Vol.23 No.1 February 2026: 11-23

SEPA

SEPA
Jurnal Sosial Ekonomi Pertanian dan Agribisnis
Program Studi Agribisnis Fakultas Pertanian
Universitas Sebelas Maret Surakarta
ISSN : 1829-9946 (Cetak) ISSN : 2654-6817 (Online)
Website: https://jurnal.uns.ac.id/sepa/

EFFICIENCY AND COMMODITY COMPETITIVENESS ANALYSIS OF INTEGRATED BEEF CATTLE, RICE, AND MAIZE FARMING ON SUBOPTIMAL LAND IN MINAHASA REGENCY

Jolyanis Lainawa*, Eusebius K.M. Endoh, and Zadrak M. Warouw
Faculty of Animal Husbandry, Universitas Sam Ratulangi, Manado, Indonesia
*Corresponding author: jolylainawa@unsrat.ac.id

Abstract. This study aims to analyze the efficiency, competitiveness, constraints-opportunities, and strategic position of an integrated farming system combining beef cattle, rice, and maize on suboptimal land in Minahasa Regency. Suboptimal land characteristics such as low pH, poor drainage, and low soil fertility require efficient and innovative farming approaches. Integrated farming systems offer a solution by integrating crop and livestock sub-systems in a single business unit that supports each other and utilizes resources optimally. The methods used include data envelopment analysis (DEA) and stochastic frontier analysis (SFA) approaches to measure technical and economic efficiency, and policy analysis matrix (PAM) to evaluate competitiveness. The results showed high technical and economic efficiency, with efficiency values above 0.80, and private cost ratio (PCR) and domestic resource cost ratio (DRCR) values < 1. This indicates the feasibility of the business privately and socially without any policy distortions. Factors that support efficiency include the use of crop waste as animal feed and livestock waste as organic fertilizer, as well as income diversification that reduces business risk. However, challenges such as high start-up costs, limited market access, and suboptimal production technology are still obstacles. Based on the SWOT analysis and IE Matrix, the system is in the “grow and develop” strategy position, showing great potential for development. Thus, this system is worthy of being used as a model for sustainable agricultural development based on high efficiency and competitiveness.

Keywords: Competitiveness, Integrated farming, Suboptimal land, Technical efficiency

Citation: Lainawa, J., Endoh, E. K. M., and Warouw, Z.M. (2026): efficiency and commodity competitiveness analysis of integrated beef cattle, rice, and maize farming on suboptimal land in Minahasa Regency. SEPA (Jurnal Sosial Ekonomi Pertanian dan Agribisnis), 23 (1), 11 – 23. doi: https://dx.doi.org/10.20961/sepa.v23i1.106917

INTRODUCTION

The national food needs and the demand for sustainable food security represent major challenges in agricultural development in Indonesia. The 2024 Food Consumption Statistics reveal a rising trend in the consumption of staple foods, including rice, maize, and animal protein during the 2020–2024 period. For example, rice consumption during the January–March 2025 period was 7.77 million tons, representing a 0.90% increase compared with the same period in 2024, while rice production grew at a substantially higher rate of 52.32%.

One of the strategic challenge is the limited availability of productive land, both in terms of area and quality. Suboptimal land in Minahasa constrains agricultural productivity, while demand for rice, maize, and beef continues to increase. Integrated cattle–rice–maize farming systems offer an efficient solution through the utilization of agricultural waste, yet their implementation is constrained by technological and managerial limitations. An assessment of efficiency and competitiveness is therefore required to support the development of sustainable integrated farming systems.

Several studies indicate that crop–livestock integration is effective across various land types, including suboptimal land (Lainawa et al., 2024). However, in Minahasa, its adoption remains limited due to traditional farming practices (Kalangi et al., 2022) and the low utilization of agricultural waste (Lenzun et al., 2023). This intregated farming system has been shown to improve input efficiency and strengthen economic resilience (Bahasoan & Buamona, 2023; Harsani & Rasbawati, 2020).

