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Beef Cattle Development with Integrated Farming System Model Based on Land Area in Minahasa District

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ABSTRACT

The objective of the study was to assess the economic, ecological, and social feasibility of integrated farming between beef cattle and food crops (rice and corn) and beef cattle and vegetables across different land area treatments (1-5 hectares). The research was conducted in Minahasa Regency from March 2024 to July 2024. The sample was determined using a stratified random sampling method. The research indicators included economic feasibility, ecological feasibility, and social feasibility, with measurement variables including (1) production costs, (2) production acceptance of cow dung waste (solid and liquid), (3) inorganic fertilizer requirements, and (4) organic fertilizer contribution to inorganic fertilizer substitution. Data analysis was conducted using the R/C, KTP/KBP, and KPO/KPA formulas. The results of the analysis indicated that the integration of beef cattle with rice, corn, and vegetable crops achieved values of economic and social feasibility greater than 1. This is interpreted to mean that any increase in production costs is followed by an increase in benefits and any increase in organic fertilizer production is followed by a corresponding contribution to replacing inorganic fertilizers. However, the availability of organic fertilizer has not been sufficient to replace the use of inorganic fertilizers in almost all land area treatments, as organic fertilizer production does not meet the required needs. Therefore, farmers still depend on inorganic fertilizers.

Keywords: Beef Cattle; Fertilizer-Feasibility; Food Crops; Integrated-Farming System; Land Area Model-Based

INTRODUCTION

One way for beef cattle farming in Minahasa District, North Sulawesi Province, to develop effectively is through an integrated rearing system. In general, beef cattle farming, especially with local Peranakan Ongole (PO) cattle in Minahasa District, is still carried out traditionally. As a result, the population development fluctuates with a tendency to decline (Kalangi et al., 2022). According to the research by Lenzun et al. (2023), beef cattle farming in Minahasa District is not well developed due to the lack of land utilization for planting forage and the unavailability of quality animal feed, such as fermented feed from agricultural waste.

The integrated farming system model is a solution for the development of beef cattle farming in Minahasa District because it is fundamentally an agricultural system that integrates livestock and crop farming activities on the same land. This approach can increase the efficiency and productivity of resources (land, labor, and other growth factors) and can enhance independence, farmer welfare, and environmental sustainability. Previous research by Lainawa et al. (2024) states that the integrated farming development model with the LEISA system (Low External Input for Sustainable Agriculture) focuses on leveraging industry attractiveness by producing four products (4Fs): fuel, fertilizer, feed, and food, utilizing biogas and aquaponics to increase production, productivity, and product competitiveness. However, this research focuses on how to utilize livestock manure as organic fertilizer and how to use plant waste as animal feed.

In this study, at least three important points must be clearly understood if our policy aims to develop agriculture with an integration pattern: whether the integration of livestock, food crops, and vegetables is economically, ecologically, and socially feasible. This feasibility is expected to guide farmers to increase farm income and improve the welfare of farm families and society. Setiawan et al. (2021) stated that the development of the agricultural sector is fundamentally aimed at improving the welfare of farmers and ensuring food security for the people of Indonesia. Agricultural development focuses mainly on increasing agricultural production, productivity, and competitiveness. Several models of crop-livestock integration in integrated farming systems will be studied, including livestock integration with food crops (rice and corn) and livestock integration with vegetable crops (horticulture).

The study by Moeis et al. (2020) shows that agricultural land is an important asset for farm households, in addition to its role as the main production factor in the agricultural sector. For this reason, land ownership and use are fundamental aspects and serve as a proxy for capabilities that affect psychological well-being (Rao, 2018). Farmers who maintain land ownership and effectively utilize their farmland will have a sense of security in production, which in turn increases their income and welfare and encourages them to remain in the agricultural sector. The results of the 2014 Indonesia Family Life Survey (IFLS) in Pratiwi and Moeis (2022), showed that only 32.7 percent of farming households owned agricultural land.

In Minahasa District, North Sulawesi Province, agricultural land use is poorly planned. Most land is used for food crops like rice and corn, and horticulture such as vegetables. Beef cattle farming typically takes place on unproductive land or in plantation areas. Consequently, the expansion of rice fields reduces cattle pasture areas, increasing costs. To reduce costs associated with purchasing inorganic fertilizers and cattle feed, integrating livestock and crops is essential in Minahasa District.

The challenge, however, lies in determining the economic, ecological, and social feasibility of integrated livestock and crop farming. This study examines integrating livestock with rice, corn, and vegetables under a zero-waste principle, where cattle manure is used as organic fertilizer and crop waste as animal feed. It specifically evaluates the feasibility of integrating beef cattle with food crops and vegetables on various land sizes (1-5 hectares). The research's novelty is its finding that both small (below 1 hectare) and large (above 1 hectare) land areas can equally achieve economic, ecological, and social feasibility in integrated crop and livestock farming.

LITERATURE REVIEW

Concept of Integrated Farming System

Crop-fish integrated farming systems are popular in many countries. Wide-scale implementation of these systems can accelerate poverty and malnutrition reduction, strengthen environmental sustainability, and mitigate global warming (Wiesner et al., 2020). This system optimizes crop waste into animal feed and livestock manure into crop fertilizer to improve soil fertility, nutrient cycling, and land productivity. Crop-cattle integration systems have the potential to be further developed in areas with both limited and extensive agricultural land. The aim is to increase production, population, productivity, and the competitiveness of livestock products.

The study by Baba et al. (2014) showed that the lack of technology for processing feces, as well as the absence of funds and skills to convert feces into organic fertilizer, are inhibiting factors. According to Haryanta et al. (2018), the concept of integrated agriculture will produce the "4Fs": food, feed, fuel, and fertilizer. Food is the main product of each farm, consisting of staple foods. Feed is derived from farming activities and used for animal and fish feed. Fuel refers to energy that can be produced in the form of heat (biogas). Fertilizer is the end product of the decomposer process in biogas production, available as solid and liquid fertilizers.

The study by Indrawati et al. (2021) combined dairy cattle farming with corn farming activities, resulting in the production of the “4Fs." These products are essential for sustainable agricultural and livestock businesses, helping to minimize external inputs. Mukhlis et al. (2018) researched the rice-cattle integration system (SIPT) and found that it can be highly beneficial due to the use of manure, which increases productivity, reduces production costs, and raises farmers' income. The income contribution from SIPT to total household income is significant. Additionally, SIPT optimizes local resources, such as using straw as animal feed and cow dung as organic fertilizer, ensuring that no waste is discarded. Elly et al. (2019) demonstrated that integrating corn crops with cattle farming can be economically advantageous and help minimize environmental pollution. An integrated farming system model is shown in Figure 1.

