



Integration of Agriculture, Livestock, and Fisheries in Creating a Balanced and Productive Agroecosystem

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Abstract

Integrating agriculture, livestock, and fisheries is a holistic approach to natural resource management that aims to create a balanced and productive agroecosystem. This research examines the potential and challenges in integrating these three sectors, as well as their impact on environmental sustainability and economic productivity. The method used is a comprehensive literature study and analysis of secondary data from various integration projects in Indonesia. The research results show that integration of the three sectors can increase the efficiency of land, water, and nutrient use, as well as reduce waste through a closed nutrient cycle. The integrated system can also increase land productivity by up to 40% compared to conventional monoculture systems. In addition, product diversification resulting from an integrated system can increase food security and farmer income. However, implementing this system faces challenges in the form of farmers' lack of technical knowledge, limited capital, and policy obstacles. To overcome these challenges, the government needs an active role in providing technical support, access to financing, and policies that support sector integration. In conclusion, the integration of agriculture, livestock, and fisheries has great potential in realizing a balanced and productive, agroecosystem, but requires a comprehensive approach and support from various stakeholders for successful implementation.

Keywords: Integrated agroecosystem, Agricultural sustainability, Product diversification

1. Introduction

Rapid global population growth and climate change have created major challenges in maintaining food security and environmental sustainability [1]. Conventional agricultural systems that focus on monoculture often face problems of land degradation, decreased productivity, and negative impacts on the environment [2]. In this context, the integration of agriculture, livestock, and fisheries has emerged as an innovative approach to overcome these challenges and create a more balanced and productive agroecosystem [3].

This integration concept is based on the principles of ecology and circular economy, where output from one sector becomes input for another sector, creating an efficient nutrient cycle and reducing waste [4]. For example, agricultural waste can be used as animal feed, while livestock manure can be used as organic fertilizer or a biogas energy source [5]. Integration with the fisheries sector can further increase the efficiency of resource use and product diversification [6].

Despite its great potential, the implementation of this integrated system still faces various challenges, including technical, economic, and policy obstacles [7]. Therefore, this research aims to

comprehensively examine the potential and challenges in integrating the agricultural, livestock, and fisheries sectors, as well as analyze the impact on environmental sustainability and economic productivity. It is hoped that the results of this research will provide valuable insights for policymakers, practitioners, and researchers in developing effective strategies for realizing a balanced and productive agroecosystem through an integrated approach.

While this integration has enormous potential, its implementation is challenging. Data shows that around 65% of farmers report needing knowledge and skills regarding the principles of integration, while 70% experience difficulties accessing the capital required for initial investment. In addition, only 30% of agricultural policies explicitly support sector integration, suggesting the need for more supportive policy reforms.

In this context, this study aims to explore the potential and challenges of integrating agriculture, livestock, and fisheries in Indonesia. By analyzing data from various integration projects implemented, this research can provide deeper insights into the benefits and barriers faced and recommendations for policies and best practices in implementing integrated agroecosystem systems. With a comprehensive approach and support from various stakeholders, the integration of these sectors can be vital to achieving sustainable food systems, improving food security, and supporting rural development in Indonesia.

2. Materials and Methods

This research uses qualitative and quantitative approaches to examine the integration of agriculture, animal husbandry, and fisheries in realizing a balanced and productive agroecosystem. The method used consists of two main components:

2.1 Comprehensive Literature Study:

- a. Conduct systematic reviews of scientific articles, technical reports, and other relevant publications from various academic databases such as Scopus, Web of Science, and Google Scholar.
- b. Identify and analyze models of integration of agriculture, livestock, and fisheries that have been developed in various countries.
- c. Examining the factors that influence the success of integrated system implementation, including technical, economic, social, and policy aspects.

2.2 Secondary Data Analysis:

- a. Collecting data from agriculture, livestock, and fisheries integration projects that have been implemented in Indonesia.
- b. Carrying out a comparative analysis between an integrated system and a conventional monoculture system, focus on the following indicators:
 - Land productivity
 - Efficient use of resources (water, nutrients, energy)
 - Environmental impact (greenhouse gas emissions, soil and water quality)
 - Product diversification and farmer income
- c. Uses descriptive and inferential statistical methods to analyze trends and patterns from collected data.

To ensure the validity and reliability of the research, data triangulation was carried out by comparing the findings from the literature study with the results of secondary data analysis. In addition, consultations were carried out with experts in the field of integrated agriculture to verify data interpretation and enrich the analysis.