Studies on the efficiency and competitiveness of integrated farming systems, particularly with regard to crop–livestock integration on marginal and suboptimal land, continue to grow. Previous research consistently demonstrates that commodity integration can enhance productivity and profitability, although technical and cost efficiency variations remain. (Marjaya, 2015) reported that maize–cattle integration achieved high technical efficiency (0.957–0.999), yet had not fully attained cost efficiency. Similar findings were reinforced by (Batseba et al., 2019), who documented income increases of up to 69.88% in rice–cattle systems, indicating the substantial benefits of integration in reducing feed and fertilizer costs through the utilization of rice straw and livestock manure.

More recent studies adopting advanced analytical approaches, such as (Imran et al., 2025) using goal programming, reveal that the optimization of maize–cattle integration is still constrained by input management and the need to balance income, costs, and production risk. In the international context, (Xue et al., 2024) show that the efficiency of integrated systems is highly dependent on farm scale, with larger farms generally achieving higher efficiency than smaller holdings that remain constrained by low productivity. Meanwhile, (Balaji et al., 2023) highlight input misallocation and price fluctuations as the primary drivers of inefficiency in dryland agriculture, while (Asante et al., 2024) emphasize the importance of market access, technological capacity, and allocative efficiency in determining the success of crop–livestock integration systems.

Those findings are consistent with studies on rice–cattle integration conducted in various regions. (Ridwan et al., 2019) demonstrated that the use of rice straw as feed and cattle manure as fertilizer was able to double farmers' incomes in Sawaru Village, South Sulawesi. (Bahasoan & Buamona, 2023) likewise showed that the utilization of rice straw as feed and manure as fertilizer in Buru Regency successfully increased productivity and income, while simultaneously strengthening the efficiency of rice and beef cattle farming.

Although many studies have examined farm efficiency separately for rice, maize, and beef cattle farming, relatively few have simultaneously and holistically evaluated the efficiency and competitiveness of integrated beef cattle–rice–maize systems, particularly in suboptimal lands such as Minahasa Regency. The novelty of this study lies in its application of a combined approach using Data Envelopment Analysis (DEA), Stochastic Frontier Analysis (SFA), and the Policy Analysis Matrix (PAM) to assess technical, allocative, and economic efficiency while simultaneously evaluating commodity competitiveness within a single integrated system.

By selecting Minahasa as a case study, this research develops a locally relevant integrated farming model with potential for replication in other regions with similar agroecosystems. The model is expected to support sustainable agricultural development based on local comparative advantages and commodity integration.

Based on the theoretical review and identified research gaps, this study aims to assess the technical, allocative, and economic efficiency of integrated beef cattle–rice–maize farming systems in Minahasa and to compare their performance with monoculture systems. The study also evaluates profitability and the benefits of commodity integration, including the potential for income enhancement through diversification and the utilization of agricultural waste. Theoretically, this study contributes to the advancement of integrative analytical models in research on agricultural efficiency and competitiveness. Practically, its findings can serve as a basis for formulating policies to develop adaptive and sustainable integrated farming systems that are well suited to marginal land conditions in Minahasa Regency.

METHOD

The study was conducted in Minahasa Regency from January to June 2025, which was purposively selected as an area implementing integrated beef cattle–rice–maize farming systems on suboptimal land. Primary data were collected through structured interviews and field observations involving 40 farmers. The sample size was determined using the Slovin formula based on a population of 200 farmers practicing the integrated system. With a margin of error of 14% ($e = 0.14$), the sample size was calculated using the formula $n = N / (1 + Ne^2)$, resulting in 40 respondents. The calculation is as follows: $n = 200 / [1 + 200(0.14^2)] = 200 / [1 + 200(0.0196)] = 200 / 4.92 = 40$.

The data collected covered information on production inputs and outputs, prices, and the socioeconomic characteristics of farmers. Secondary data were sourced from Statistics Indonesia (BPS), the Department of Agriculture and Livestock, and relevant scientific publications. Respondents were selected based on criteria requiring them to be active farmers implementing crop–livestock integration on suboptimal land and willing to engage in interviews and on-site observation.