Figure 1. General Model of Integrated Farming System

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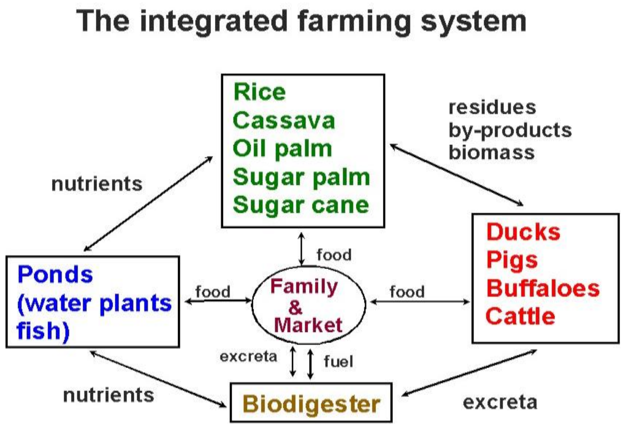

Source: Preston (2000)

The principle of integration in Integrated Farming Systems (Preston, 2000) must consider the following: (1) Agroecosystems with high diversity, which can provide greater assurance for farmers in a sustainable manner; (2) The need for functional diversity, which can be achieved by combining plant and animal species with complementary traits that interact synergistically and positively, thereby enhancing not only stability but also the productivity of agricultural systems with lower inputs; (3) The implementation of sustainable agriculture requires the support of human resources, knowledge and technology, capital, product and consumer relations, and addressing the balance between agriculture's developmental mission and sustainability; (4) Maximizing functional diversity to create complex and integrated agricultural systems that utilize existing resources and inputs optimally; (5) Identifying combinations of plants, animals, and inputs that lead to high productivity, production security, and conservation of resources, which are compatible with the limitations of land, labor, and capital. This approach forms a robust agroecosystem.

Highly diverse agroecosystems offer a greater guarantee of farming success. Functional diversity can be achieved by combining plant and animal species with complementary traits that interact synergistically and positively. This not only improves stability but also enhances the productivity of the farming system with lower inputs. The advantages of this system include minimal or no external inputs due to waste cycling among organisms, increased biodiversity—especially through the use of local resources—enhanced nitrogen fixation, higher plant resistance to pests and invaders, and the production of biogas as a by-product for household fuel (Preston, 2000).

Plant Waste and Cattle Manure as Organic Fertilizer

Rice straw is an agricultural waste that has the potential to be used as animal feed. Its potential as feed is indicated by the amount of rice straw produced, which can be estimated from rice production. According to Muhakka et al. (2017), the production of rice straw compared to rice production has an average ratio of 1:1. However, rice straw has certain drawbacks when used as animal feed, including low crude protein content, high levels of crude fiber, lignin, and silica, low mineral content, low digestibility, and low palatability. Therefore, efforts are needed to improve the quality of rice straw for animal feed, such as: (1) enhancing its nutritional value and digestibility, (2) addressing deficiencies by adding nitrogen or minerals, (3) increasing energy availability, and (4) improving palatability to encourage consumption. For this reason, a technology is needed to improve the quality of rice straw as animal feed that is: (1) easy, practical, and economical, (2) processed straw must be cheaper or at least not more expensive than other feeds with equivalent nutritional value, (3) uses affordable or already available equipment for farmers, and (4) utilizes inexpensive materials.

The ammoniation process using a urea solution plays a significant role by hydrolyzing lignocellulose bonds, breaking down hemicellulose bonds, adjusting or developing cellulose fibers to facilitate the penetration of cellulase enzymes, and increasing nitrogen levels, which in turn raises crude protein content. The benefits of ammoniation include enriching the protein content by 2 to 4 times the original protein content, increasing digestibility, and enhancing the quantity of feed consumption (Muhakka et al., 2017).

In addition to rice crop waste, corn crop waste can also be used as animal feed. Corn crop waste has great potential as a feed ingredient due to its high fiber content, making it suitable for ruminant cattle feed. The utilization of corn waste through technology includes making hay, silage, and fermentation (Bunyamin et al. in Bahasoan & Buamona, 2023). Corn crop waste can be converted into animal feed through silage, which is produced by fermenting forage with high water content. After corn is harvested, the leaves, stems, and cobs can be used as feed for beef cattle.

The integration of cattle and horticultural crops aims to utilize vegetable scraps that have been harvested and are no longer marketable but can be repurposed as feed. Vegetable scraps and cattle manure can be used to produce compost and organic fertilizer. Vegetable crop waste can serve as a source of feed for beef cattle, while cow manure is ideal for composting due to its nutrient content, including 0.33% nitrogen, 0.11% phosphorus, 0.13% potassium, and 0.26% calcium. Compost (organic) fertilizer is considered the best and most natural soil improver compared to artificial/synthetic alternatives. Although organic fertilizers generally have low macronutrients (N, P, K), they contain sufficient micronutrients necessary for plant growth. In the integration of rice plants with cattle, providing organic fertilizer for rice plants (per hectare every 6 months) requires 4.72 livestock units (LU), assuming that the feces produced are fully utilized as organic fertilizer. The composting process is divided into four stages: the stirring process, mixing at 1 week, mixing at 2 weeks, and compost packaging. The conversion of cattle manure into value-added products provides environmentally friendly alternative energy, addresses environmental pollution caused by livestock waste, improves energy efficiency, and enhances community welfare (Sari & Emawati, 2020).

Waste-Free Integrated Farming System Concept

Integrated agriculture is a sustainable system based on the principle that everything produced will return to nature, meaning that waste generated is reused as a valuable resource. The crop-livestock integration model developed in various regions and countries focuses on a “zero waste production system” concept, where all waste from livestock and crops is recycled and reintegrated into the production cycle. Crop, livestock, and fisheries farming generate various types of waste that can pollute the environment if not properly managed. Therefore, effective agricultural waste management is essential to reduce environmental pollution while minimizing external energy inputs, thereby increasing farming efficiency and ensuring food security for a region. This concept is known as LEISA. One approach to implementing the LEISA concept in farming is through a Crop-Livestock-Fish Integration System (SITTI) (Atria et al. in Istiqomah & Kusumawati, 2022).

With a waste-free approach, every hectare of agricultural land can produce enough feed to raise 2-3 cattle per hectare. In this system, cattle serve as a “compost factory,” using plant waste as raw material, which is then converted into organic fertilizer for crops. To increase the beef cattle population at a reasonable production cost, integrating livestock with food crops, plantations, and industrial forest plantations is feasible from technical, economic, and social perspectives. One of the keys to success in this model is ensuring that no material is wasted, alongside the correct and efficient utilization of innovations, which is central to the concept of integrated agriculture.

