private sector, and farmer organizations—is needed to drive institutional and technical innovation. Strategic steps recommended by this study include holistic and participatory area-based planning, strengthening of local institutions, and the development of incentive policies that are responsive to field realities.

The findings of this study offer both conceptual and practical contributions to the development of sustainable agricultural policy. Conceptually, the zero-waste-based integration system can serve as an alternative agricultural development model that reinforces the link between resource efficiency, economic productivity, and environmental sustainability. Practically, the study underscores the need for more integrated policy interventions focused on enhancing farmer capacity and empowering local communities. As such, the development of this system is not only relevant for Barru Regency but also holds potential for replication in other regions with similar agroecological and socio-economic characteristics

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