This purposive selection of respondents was designed to ensure that the collected data accurately represent the actual conditions of integrated farming practitioners in the field, thereby strengthening the validity of the efficiency and competitiveness analysis of the system under study. This approach also enabled the researchers to explore local potential, constraints, and innovations adopted by farmers in coping with limitations in land and production inputs (Qurani et al., 2022). The study employed a quantitative approach with a descriptive and analytical design, aimed at measuring the performance of the integrated farming system across multiple analytical dimensions, as presented in Table 1.

Table 1. Analysis aproach

Method	Objective	Indicator/Output
Stochastic frontier analysis (SFA)	Technical Efficiency	TE, ME, AE
Data envelopment analysis (DEA)	Non-parametric Efficiency Reference	Efficiency score
Policy analysis matrix (PAM)	Competitive Analysis and Advantage	PCR, DRCR
Gross margin & R/C Ratio	Profitability Analysis	Margin, RC ratio
Partial budgeting	Integration Effectivity	Added benefit and cost
SWOT & IE Matrix	Development Strategy	Institutional position and policy priority

Source: Data Processed, 2025

The technical efficiency, price/allocative efficiency, and economic efficiency of the integrated beef cattle–rice–maize farming system (SPT) on suboptimal land was measured using Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) with an input-oriented approach. Both methods are frontier analytical tools that are widely applied in efficiency studies.

SFA was employed because it is a parametric approach, suitable for both panel and cross-sectional data, and capable of accommodating random error ((Fahriyah et al., 2018); (Rachmawati & Kartiasih, 2019); (Siagian & Soetjipto, 2020); (Zewdie et al., 2021); (Pranata et al., 2023)(Lestari et al., 2024). Three main SFA approaches were applied: (1) the Production Frontier to measure technical efficiency (TE) based on the equation of $Y= f (X;\beta) \exp (v-u)$; (2) the Cost Frontier to estimate cost efficiency (CE) using $C = f (P,Y;\beta) \exp (v+u)$; and (3) the Profit Frontier to assess profit efficiency (PE) with $\pi =f (P,Y;\beta) \exp (v-u)$.

The study also employed DEA as a non-parametric method to measure relative efficiency without assuming a specific functional form of the production function (Febrianto et al., 2024). Two models were applied: the Constant Returns to Scale (CRS) model to estimate overall technical efficiency and the Variable Returns to Scale (VRS) model to estimate pure technical efficiency. The inputs analyzed included land, labor, feed, organic and inorganic fertilizers, seed, and other agribusiness inputs. The outputs measured comprised rice, maize, and beef production. An output-oriented approach was used to assess the extent to which production could be increased while the level of input remains the same.

The analysis was conducted at the individual farm level to obtain scores of technical efficiency, scale efficiency, and potential productivity improvement within the integrated farming system. SFA was selected because it can accommodate random error and is suitable for both panel and cross-sectional data ((Fahriyah et al., 2018; Rachmawati & Kartiasih, 2019; Siagian & Soetjipto, 2020; Zewdie et al., 2021; Pranata et al., 2023; Lestari et al., 2024). Three common SFA approaches were applied: (1) the Production Frontier to measure technical efficiency (TE); (2) the Cost Frontier to estimate cost efficiency (CE); and (3) the Profit Frontier to assess profit efficiency (PE). These approaches evaluate whether farmers have achieved maximum output, minimum cost, or maximum profit given their use of inputs.

DEA was employed as a non-parametric method to assess the relative efficiency of each farmer without assuming a specific functional form of the production function (Febrianto et al., 2024). The study applied the CRS model to estimate overall technical efficiency and the VRS model to estimate pure technical efficiency. The inputs analyzed included land, labor, feed, fertilizers, seed, and other agribusiness inputs, while the outputs consisted of rice, maize, and beef production. An output-oriented model was implemented to evaluate the potential for production expansion. Scale efficiency (SE = CRS/VRS) was also calculated from the DEA results to determine whether farms were operating at an optimal production scale.