Agricultural waste from food, vegetables, fruits, plantations, and other crops can be used as raw material for composting or organic fertilizer production. Livestock waste can be converted into organic fertilizer in both solid and liquid forms and can also serve as raw material for biogas or bioenergy production. Solid and liquid waste from the biogas production process can further be used as organic fertilizer. Fresh agricultural waste can be directly used as animal feed, including straw, corn stover, vegetable waste, and crop residues. The integration of crop-livestock systems following the LEISA and zero-waste principles aligns with the concept of environmentally sustainable development.

LEISA increases the efficiency of natural resource use and reduces greenhouse gas emissions. Sourcing feed from plantation crop waste, food crops, or agro-industry does not require special land, thereby conserving land and water resources. However, planting feed crops and food crops specifically for livestock would necessitate the use of new land and water resources (Istiqomah & Kusumawati, 2022).

RESEARCH METHOD

The research was conducted in Minahasa District from March 2024 to July 2024. The location was chosen based on the potential for beef cattle farming, food crops, and vegetable crops currently being developed by farmers in the district. Primary data were collected through interviews with informants, while secondary data were gathered from books, journals, the internet, and other related sources. The study population consisted of all farmers engaged in beef cattle, rice, corn, and vegetable farming. Sampling was carried out using the Stratified Random Sampling Method, which involves dividing the population into smaller groups based on the respondent's farm size, specifically; 0.5-1 hectare, 2 hectares, 3 hectares, 4 hectares, and 5 hectares. The total number of respondents was 60 farmer households from the Langowan Barat, Tompaso Barat, and Kawangkoan Barat sub-districts.

Three integration patterns were observed: (1) integration of beef cattle and rice, (2) integration of beef cattle and corn, and (3) integration of beef cattle and vegetable crops. The research indicators included economic feasibility, ecological feasibility, and social feasibility, with measurement variables comprising: (1) production (operational) costs, including fixed and variable costs, measured in rupiah per production cycle; (2) farm income obtained from integrated farming, measured in rupiah per production cycle; (3) production of cow dung waste (solid and liquid), measured in kilograms per production cycle; (4) inorganic and organic fertilizer requirements, measured in kilograms per production cycle; and (5) the contribution of organic fertilizer to inorganic fertilizer substitution, measured in kilograms per farming period.

Data analysis included: (1) using the R/C (Revenue/Cost) ratio to determine the economic feasibility of each integration system; (2) applying the KTP/KBP formula, which calculates ecological feasibility by dividing the fertilizer needs (KTP) by the availability of organic fertilizer from cattle waste (KBP); and (3) assessing social feasibility using the KPO/KPA formula, which evaluates the contribution of organic fertilizers in substituting inorganic fertilizers. This is determined by dividing the availability of organic fertilizers

(KPO) by the need for inorganic fertilizers (KPA) in kilograms per period. This analysis interprets how much organic fertilizer contributes to reducing (saving) production costs associated with purchasing inorganic fertilizers.

RESULTS

Characteristics of the Study Area

According to Central Agency of Statistics of Minahasa (BPS Minahasa Regency, 2024), Minahasa Regency consists of 25 sub-districts, 227 villages, and 43 urban villages, with a total population of 350,317. It is comprised of one inhabited island, located within North Sulawesi Province. Geographically, it is situated between 01º01'00" - 01º29'00" N latitude and 124º34'00"- 125º05'00" E longitude. Minahasa Regency is bordered by Manado City to the north, Southeast Minahasa Regency to the south, North Minahasa Regency and the Maluku Sea to the east, and the Sulawesi Sea and South Minahasa Regency to the west. The regency has a land area of 1,141.64 km² (114,164 ha) and an estimated water area (lakes) of 46.54 km² (4,654 ha). Climatologically, Minahasa Regency experiences a moderate rainfall pattern, with wet areas receiving more than 2,000 mm of rainfall per year and dry areas receiving less than 2,000 mm per year.

The agriculture sector (including livestock, forestry, and fisheries) contributed 32.87% to the Gross Regional Domestic Product (GRDP) of Minahasa Regency in 2022 and provides significant opportunities for improving food security, reducing poverty, and promoting dynamic economic growth. Rice and corn are staple crops in Minahasa Regency, contributing almost 20.251% of the district's total cereal production. The production of paddy rice has shown a declining trend over the past five years, from 91,468.3 tons in 2018 to 70,161 tons in 2022. The production levels of paddy rice, field rice, and corn in Minahasa Regency are presented in Table 1.

Table 1. Production of Rice Paddy, Paddy Field, and Maize in 2018-2022 (tons)

Commodities	2018	2019	2020	2021	2022	5 Years
Paddy Rice	91,468	82,406	78,911	81,684	70,161	404,630
Paddy Field	11,058	14,030	259	855	-	26,202
Corn	251,122	169,476	184,506	139,921	158,424	903,449

Rice paddy production at the sub-district level in Minahasa Regency over the last four years (2020-2023) has been analyzed and is presented in Table 2. The production of paddy rice increased in 2023 in six sub-districts, with the highest increase in West Kakas Sub-district, where rice paddy production rose by 3,889 tons compared to 2020. The detailed production of paddy rice per sub-district from 2020 to 2023 is presented in Table 2.

Table 2. Production of Paddy Rice Per Sub-District in Minahasa District Year 2020 – 2023 (tons)

No.	District	Year/Production				Total
		2020	2021	2022	2023	
1	North Tondano	1,955	2,284	1,578.9	1,430.0	7,248
2	West Tondano	7,560	7,846	4,845.0	3,877.5	24,129
3	East Tondano	11,438	8,967	5,386.5	5,980.8	31,772
4	South Tondano	5,498	4,489	2,331.3	2,975.5	15,294
5	Remboken	2,911	3,136	2,696.1	2,568.5	11,312
6	Eris	2,311	3,155	2,707.5	1,425.0	9,599
7	Kombi	90	314	34.2	0.0	438

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8	Lembean East	0	0	0,0	0,0	0
9	Kakas	8,202	5,566	7,096.5	3,239.5	24,104
10	Kakas West	9,201	9,015	7,888.8	13,090.0	39,195
11	Langowan West	3,884	5,785	4,719.6	4,835.0	19,224
12	Langowan East	6,773	6,625	7,877.4	10,202.5	41,478
13	Langowan South	1,408	1,376	2,217.3	1,379.4	6,381
14	Langowan North	3,209	3,819	2,568.2	2,244.0	11,840
15	Tompaso	5,578	7,958	8,726.7	4,845.0	27,108
16	Tompaso West	1,227	2,194	1,596.0	1,599.6	6,617
17	Kawangkoan	473	787	370.5	264.0	1,895
18	North Kawangkoan	489	510	421.8	495.0	1,916
19	West Kawangkoan	2,077	2,465	1,345.2	1,188.0	7,075
20	Sonder	3,857	3,969	3,705.0	2,706.0	14,237
21	Tombariri	0	0	0.0	0.0	0
22	East Tombariri	771	1,424	1,048.8	359.6	3,603
Minahasa Regency		80,932	83,705	71,183	76,728	-

For corn crops, there has been a decrease in production each year due to the reduction in the planting and harvesting areas. The highest corn production was in 2020, amounting to 196,506 tons, with the largest contribution from East Tombariri Sub-district, totaling 19,500 tons. Corn production decreased in 2023 compared to previous years. Details of corn production from 2020 to 2023 are presented in Table 3.