Research limitations include a focus on the Indonesian context, although case studies from other countries are also considered for comparison and learning. The time period covered in secondary data analysis is the last 10 years to ensure relevance to current conditions.

It is hoped that the results of this research method will provide a comprehensive understanding of the potential, challenges, and impacts of the integration of agriculture, livestock, and fisheries, as well as provide an empirical basis for policy recommendations and best practices in implementing integrated agroecosystem systems.



3. Results

3.1 Efficient Use of Resources

The integration of agriculture, livestock, and fisheries shows a significant increase in resource use efficiency compared to conventional monoculture systems.

Table 1. Comparison of Resource Use Efficiency [8]

Indicator	Integrated System	Monoculture System	Efficiency Improvement
Water Use (m ³ /ha/year)	7,500	10,000	25%
Fertilizer Use (kg/ha/year)	350	500	30%
Energy Use (MJ/ha/year)	15,000	20,000	25%

Integrated systems show significant efficiency improvements in resource use. Water use was reduced by 25%, from 10,000 m³/ha/year in a monoculture system to 7,500 m³/ha/year in an integrated system. This is achieved through recycling water from fish ponds to agricultural land and more effective use of rainwater.

Fertilizer use decreased by 30%, from 500 kg/ha/year to 350 kg/ha/year. This decrease is caused by the use of livestock manure as organic fertilizer, which not only reduces the need for chemical fertilizers but also increases long-term soil fertility. Cow manure, for example, contains 0.5% N, 0.3% P, and 0.5% K, which is equivalent to 25 kg of NPK fertilizer per ton [18].

Energy efficiency increased by 25%, with energy use falling from 20,000 MJ/ha/year to 15,000 MJ/ha/year. This is achieved through the production of biogas from livestock and agricultural waste, which can be used for on-farm energy needs such as water pumping and crop processing.



Figure 1. Nutrient cycle in the integrated system [26]

Integrated systems allow the utilization of waste from one sector as input for another sector, creating a closed nutrient cycle that reduces the need for external inputs and minimizes waste [9].

3.2 Increased Land Productivity

The results of the analysis show that the integrated system can increase land productivity significantly.

Table 2. Comparison of Land Productivity (ton/ha/year) [10]

Commodity	Integrated System	Monoculture System	Improvement
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Rice	6.5	5.0	30%
Fish	2.0	1.5	33%
Livestock (Cattle)	0.8	0.5	60%

Land productivity increases significantly in an integrated system. Rice production increased 30%, from 5.0 tons/ha/year to 6.5 tons/ha/year. This increase was due to improved soil fertility from organic inputs and better pest management through crop rotation.

Fish production increased 33%, from 1.5 tons/ha/year to 2.0 tons/ha/year. This increase results from the use of agricultural waste as fish feed and the use of nutrient-rich pond water for crop irrigation.

Livestock (cattle) productivity increased by 60%, from 0.5 tons/ha/year to 0.8 tons/ha/year. This is achieved through the use of agricultural waste as feed, which reduces feed costs and increases feed conversion efficiency.

This increase in productivity is caused by the synergy between sectors, where agricultural waste is used as animal and fish feed, while livestock manure is used as organic fertilizer and a source of nutrition for fish [11].

3.3 Environmental Impact

Integrated systems show a 30% reduction in greenhouse gas emissions compared to monoculture systems. For a scale of 100 hectares, the monoculture system produces around 500 tons of CO₂ equivalent per year, while the integrated system only produces 350 tons of CO₂ equivalent per year.

This decline was caused by several factors:

- Reduction in the use of chemical fertilizers, which produce N₂O emissions in their production and application.
- Utilization of livestock manure for biogas, which reduces methane emissions from conventional manure management.
- Increased carbon sequestration in soil through the addition of organic matter.

In addition, integrated systems increase local biodiversity. Studies in West Java showed a 40% increase in the diversity of beneficial insect species and a 25% increase in bird populations on integrated agricultural land compared to monoculture [19].

3.4 Product Diversification and Farmer Income

The integration of the agriculture, livestock, and fisheries sectors provides significant product diversification opportunities.

Table 3. Product Diversification and Contribution to Farmer's Income [13]

Product	Contribution to Income (%)
Food Crops	45%
Livestock Products	30%
Fishery Products	20%
By-products	5%

Product diversification in an integrated system provides better economic security for farmers. Food crops contribute 45% of income, livestock products 30%, fishery products 20%, and by-products such as compost and biogas 5%.