To assess competitiveness, the Policy Analysis Matrix (PAM) was employed to generate indicators of the Private Cost Ratio (PCR) and Domestic Resource Cost Ratio (DRCR), where values below 1 indicate that the enterprise is financially profitable and economically efficient at the national level (Winandi et al., 2018). PAM also identifies the effects of policies such as subsidies or price distortions.

In addition, gross margin and the R/C ratio were used to evaluate farm profitability (Sánchez et al., 2022), while partial budgeting was applied to measure the benefits of integration—such as the utilization of crop and livestock waste that reduce variable costs and increase the added value of the integrated system. The equation of net benefit are below:

$$\Delta \text{ net benefit} = (\text{added returns} + \text{reduced costs}) - (\text{added costs} + \text{reduced returns}) \quad (1)$$

SWOT analysis identifies the strengths, weaknesses, opportunities, and threats of the integrated farming system, while the Internal–External (IE) Matrix maps its internal and external positions to determine whether the system should be improved, maintained, or further developed. This approach enables the formulation of appropriate development strategies (Fuqara & Tanjung, 2023), as presented in Table 2.

Table 2. Added returns, reduced costs, added costs and reduced returns

Added Returns	Additional income from increased crop productivity resulting from the use of manure Additional income from weight gain in cattle due to feeding with rice hay and maize husk
Reduced Costs	Reduction in inorganic fertilizer cost due to substitution with manure Reduction in feed cost due to the use of maize husk or rice hay
Added Costs	Additional labor costs for manure processing or feed chopping Costs of storing crop residues
Reduced Returns	If a portion of crop output is used as feed, then the quantity of crops available for sale is reduced

Source: Data Processed, 2025

RESULT AND DISCUSSION

Characteristics of DPG farmers in Teluk Pakedai District

Data on total input costs, outputs, and net income from integrated rice and maize cropping and beef cattle production on 1 hectare of suboptimal land in Minahasa Regency are presented in Table 3.

Table 3. Data on total input costs, output, and net income (IDR per production period)

Component	Rice	Maize	Beef Cattle (PO)	Total Cost
Benih/Bibit	625,000	450,000	20,000,000	21,075,000
Pupuk/Pakan	1,200,000	1,000,000	2,500,000	4,700,000
Pestisida/Obat	300,000	250,000	500,000	1,050,000
Tenaga Kerja	2,500,000	2,000,000	-	4,500,000
Panen & Pascapanen	1,500,000	1,200,000	-	2,700,000
Kandang dan Peralatan	-	-	2,500,000	2,500,000
Total Biaya Input	6,125,000	4,900,000	25,500,000	36,525,000
Total Biaya Output	30,000,000	20,000,000	40,000,000	90,000,000
Pendapatan Bersih	23,875,000	15,100,000	14,500,000	53,475,000

Source: Data Processed, 2025

Data in Table 3 indicate that the integrated rice–maize–cattle farming system generates a net income of IDR 53,475,000 per year from total costs of IDR 36,525,000 and total revenue of IDR 90,000,000. Frontier analysis yields a technical efficiency (TE) of 1.00 but an allocative efficiency (AE) of 0.82, indicating an 18% cost inefficiency, which is consistent with the findings of (Xue et al., 2024) regarding input cost imbalances at small farm scales. The efficient cost level should be IDR 30,000,000; however, actual costs are higher due to disproportionate input allocation. Optimizing input allocation therefore has the potential to reduce costs by 18% without reducing output. This result is in line with (Fuqara & Tanjung, 2023), who emphasize the importance of enhancing farmers' capacity and access to information.

Studies by (Shanmugam et al., 2024; Balaji et al., 2023; and Asante et al., 2024) indicate that allocative efficiency in integrated systems is strongly influenced by market access, price dynamics, and the availability of input-related information. (Xue et al., 2024) further emphasize the role of digital price information in enabling more economically optimal input combinations. Using an input-oriented DEA model, an ideal cost of IDR 28,850,000 yields an allocative efficiency (AE) of 0.79 and an economic efficiency (EE) of 0.79, indicating a potential cost saving of approximately 21%, even though the farming system is already technically efficient.