Table 3. Maize Production Per Sub-District in Minahasa District Year 2020 - 2023 (tons)

No.	District	Year/Production				Total
		2020	2021	2022	2023	
1	North Tondano	3,642	6,186	7,482.45	20,318	20,318
2	West Tondano	8,346	6,552	6,028.03	24,617	24,617
3	East Tondano	6,894	3,732	8,576.27	20,156	20,156
4	South Tondano	8,580	3,978	6,154.24	22,252	22,252
5	Remboken	11,970	5,635	7,969.26	29,486	29,486
6	Eris	6,600	4,650	6,544.89	20,083	20,083
7	Kombi	7,134	4,062	7,043.72	21,534	21,534
8	Lembean East	4,890	2,658	5,396.98	14,430	14,430
9	Kakas	11,520	8,197	4,681.79	27,477	27,477
10	Kakas West	11,952	13,853	6,863.42	33,436	33,436
11	Langowan West	4,290	3,276	2,902.83	10,942	10,942
12	Langowan East	1,176	1,194	1,135.89	3,732	3,732
13	Langowan South	4,452	3,624	2,830.71	11,737	11,737
14	Langowan North	1,260	1,599	1,364.27	4,769	4,769
15	Tompaso	9,516	9,498	10,848.10	35,621	35,621
16	Tompaso West	7,494	6,210	5,306.83	19,821	19,821
17	Kawangkoan	7,968	5,109	5,853.74	19,027	19,027
18	North Kawangkoan	3,600	3,684	2,836.72	11,441	11,441
19	West Kawangkoan	7,932	12,960	13,288.00	39,076	39,076
20	Sonder	13,110	10,884	8,504.15	35,504	35,504
21	Tombariri	12,000	4,728	9,231.36	29,556	29,556
22	East Tombariri	19,500	9,138	8,480.11	40,808	40,808
23	North Tondano	8,250	2,862	4,381.29	16,164	16,164
24	West Tondano	6,972	1,422	8,155.57	18,299	18,299
25	East Tondano	7,458	4,230	6,623.02	19,213	19,213

Minahasa Regency	196,506	139,921	158,484	54,588	549,499

Integration of Rice Crops with Beef Cattle
The beef cattle farming observed in this study is based on land area criteria, measured with the standard Adult Unit (AU). An Animal Unit (AU) is a unit for livestock based on feed consumption, where each AU is assumed to represent the consumption of one adult cow. The age categories of beef cattle are: calves (0-12 months), young cattle (1-2 years), and adult cattle (>2 years). With a land area of 1 hectare, the observed beef cattle numbered 2 head; for a land area of 2 hectares, 4 head; for 3 hectares, 6 head; for 4 hectares, 8 head; and for 5 hectares, 10 head.

Minahasa Regency is currently developing farming systems based on integrated farming principles, particularly the integration of crops and beef cattle. Farmers commonly raise Peranakan Ongole (PO) cattle. One of the main challenges faced by farmers in Minahasa is the provision of feed. Therefore, they integrate farming with agricultural crops, such as rice, to meet livestock feed needs. Additionally, in rice cultivation, farmers encounter challenges in sourcing fertilizer. Thus, maintaining beef cattle is considered crucial for providing fertilizer, which is produced in the form of feces and urine.

Based on these potentials and challenges, both rice and beef cattle commodities have the potential for integrated development in Minahasa Regency. This integration can produce main products (rice and meat) and by-products (straw, bran, manure, and raw materials for biogas production). The fertilizer needs and availability of organic fertilizer for integrated rice and beef cattle farming are presented in Table 4.

Table 4. Fertilizer Requirement and Availability of Organic Fertilizer for Rice Plantation Integration with Beef Cattle for One Planting Season in Minahasa Regency (90 Days Period)

Land Area (ha)	Number of Livestock (head)	Production/Day			Fertilizer Requirement (kg/day)			
		Feces (kg)	Urine (liter)	Total Organic Fertilizer (kg)	Inorganic	Solid Organic	Liquid Organic	Total Organic Fertilizer
1	2	20	16	36	300	148	7	155
2	4	40	32	72	600	296	14	310
3	6	60	48	108	900	444	21	465
4	8	80	64	144	1200	592	28	620
5	10	100	80	180	1500	740	35	775

The calculation of fertilizer requirements is based on the regulation of the Minister of Agriculture Number 40/Permentan/Ot.140/4/2007 (Indonesian Ministry of Agriculture, 2007) concerning recommendations for N, P, and K fertilization in site-specific paddy rice cultivation. For low productivity levels (<5 t/ha), 200 kg/ha of urea is required; for medium productivity levels (5-6 t/ha), 250-300 kg/ha of urea is needed; and for high productivity levels (>6 t/ha), 300-400 kg/ha of urea is required.

The SIPT program is one of the alternatives for increasing rice and beef production while boosting farmers' income. Therefore, the development of this system must consider aspects of economic feasibility, ecological feasibility, and social feasibility. The results of the analysis of the economic, ecological, and social feasibility of rice and cattle integration are presented in Table 5.

Table 5. Economic, Ecological, and Social Feasibility of Rice and Beef Cattle Integration in Minahasa District Beef Cattle in Minahasa District/Production

Land Area (ha)	Number of Livestock (head)	Revenue (IDR)	Production Cost (IDR)	Economic Feasibility	Ecological Feasibility	Social Feasibility
1	2	41,268,500	22,034,848	1.67	0.23	1.93
2	4	82,537,000	39,662,726	1.67	0.23	1.93
3	6	123,805,500	56,188,862	1.67	0.23	1.93
4	8	165,074,000	70,511,514	1.67	0.23	1.93
5	10	206,342,500	82,630,680	1.67	0.23	1.93

Economic feasibility is determined by the ratio between benefits and production costs, with an average value of 1.67 (Table 5). This indicates that the integration of rice crops and beef cattle is feasible, as the benefits to farmers exceed the costs incurred. This figure also shows that for every unit increase in production costs, there is a 1.67 unit increase in benefits.