Cash flow analysis shows that the integrated system increases farmers' net income by 40-60% compared to the monoculture system. For 1 hectare of land, annual net income increases from IDR 25 million to IDR 35-40 million [20].



More importantly, this diversification reduces economic risk. Monte Carlo simulations show that in an extreme climate change scenario, the probability of financial loss in an integrated system is 15%, compared to 40% in a monoculture system [21].

This diversification increases farmers' economic resilience to price fluctuations and the risk of crop failure in one sector [14].

3.5 Implementation Challenges

Despite the significant benefits, the implementation of integrated systems faces several major challenges:

- a. Technical knowledge: 65% of farmers report a lack of knowledge and skills. A survey of 500 farmers in 5 provinces showed that only 20% fully understood the principles of agriculture-livestock-fisheries integration [15].
- b. Capital: 70% of farmers experience difficulty accessing capital. Financial analysis shows that the initial investment for a 1-hectare integrated system is around IDR 50-75 million, which is 50% higher than a conventional monoculture system [16].
- c. Policies: Only 30% of agricultural policies explicitly support sector integration. Policy analysis in 10 districts shows that most government programs still focus on increasing monoculture food crop production [17].

To overcome these challenges, a comprehensive approach is needed that involves:

- Intensive training programs for farmers and agricultural extension workers.
- Innovative financing schemes, such as group-based microcredit or payments for environmental services.
- Policy reforms that encourage cross-sector integration and incentives for the adoption of sustainable agricultural practices.

The research results show that the integration of agriculture, animal husbandry, and fisheries has great potential in realizing a balanced and productive agroecosystem. This system is able to increase the efficiency of resource use, land productivity, and economic resilience of farmers, as well as reduce negative impacts on the environment. However, successful implementation requires policy support, increased farmer capacity, and access to adequate capital.

4. Discussion

The results of this research show that the integration of agriculture, livestock, and fisheries has significant potential in creating a more balanced and productive agroecosystem. The observed increases in resource use efficiency, land productivity, and income diversification are in line with the findings of previous studies in various developing countries [22]. However, the scale and intensity of the increase observed in the Indonesian context may be higher due to tropical climate conditions that favor more intensive biological interactions between system components.

The 30% reduction in greenhouse gas emissions observed in the integrated system is an important contribution to climate change mitigation. This figure is higher than global estimates which range between 10-20% [23], possibly due to higher land use intensity in Indonesia and greater potential for carbon sequestration in tropical soils.

An increase in farmer income of 40-60% shows the potential of an integrated system to improve the welfare of rural communities. However, it should be noted that this increase may not be uniform across all regions and depends on various factors such as market access, input availability, and local policies [24].

The implementation challenges identified, particularly regarding technical knowledge and access to capital, reflect the complexity of the integrated system. This emphasizes the importance of a holistic approach to agricultural development, which includes not only technological innovation but also capacity development and policy reform [25].

Although the results of this study are promising, several limitations need to be noted. First, the data used mostly comes from pilot projects and may not fully represent the conditions of smallholder farmers in general. Second, economic analysis does not fully take into account



transaction costs and long-term risks. Third, the socio-cultural impacts of the transition to integrated systems have not been explored in depth.

5. Conclusions

The integration of agriculture, livestock, and fisheries offers a promising solution for realizing a balanced and productive agroecosystem in Indonesia. These systems demonstrate significant improvements in resource use efficiency, land productivity, and farmers' economic resilience while reducing negative environmental impacts.

However, successful implementation requires a comprehensive and adaptive approach. Key recommendations include:

- a. Development of intensive and sustainable training programs to increase the technical capacity of farmers and extension workers.
- b. Innovation in financing schemes adapted to the characteristics of integrated systems, including longer investment return periods.
- c. Policy reforms that encourage cross-sector integration and provide incentives for the adoption of sustainable agricultural practices.
- d. Invest in long-term research to optimize synergies between system components and comprehensively measure social-ecological impacts.
- e. Development of a value chain that supports product diversification from an integrated system, including certification and marketing of environmentally friendly products.

With the right approach, the integration of agriculture, livestock, and fisheries can be the key to realizing a sustainable food system, increasing food security, and supporting rural development in Indonesia.

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