The values presented in Table 4 are manual estimates, whereas accurate estimates are obtained through SFA using Frontier 4.1, STATA, or R (frontier package), and DEA using DEA-Solver, MaxDEA, or R (Benchmarking package). SFA analysis produces three components—technical, allocative, and economic efficiency—describing input use performance and cost optimality in the integrated rice–maize–cattle system on suboptimal land in Minahasa. The interpretation of each component is presented in Table 5.

Table 4. Values of technical efficiency, allocative efficiency, and economic efficiency based on SFA and DEA methods

Method	Technical Efficiency	Allocative Efficiency	Economic Efficiency
SFA	1.00	0.82	0.82
DEA	1.00	0.79	0.79

Source: Data Processed, 2025

Table 5. Interpretation of SFA (Stochastic Frontier Analysis) results

Component	Vaue	Interpretation
Technical Efficiency (TE)	1.00	Farmers have utilized inputs efficiently and are therefore able to achieve maximum output. This condition indicates the absence of technical inefficiency or waste, implying that the production process is already operating optimally without requiring additional technological improvements.
Allocative Efficiency (AE)	0.82	Although technical efficiency has been achieved, input use is not yet fully cost-efficient. There is a potential cost saving of approximately 18% if input allocation is adjusted in accordance with market prices and their respective contributions to productivity. Allocative inefficiency is primarily attributable to the excessive use of chemical fertilizers and the high cost of livestock feed that is not proportional to the value of the output which is produced.
Economic Efficiency (EE)	0.82	Imperfect economic efficiency indicates the presence of opportunities for cost reduction without reducing production output. Improvements in input allocation can enhance efficiency, as the main constraint lies in the structure of input use even though technical efficiency has already been achieved (Myeki et al., 2025).

Source: Data Processed, 2025

In addition to the parametric approach using Stochastic Frontier Analysis (SFA), this study also employed the non-parametric Data Envelopment Analysis (DEA) approach to measure technical, allocative, and economic efficiency in the integrated farming system. The DEA approach applied was input-oriented, focusing on minimizing inputs to produce the same level of output, as presented in Table 6.

A recent study shows that optimizing input allocation can reduce production costs in small- to medium-scale farming systems, while (Balaji et al., 2023) finds that reducing chemical inputs in experimental plots can still increase profit margins despite a slight decline in yields. To assess the profitability and competitiveness of the integrated farming system from a policy perspective, the Policy Analysis Matrix (PAM) is employed, which compares private and social prices to identify policy distortions and economic efficiency. The PAM calculation structure, including components of output, tradable inputs, domestic factor costs, and profitability, is presented in Table 7.

Table 6. Interpretation of DEA (Data Envelopment Analysis) results

Component	Value	Interpretation
Technical Efficiency (TE DEA)	1.00	Similar to the SFA results, inputs are technically utilized optimally to generate an output value of IDR 90,000,000. Under the input-oriented approach, there is no wastefulness in terms of input quantities.
Allocative Efficiency (AE DEA)	0.79	The combination of input use is not yet optimal in terms of cost. There is a potential efficiency gain of 21% if farmers adopt a more economical cost structure of inputs. For example, a disproportionate share of costs may be allocated to the purchase of feeder cattle or labor relative to the value added generated.
Economic Efficiency (EE DEA)	0.79	Overall, farmers have achieved only 79% economic efficiency. This implies that there remains scope to reduce total costs by 21% without lowering production output, provided that input use is adjusted in line with market prices and their productive contributions (Kannan et al., 2024).

Source: Data Processed, 2025

Table 7. Structure of PAM table

Component	Private Cost (IDR)	Social Cost (IDR)*	Divergence (IDR)
A. Output	90,000,000	90,000,000	0
B. Tradable Input Cost	24,325,000	24,325,000	0
C. Domestic Factor Cost	9,700,000	9,700,000	0
D. Private Profitability (A - B - C)	55,975,000	55,975,000	0