Ecological feasibility is calculated by dividing the availability of organic fertilizer by the need for fertilizer. The average feasibility value for each land area integrating rice and beef cattle in Minahasa Regency is 0.23 (Table 5). This suggests that, under current conditions, the availability of organic fertilizer cannot replace inorganic fertilizer, and farmers remain dependent on inorganic fertilizers.

Social feasibility is determined by the ratio of inorganic fertilizer usage to the contribution of organic fertilizer. Based on the calculations, the average feasibility value for each land area is 1.93 (Table 5). This means that organic fertilizer contributes to reducing the need for inorganic fertilizer, allowing farmers to increase their income by reducing the cost of purchasing inorganic fertilizer. The social value refers to the reduction in farmers' burden due to the use of beef cattle manure as organic fertilizer, which also prevents soil degradation and potential groundwater contamination. A value of 1.93 indicates that for every unit increase in organic fertilizer, there is a 1.93 unit reduction in the use of inorganic fertilizer.

Research by Zahara et al. (2017) showed that the ratio of revenue to costs (R/C ratio) is 2, indicating that integrated rice farming with beef cattle is feasible. Sjofjan (2021) found that using organic fertilizers in rice cultivation can reduce fertilizer production costs by 60%. Mukhlis et al. (2018) demonstrated that the SIPT provides benefits by using organic fertilizer from processed beef cattle manure, which can increase productivity, reduce production costs, and raise farmers' income. Research by Muhakka et al. (2017) found that the production ratio of rice straw to rice is on average 1:1, with low crude protein content, high levels of crude fiber, lignin, and silica, low mineral content, low digestibility, and low palatability. Therefore, efforts are needed to improve the quality of rice straw so that it can be effectively used as animal feed.

Integration of Maize Crops and Beef Cattle

Corn plant waste, including stalks, leaves, cobs, and cob cores, represents a significant by-product of maize cultivation. For every hectare of corn planted, the potential waste generated averages 8 tons (BPTP West Sumatra in Indrawanto & Atman, 2017). The upper stems and leaves, which constitute about 60% of the total waste, can be used as a base material for making silage for large ruminants. The conversion yield of this silage base material into silage averages 70%. The remaining 40% of corn plant waste, such as lower stems and cobs, can be utilized as the base material for making solid organic fertilizer, with an average conversion yield of 60%. The maize-cattle integration approach is a holistic method that utilizes crop and livestock resources to enhance both maize and cattle productivity. The input-output values for this integration are presented in Table 6.

Table 6. Input-Output Values of Maize and Beef Cattle Integration in Minahasa District/Production

Land area (ha)	Number of livestock (head)	Maize Output (IDR)	Cattle Output (IDR)	Maize Input (IDR)	Cattle Input (IDR)
1	2	20,889,000	60,000,000	11,125,800	50,252,200
2	4	41,778,000	120,000,000	22,251,600	100,504,400
3	6	62,667,000	180,000,000	33,377,400	150,756,600
4	8	83,556,000	240,000,000	44,503,200	201,008,800
5	10	104,445,000	300,000,000	55,629,000	251,261,000

For a land area of 1 hectare, the input value includes the corn crop production costs of IDR 11,125,800/hectare and beef cattle production costs of IDR 50,252,200/hectare. The output value comprises the revenue from corn planting, which is IDR 20,889,000/hectare, and revenue from beef cattle raising, which is IDR 60,000,000/hectare. As land area increases from 2 to 5 hectares, the input-output values vary depending on the number of corn plants and the number of beef cattle raised.

An increase in land area results in a significant rise in both input and output values, indicating that larger land areas lead to greater costs and revenues. However, this finding contrasts with research by Syamsidar in Indrawanto and Atman (2017), which suggests that as land area increases, the contribution of livestock decreases: land areas <0.5 ha contributed 58%, 0.5-1.0 ha contributed 51%, and >1.0 ha contributed only 32%. The fertilizer needs and availability of organic fertilizer for maize-beef cattle integration in Minahasa District during one production season are presented in Table 7.

Table 7. Fertilizer Needs and Availability of Organic Fertilizer Integration Maize Crops with Beef Cattle in One Season Planting Production in Minahasa Regency (75 Days Period)

Land Area (ha)	Number of Livestock (head)	Production/Day			Fertilizer Requirement (kg/day)			
		Feces (kg)	Urine (liter)	Total Organic Fertilizer (kg)	Inorganic	Solid Organic	Liquid Organic	Total Organic Fertilizer
1	2	20	16	36	300	148	7	155
2	4	40	32	72	600	296	14	310
3	6	60	48	108	900	444	21	465
4	8	80	64	144	1200	592	28	620
5	10	100	80	180	1500	740	35	775

The study reveals a significant gap between the need for fertilizer and the availability of organic fertilizer in Minahasa District, which explains why farmers continue to rely on inorganic fertilizers. The economic, ecological, and social feasibility values for maize crops and beef cattle are presented in Table 8.

Table 8. Economic, Ecological, and Social Feasibility Values of Maize and Beef Cattle Integration in Minahasa District

Land Area (ha)	Number of Livestock (head)	Economic Feasibility		Ecological Feasibility	Social Feasibility
		Maize	Cattle		
1	2	1.87	1.93	0.23	1.93
2	4	1.87	1.93	0.23	1.93
3	6	1.87	1.93	0.23	1.93
4	8	1.87	1.93	0.23	1.93
5	10	1.87	1.93	0.23	1.93

Economic feasibility is determined by dividing benefits by production costs, with an average value of 1.87 for corn and 1.93 for beef cattle (Table 8). This shows that integrating maize with beef cattle is viable, as the benefits exceed costs. A 1-unit increase in production costs for corn results in a 1.87 increase in benefits, and for beef cattle, a 1.93 increase.

Ecological feasibility is measured by the ratio of organic fertilizer availability to fertilizer needs. The average value for corn and beef cattle integration in Minahasa is 0.23 (Table 8), indicating insufficient organic fertilizer supply, requiring farmers to still use inorganic fertilizers.

Social feasibility is calculated by comparing inorganic fertilizer use to organic fertilizer contribution. The average value is 1.93 (Table 8), suggesting that organic fertilizer can partially replace inorganic fertilizer, allowing farmers to reduce costs and increase income. A 1-unit increase in organic fertilizer use reduces inorganic fertilizer use by 1.93 units.