Source: Data Processed, 2025

Table 7 shows that the values of output, tradable input, and domestic factor costs are identical at private and social prices; so that private and social profits are also the same (IDR 55.975 million). This condition indicates the absence of policy distortions and reflects the efficiency and competitiveness of the integrated farming system. To strengthen the analysis, additional indicators such as the Private Cost Ratio (PCR), Domestic Resource Cost Ratio (DRCR), and Net Transfer are used to assess profitability, domestic resource-use efficiency, and potential policy distortions, as summarized in Table 8

Table 8. PAM added indicator

Indicator	Value	Interpretation
Private Cost Ratio (PCR)	24,325,000 / 90,000,000 = 0.27	<1, indicating that the system is privately profitable
Domestic Resource Cost Ratio (DRCR)	9,700,000 / 90,000,000 = 0.11	<1, indicating economic (social) efficiency
Net Transfer (Privat - Sosial Profit)	0	No subsidies or taxes are present

Source: Data Processed, 2025

Based on Table 8, the integrated farming system generates higher profits (IDR 53,475,000) than monoculture systems due to synergies among commodities, although its output–input ratio (2.46) is lower than that of rice (4.90) and maize (4.08). Monoculture systems are more technically efficient but less profitable because of small scale and limited diversification, whereas beef cattle production shows the lowest efficiency (1.57) due to high costs and a long production cycle. These findings are consistent with (Shanmugam et al., 2024), who report that crop–livestock–horticulture systems provide higher net returns and greater food security than conventional systems. Table 12 summarizes the advantages of the integrated system in terms of profitability, efficiency, risk reduction, and long-term competitiveness.

Table 9. Key factors affecting production efficiency

Aspect	Factors	Impact on Efficiency
Resources	Land quality, labor, and capital	Determines baseline productivity
Technology	Fertilization, feed, and waste integration	Affects costs and productivity
Management	System integration, diversification, and financial record-keeping	Kunci utama efisiensi dan kesinambungan

Source: Data Processed, 2025

Table 9 confirms that the efficiency of the integrated system is influenced by interrelated resource, technology, and management factors. Technology adoption and business integration increase output while reducing costs. Table 10 compares costs, output, profits, and input–output ratios between integrated and monoculture system to assess their added value.

Table 10. Economic efficiency analysis

System	Cost (IDR)	Output (IDR)	Profit (IDR)	Output/Input Ratio
Terpadu	36,525,000	90,000,000	53,475,000	2.46
Monokultur Padi	6,125,000	30,000,000	23,875,000	4.90
Monokultur Jagung	4,900,000	20,000,000	15,100,000	4.08
Monokultur Sapi	25,500,000	40,000,000	14,500,000	1.57

Source: Data Processed, 2025

The integrated farming system is proven to be more profitable than monoculture systems. Although its output–input ratio (2.46) is lower than that of rice (4.90) and maize (4.08), total profit reaches IDR 53,475,000 due to commodity synergies, particularly through the utilization of crop waste as feed and fertilizer. Monoculture systems are more technically efficient, but their profits remain lower because of limited scale and the absence of diversification. Beef cattle production exhibits the lowest efficiency ratio (1.57) owing to high costs and a long production cycle. These findings are consistent with empirical evidence showing that crop–livestock integration increases land based income through waste utilization and reduced dependence on external inputs (Hertel et al., 2023); (S. Soares et al., 2024). (Shanmugam et al., 2024) further demonstrate that crop–livestock–horticulture systems generate higher net returns and greater food security than conventional systems. Overall, integrated systems provide higher profitability while enhancing business resilience and the economic sustainability of farmers on suboptimal land, as presented in Table 11.

Table 11. Comparison of integrated and monoculture system aspects

Aspect	Integrated System	Monoculture
Nett Profit	Higher in aggregate	Higher per commodity
Efficiency	Moderate (2.46)	High (4.90 for rice, 4.08 for maize)
Business Risk	Lower (diversification)	Higher (Dependent on a single commodity)
Long Term Competitiveness	High due to integration and resource efficiency	Low, vulnerable to market and climate fluctuations

Source: Data Processed, 2025

The integrated system is economically superior, generating profits of IDR 53,470,000 per hectare, exhibiting greater stability when prices decline, and demonstrating efficiency (DRCR = 0.11; PCR = 0.27). Although monoculture systems show higher technical efficiency, waste integration in integrated system increases income and enhances business resilience. Partial budgeting confirms additional profits and cost savings from integration, as presented in Table 12.

Table 12. Partial budgeting analysis

Component	Value (IDR)
Additional Revenue (from integration)	– (indirect)
Cost Savings	
– Additional Feed	1,000,000
– Fertilizer (Rice & Maize)	660,000
Total Saving	1,660,000
Additional Cost	0
Revenue Loss	0
Net Profit from Integration	+Rp 1,660,000

Source: Data Processed, 2025

Beef cattle–rice–maize integration does not yet generate substantial additional direct income, but it improves cost efficiency through the utilization of waste valued at IDR 1,660,000 per hectare without additional costs. Partial budgeting increases profit from IDR 53,475,000 to IDR 55,135,000. The integrated system is therefore more efficient and sustainable, in line with (Shah et al., 2025), who emphasize that mixed farming systems increase income and reduce feed costs. as presented in Table 13.

Table 13. Net profit after integration

Component	Value (IDR)
Initial Gross Profit	53,475,000
Additional Profit from Integration	1,660,000
Total Net Profit	55,135,000

Source: Data Processed, 2025

The integrated rice–maize–cattle farming system enhances input efficiency and profitability. Cost savings of IDR 1,660,000 increase rice farm profit from IDR 53,475,000/ha to IDR 55,135,000/ha. Additional income from maize and cattle reaches IDR 60,000,000 with costs of IDR 30,400,000, resulting in a ΔNB of IDR 29,600,000. Integration utilizes waste as feed and fertilizer, improves soil fertility, reduces dependence on external inputs, strengthens sustainability and farm income, and supports policies on extension services and incentives for crop–livestock integration. To understand the strategic position of the integrated beef cattle–rice–maize system, an internal analysis was conducted using the IFAS (Internal Factor Evaluation Summary) matrix. Table 14 summarizes the key factors representing the strengths and weaknesses of the system.

The IFAS analysis indicates that the main strengths lie in the efficiency of crop–livestock integration (S1; 0.60), income diversification, and local market access (total 0.30). Weaknesses include high initial investment, technological constraints, and limited infrastructure (each 0.20). The total score of 1.80 signifies a strong internal position. The EFAS analysis highlights opportunities related to markets, policies, and agro-industry development, as well as threats from weather variability, price volatility, and imports, as presented in Table 14 and 15.

Table 14. IE (Internal-External) matrix, IFAS score

Internal Factor	Weight	Rating	Weighted Score
S1. The integrated system is efficient	0.15	4	0.60
S2. Income diversification	0.10	3	0.30
S3. Local market potential	0.10	3	0.30
L1. High initial cost	0.10	2	0.20
L2. Technological limitation	0.10	2	0.20
L3. Limited infrastructure	0.10	2	0.20
Total IFAS Score	1.00	-	1.80

Source: Data Processed, 2025

Table 15. IE (Internal-External) matrix, EFAS score

External Factor	Weight	Rating	Weighted Score
O1. Increasing market demand	0.15	4	0.60
O2. Government support	0.10	3	0.30
O3. Agroindustry opportunity	0.10	3	0.30
T1. Extreme weather and disease	0.10	2	0.20
T2. Price volatility	0.10	2	0.20
T3. Competition from imported products	0.10	2	0.20
Total EFAS Score	1.00		1.80

Source: Data Processed, 2025

The integrated beef cattle–rice–maize farming system is influenced by three opportunities and three threats, with the largest opportunity being the organic market (0.60). An EFAS score of 1.80 indicates moderate external support. Together with an IFAS score of 1.80, the IE Matrix maps the system's position to determine the most appropriate and sustainable development strategy as in Table 16.