Research conducted by Sunanto and Nasrulah in Indrawanto and Atman (2017) on 1 hectare of corn land with 1 beef cow found that added value was gained in the form of increased cow weight, corn waste sales, and organic fertilizer. The farm income from corn-cow integration for one season of corn planting and 72 days of cattle rearing yielded an R/C ratio of 1.57.

There are several benefits of utilizing this maize-cow integration technology, including (1) diversification in the use of production resources; (2) increased soil fertility due to the use of solid and liquid organic fertilizers (urine) derived from cows; (3) reduced production failures; (4) increased corn crop productivity due to the use of solid and liquid organic fertilizers; (5) enhanced cattle productivity through the use of feed derived from corn waste; (6) more efficient use of labor; (7) more efficient use of production facilities; (8) reduced environmental pollution from chemical use; and (9) increased farmer income and welfare.

Maize-cattle integration technology is implemented as a model where the primary products of cattle are meat and milk, which can be sold directly to the market. The waste or by-product, urine, can be used as a source of organic fertilizer for corn plants. Cow manure can also serve as a source of organic fertilizer for corn crops and as a source of biogas. The biogas produced can be used as stove fuel, an electrical energy source, and cow dung residue. The remaining cow dung can also be used as a source of organic fertilizer for corn plants. Meanwhile, the primary yield of maize crops is seeds (dried beans), which can be sold directly to the market. The waste or by-products such as stems, leaves, cobs, and cob cores can be used as a source of organic fertilizer and animal feed. This model applies the concept of cleaner production, resulting in zero-waste farming.

The results of research by Elly et al. (2019) show that the integration of maize crops and cattle can be economically beneficial and help minimize environmental pollution. Corn crop waste has great potential as an animal feed ingredient due to its high fiber content, making it suitable for cattle ruminant feed. The utilization of corn waste through technologies such as haymaking, silage, and fermentation (Bunyamin et al. in Bahasoan & Buamona, 2023) further enhances its value. Specifically, the use of corn crop waste as animal feed through silage involves the fermentation of forage with high water content, producing nutritious feed.

Integration of Horticulture with Beef Cattle
Horticulture focuses on the cultivation of fruit plants (pomology/fruticulture), flower plants (floriculture), vegetable plants (olericulture), medicinal plants (biopharmaca), and gardens (landscaping). One of the characteristics of horticultural products is that they are perishable because they are fresh. However, this study focuses only on leeks, potatoes, carrots, and cabbage. Average production, revenue, costs, and income per year per hectare are presented in Table 9.

Table 9. Production, Revenue, Cost, and Income of Leek Potato, Carrot, and Cabbage Crops per Year/Hectare

No.	Description	Leek	Potato	Carrot	Cabbage
1	Production (Kg)	3,457	3,724	2,870	3,311
2	Price (Rp/Kg)	5,333	11,000	6,000	3,500
3	Revenue (Rp)	14,162,223	45,173,334	11,476,667	11,485,834
4	Variable Cost				
	- Seeds	3,594,445	11,481,250	128,334	137,500
	- Organic fertilizer	1,286,111	1,230,167	1,281,500	1,320,000
	- Inorganic fertilizer	382,278	314,417	333,667	346,500
	- Herbicide	343,513	350,167	335,501	333,667
	Labor Hours				
	- Land Processing	2,187,945	1,994,967	1,650,950	2,926,367
	- Planting Technique	334,381	316,296	339,671	393,342
	- Fertilization	321,019	306,030	321,750	342,696
	- Pest and Disease Control	272,395	252,217	286,688	318,542
	- Harvesting	2,220,236	2,130,654	2,199,450	2,505,700
5	Fixed Costs				
	- Tool Depreciation	130,134	114,691	113,936	76,057
	- Land Tax	26,806	25,209	27,500	32,084
6	Total Cost (4+5)	11,099,263	18,516,065	7,018,946	8,732,455
7	Revenue (3-6)	3,062,960	26,657,269	4,457,722	2,753,379
8	Economic feasibility	1.27	2.44	1.64	1.32

The economic feasibility values for leek, potato, carrot, and cabbage are 1.27, 2.44, 1.64, and 1.32, respectively. The average value obtained is greater than 1. This indicates that cultivating leek, potato, carrot, and cabbage on various planting areas is profitable for farmers because the revenue obtained is greater than the costs incurred. Integration with beef cattle lowers costs because cow dung (organic fertilizer) helps replace the inorganic fertilizers that farmers buy at relatively high prices. The fertilizer needs and availability of

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organic fertilizer for the integration of leek, potato, carrot, and cabbage crops with beef cattle in one production season in Minahasa District are presented in Table 10.

Table 10. Fertilizer Requirement and availability of Organic Fertilizer Crop Integration Leeks, Potatoes, Carrots, and Cabbage with Beef Cattle in One Growing Season Production in Minahasa District (75 Days Period)

Land area (ha)	Number of livestock (head)	Production/Day			Fertilizer Requirement (kg/day)			
		Feces (kg)	Urine (liter)	Total Organic Fertilizer (kg)	Inorganic	Solid Organic	Liquid Organic	Total Organic Fertilizer
1	2	20	16	36	300	148	7	155
2	4	40	32	72	600	296	14	310
3	6	60	48	108	900	444	21	465
4	8	80	64	144	1200	592	28	620
5	10	100	80	180	1500	740	35	775

The results indicate that there is a significant difference between the fertilizer needs for vegetable crops and the availability of organic fertilizer in Minahasa District. This condition explains why farmers still use inorganic fertilizers. Based on the data in Table 10, the ecological feasibility value is 0.23, meaning that the availability of organic fertilizer is insufficient to meet the needs, so farmers continue to depend on inorganic fertilizers. Meanwhile, the social feasibility value is 1.94. This indicates that organic fertilizer can partially replace inorganic fertilizer, giving farmers the opportunity to increase their income by reducing the cost of purchasing inorganic fertilizer. A value of 1.94 suggests that for every 1 unit increase in the use of organic fertilizer, there will be a corresponding reduction of 1.94 units in the use of inorganic fertilizer.

DISCUSSION

The Role of Beef Cattle in Integrated Farming Systems with Food Crops and Horticulture

One of the potential benefits of beef cattle in an integrated farming system is the production of livestock waste, consisting of feces and urine. Cow manure is categorized as livestock waste, which includes all by-products from livestock operations, such as solid waste (feces), liquid waste (urine), and gases (H_2S, NH_3, CO_2, and CH_4). Cow manure is a material with potential for composting because it contains nutrients such as nitrogen (0.33%), phosphorus (0.11%), potassium (0.13%), and calcium (0.26%). Compost is the best and most natural soil improver compared to artificial or synthetic alternatives. Generally, organic fertilizers contain low levels of macronutrients like nitrogen, phosphorus, and potassium, but they have sufficient micronutrients essential for plant growth (Bahasoan & Buamona, 2023).

Untreated livestock waste can become a source of pollutants, leading to water, air, and soil pollution. Livestock waste contributes to environmental damage in the form of global warming, which occurs due to the degradation of the ozone layer. This damage is partly caused by methane gas (CH_4) produced from feces and urine. Methane gas emissions from livestock waste account for 20-35% of total emissions released into the atmosphere. If not managed properly, this manure waste can have adverse effects on the agricultural environment; however, when properly managed, it provides significant benefits to farmers, particularly by reducing fertilizer costs and meeting farmers' energy needs.

Organic fertilizers can be divided into two categories: solid organic fertilizers and liquid organic fertilizers. Traditionally, manure has been the primary livestock waste used as organic fertilizer in the form of compost. However, liquid livestock waste, particularly urine, has not been widely processed into liquid organic fertilizer due to the difficulty of collecting it and its pungent odor, despite urine having a higher nutrient content than solid waste.

Research data from the Research and Development Center of the Indonesian Ministry of Agriculture, cited by Sjofjan (2021), indicates that cow urine contains regulatory substances such as IAA, which can enhance plant vegetative growth. Additionally, liquid fertilizer made from urine offers various benefits, including improving soil conditions, promoting growth, deterring plant pests, and nourishing the environment without leaving harmful residues on crops, making it safe for consumption.

According to Budiari et al. (2020), the average solid waste produced per day during three months of observation was 10.32 kg. This finding reflects the relationship between body weight gain, the amount of feed consumed, and the amount of waste produced. Cattle waste also contributes 12-41% of methane gas (CH_4) emissions in the agricultural sector. Cattle excrete feces and urine daily, amounting to approximately 12% of their body weight. If not properly processed, this waste can lead to environmental pollution, as livestock feces contain compounds such as NH_3 and other harmful substances.

Wahyuni in Nurkholis et al. (2021) noted that biogas can produce energy with a calorific value of 6,400 - 6,600 kcal/m³. The energy content of 1m³ of biogas is equivalent to 0.62 liters of kerosene, 0.46 liters of LPG, 0.52 liters of diesel oil, 0.08 liters of gasoline, or 3.5 kg of firewood. Hidayati et al. (2019) found that 1 kg of cow dung can support the production of 40 liters of biogas. A single cow can produce 15 kg of manure per day, which can generate 0.2 kWh. One cow can also produce 10 kg of manure waste and approximately 0.36 m³ of biogas, which is estimated to be equivalent to 1.5 liters of kerosene.

Despite these potentials, farmers in Minahasa District still consider cow urine as waste, and thus it remains largely unused. However, cow urine can be processed into high-quality liquid fertilizer, which can replace chemical fertilizers. Liquid organic fertilizer, in fact, contains a more comprehensive range of nutrients than inorganic fertilizers. Utilizing livestock liquid waste as liquid organic fertilizer offers an alternative for processing livestock waste into useful products with promising market potential. Liquid organic fertilizer derived from livestock urine, known as Bio-urine, can reduce the use of inorganic fertilizers, which have harmful side effects on agricultural soils when used over long periods and in inappropriate doses. Cow urine contains nitrogen (N), phosphorus (P), potassium (K), and organic matter, which play a role in improving soil structure (Hendriyatno et al., 2019). Additionally, it contains growth-stimulating substances, such as Indole-3-Acetic Acid (IAA), which can act as growth regulators. The distinctive smell of livestock urine can also repel various plant pests, making it a natural biopesticide.

The concept of a crop-livestock integration system in farming in Minahasa District emphasizes optimizing the balance of waste utilization from each commodity. The problem encountered in the field is that cattle waste management is not yet optimal, particularly in providing organic fertilizer to each farmer.

Budiari et al. (2020) study on cattle fattening in Antapan village, Baturiti sub-district, Tabanan district, showed that cattle weight gain increased monthly from an initial body weight of 272.96 kg to 303.33 kg, with an average weight gain of 0.51 kg/head/day. Budiari et al. (2020) also reported that the average solid waste produced per day during the three-month observation period was 10.32 kg. This result indicates that increased livestock weight leads to higher feed consumption and, consequently, more feces production. Swastike et al. (2015) found that each cow produces 15-20 kg of fresh feces and 10-15 liters of urine daily. In a four-month fattening operation, 1,800-2,400 kg of fresh feces and 1,200-1,800 liters of urine are produced, while a calf-producing cow rearing operation yields an average of 5,400 kg of fresh feces and 3,600-5,400 liters of cow urine annually. The adverse effects of feces and urine waste include pollutants from methane gas (CH_4) and serve as breeding grounds for disease-causing microorganisms.

Musnamar in Budiari et al. (2020) reported that feed containing high crude fiber results in lower digestibility, leading to more feed being excreted as feces. Badung et al. in Budiari et al. (2020) noted that higher feed consumption increases the feed flow rate, resulting in more undigested crude fiber (lignin and silica) being expelled as feces. Manure production is significantly influenced by season and feed consumption.

The average body weight gain of 0.51 kg/head/day, combined with a total ration consumption of 30.10 kg/day, results in 34.29% feces production. Meanwhile, water consumption of 12.34 liters/day leads to 65.25% urine production. Increased body weight gain, along with higher feed and water consumption, contributes to increased feces and urine production. Haryanto in Budiari et al. (2020) reported that a cow produces 8-10 kg of feces daily, and after composting, only 4-5 kg per day, resulting in one cow producing 1.5-2 tons of compost annually.

The variation in livestock rearing locations and seasonal influences affects the moisture content of solid manure. In lowland areas with a dry climate and during the dry season, this impacts the moisture of the waste produced. A cow can produce 2.06 kg of compost per day with 25% moisture, totaling 743.04 kg annually. The potential bio-urine production is 6.22 liters per day, with a shrinkage of 23.31% compared to fresh urine, resulting in 2,239.20 liters annually.

Currently, farmers in Minahasa District produce 18-20 kg of organic fertilizer from two cattle, which is insufficient to replace inorganic fertilizers for food and horticultural crops. To compensate, farmers buy additional organic fertilizer from outside sources. The need for organic fertilizer can be met by optimizing bio-urine use and increasing the livestock population. More livestock would enhance manure production, which could be processed into fertilizer. Integration of cattle and vegetable crops can further improve fertilizer production, using vegetable waste as cattle feed to increase manure and bio-urine output for vegetable crops.

Waste-Free Integrated Farming System Concept

Farming livestock, food crops, and horticulture generate various types of waste that can harm the environment if not managed properly. Effective agricultural waste management is crucial to reduce pollution, minimize external energy inputs, and enhance farming efficiency and regional food security. In Minahasa District, the livestock and crop integration model should focus on a “zero waste production system,” where all agricultural waste is recycled and reused in the production cycle.

Excessive use of agrochemicals like fertilizers and pesticides can harm the agricultural environment. High doses of chemical fertilizers over time can reduce soil fertility, disrupt nutrient balance, and decrease organic matter. While fertilizers provide essential nutrients for optimal plant growth, artificial fertilizers can make soil acidic, lowering agricultural productivity. Nitrogen in fertilizers can also contaminate water sources. To address these issues, developing an ecologically sustainable integrated farming model is essential, combining environmental protection, farm profitability, social justice, public health, and economic welfare.

Organic fertilizers, derived from plant or animal materials, improve soil structure, fertility, water retention, and nutrient content without causing environmental harm. Compost and manure are types of organic fertilizers produced from decomposed organic waste. Compost, made from plant residues, is environmentally friendly, cost-effective, easy to produce, and uses readily available materials. The characteristics of organic fertilizer raw materials are detailed in Table 11.

Table 11. Requirements for the Characteristics of Organic Fertilizer Raw Material

Characteristic	Category	
	Good	Ideal
C/N ratio	20:1 – 40:1	25:1 – 30:1
Water content	40 - 65%	50 - 60%
Oxygen concentration	>5%	≥5%
Oxygen concentration	⅛ - ½	Varies
pH	5.5 – 9	6.5 – 8.5
Density (kg/m3)	< 0.7887	
Temperature	< 0.7887	54 -60

Source: Djaja in Istiqomah and Kusumawati (2022)

The livestock-crop integration model should be oriented towards the concept of a "zero waste production system," where all waste from livestock and crops is recycled and reused in the production cycle. This concept can be referred to as LEISA. One way to apply the LEISA concept to a farm is by implementing a Crop-Livestock Integration System. Through a waste-free approach, every hectare of farmland can produce feed for raising 2-3 cows per hectare. In this system, cow dung serves as a producer of manure (organic) and biogas, while plant waste acts not only as animal feed but also as compost material, which is ultimately used as organic fertilizer for plants.

In an effort to increase the beef cattle population at a reasonable production cost, the approach of integrating beef cattle with food crops and horticulture is feasible to develop both economically, ecologically, and socially. One key to the success of this pattern is that no material is wasted, and innovations are utilized correctly and efficiently, aligning with the concept of integrated agriculture. Agricultural waste (rice, corn, and vegetables) studied in this research can be used as cattle feed and as raw material for the production of organic fertilizer (compost).

Rice straw waste has the potential to be used as feed for beef cattle. The use of rice straw as animal feed is a common practice among farmers in Minahasa District, especially during the dry season. The utilization of rice straw as animal feed has only reached 31-39%, while 36-62% is burned or used as fertilizer, and around 7-16% is used for industrial purposes (Istiqomah & Kusumawati, 2022). Furthermore, the by-products of the main harvested corn crop that can be used as beef cattle feed provide raw materials for fiber sources/substitutes for forage, such as straw, corn cobs, and *klobot*, which are beneficial as feed ingredients, both before and after processing.

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Vegetable waste is typically disposed of through open dumping without further management, leading to environmental disturbances and unpleasant odors. Vegetable waste contains low nutrition, with crude protein at 1-15% and crude fiber at 5-38% (Yanti et al., 2022). Therefore, vegetable waste needs to be managed properly, as it has the potential to be developed into more useful materials. One potential use of vegetable waste is as a liquid organic fertilizer. Vegetable waste is beneficial for soil fertility, making it a promising candidate for conversion into liquid organic fertilizer and local microorganisms.

The resulting organic fertilizer is very rich in elements needed by plants. Cow manure, consisting of feces and urine, is the most produced livestock waste, with most of the manure produced by beef cattle (ruminants). Manure is a source of protein, calcium, phosphorus, and minerals, with a diverse range of amino acids. However, beef cattle manure must be processed before use. If not processed, the manure can emit a pungent odor and potentially become a source of disease. In general, cattle waste can be categorized into solid waste (feces, bedding, entrails/rumen, dead cattle), liquid waste (urine, livestock washing water), and gas waste (NH_3, H_2S, CH_4, and other gases related to odor).

CONCLUSION

This study successfully examined the general objectives of the research, namely the integration of livestock with rice, corn, and vegetable crops, based on the principle of zero waste. This was achieved by utilizing beef cattle manure as organic fertilizer and agricultural crop waste as animal feed. The specific objectives were to study the economic, ecological, and social feasibility of integrating beef cattle with food crops (rice and corn) and vegetables on different land area treatments (1-5 hectares).

The integration system of beef cattle with rice, corn, and vegetable crops has the potential to be further developed in Minahasa District, even with different farm sizes between 1 hectare and 5 hectares, as it provides a similar yield trend.

The Stratified Random Sampling method was able to produce economic and social feasibility values above 1, and ecological feasibility values below 1. This means that the integration system of beef cattle with rice, corn, and vegetable crops in Minahasa District, across different land area treatments, provides economic and social benefits, making integrated farming viable. However, the ecological feasibility value being below 1 indicates that the production of beef cattle manure as organic fertilizer has not yet been able to fully replace the use of inorganic fertilizers. Therefore, to improve the integration of beef cattle with rice, corn, and vegetable crops in Minahasa District, it is necessary to increase the beef cattle population.

The consistent results across different land area treatments in the farming integration of beef cattle with rice, corn, and vegetables in Minahasa District suggest that the size of agricultural land is not a barrier to the development of integrated farming systems in the region.

The applied concept of integrating beef cattle with rice, corn, and vegetable crops in an integrated farming system produces the "F4s" concept. Food refers to sources of human food, including rice, corn, vegetables, and beef cattle products (meat and its derivatives). Feed pertains to food for beef cattle. Fuel is generated as energy in various forms, such as heat energy (biogas) for domestic needs like cooking, heat energy for the food industry in rural areas, and for small industries. The final product of biogas production is biofertilizer, which comes in the form of liquid organic fertilizer and compost. Fertilizer is produced when the remaining agricultural products, through decomposer and pyrolysis processes, are converted into compost (organic fertilizer) with various nutrient contents and relatively high C-Organic levels. This system requires cooperation in the form of partnerships between the government, the private sector, and farmers.

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DECLARATION OF CONFLICTING INTERESTS
The authors declared no potential conflicts of interest.

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