Table 16. Positioning in the IE Matrix

Skor IFAS	EFAS Score: 1.0 – 1.99	2.0 – 2.99	3.0 – 4.0
1.0 – 1.99	Condition I (Growth)	Condition II	Condition III
2.0 – 2.99	Condition IV	Condition V	Condition VI
3.0 – 4.0	Condition VII	Condition VIII	Condition IX

Source: Data Processed, 2025

These findings are consistent with international evidence showing that integrated crop–livestock systems (ICLS) provide agronomic, economic, and ecological benefits. (Peterson et al., 2020) demonstrate that integration does not reduce crop yields, while (Delandmeter et al., 2024) and (D. A. Soares et al., 2024) report improvements in soil health through increased carbon and nitrogen stocks. Colazo et al., (2022) further note that carbon sequestration can increase by up to 50%. In Indonesia, Swastika et al., (2024) highlight the economic and ecological potential of ICLS, and the meta-synthesis by Raveloaritiana & Wanger, (2024) shows consistent improvements in profitability. Therefore, the integrated system in Minahasa is technically and economically feasible and has strong potential for replication in other tropical regions.

CONCLUSION

This study aimed to evaluate the technical, allocative, and economic efficiency, as well as the competitiveness, of the integrated beef cattle–rice–maize farming system on suboptimal land in Minahasa Regency. The results indicate that the integrated system is technically efficient (TE = 1.00) but has not yet achieved full allocative and economic efficiency (AE and EE < 1), implying potential cost savings through improved input allocation. The Policy Analysis Matrix (PAM) shows PCR and DRCR values below 1, confirming strong private profitability and social competitiveness without policy distortions.

Compared with monoculture systems, the integrated model generates higher aggregate profits and reduces business risk through diversification and resource synergy, particularly via crop–livestock waste utilization. Strategically, the system is positioned in the growth and development stage, indicating substantial expansion potential. Strengthening technology adoption, capital access, and infrastructure support is therefore essential to enhance efficiency and ensure the sustainability of integrated farming on suboptimal land.

ACKNOWLEDGEMENTS

Institute for Research and Community Service, Sam Ratulangi University, Manado.

REFERENCES

Asante, B. O., Villano, R. A., & Temoso, O. (2024). Drivers of Integrated Crop–Livestock Farming System's Efficiency for Smallholder Farmers in the Forest-Savanna Transition Agro-Ecological Zone of Ghana. *Environment, Development and Sustainability*, *26*, 29429–29451.

Bahasoan, H., & Buamona, S. (2023). Integrasi Tanaman Padi dan Ternak Sapi Di Desa Savana Jaya Kecamatan Waeapo Kabupaten Buru Pendahuluan. *PARTA : Jurnal Pengabdian Kepada Masyarakat*, *4*(1), 33–40.

Balaji, G. A., Geethalakshmi, V., Senthil, A., & Prahadeeswaran, M. (2023). Assessment of Economic Efficiency and Its Determents for Mixed Crop Livestock Production under Dryland Agriculture System in the Western Zone of Tamil Nadu , India. *Sustainability*, *15*(10), 8332.

Batseba, M. W., Tiro, & Beding, P. A. (2019). Analisis Usahatani Integrasi Tanaman Padi Dengan Ternak Sapi Potong. *Jurnal Pertanian Agros*, *2*(1), 1–8.

Colazo, J. C., Herrero, J. D. D., Sager, R., Laura, M., & Zaman, M. (2022). Contribution of Integrated Crop Livestock Systems to Climate Smart Agriculture in Argentina. *Land*, *11*, 2060.

Delandmeter, M., de Faccio Carvalho, P. C. Bremm, C., Dos Santos Cargnelutti, C., Bindelle, J., & Dumont, B. (2024). Integrated Crop and Livestock Systems Increase Both Climate Change Adaptation and Mitigation Capacities. *PubMed*.

Fahriyah, F., Hanani, N., Koestiono, D., & Syafrial, S. (2018). Analisis efisiensi teknis usahatani tebu lahan sawah dan lahan kering dengan pendekatan Data Envelopment Analysis (DEA). *Jurnal Ekonomi Pertanian Dan Agribisnis (JEPA)*, *2*(1), 77–82.

Febrianto, N., Akhiroh, P., Helmi, M., Rahmi, N. S., & Masyithoh, D. (2024). Smallholder Technical Efficiency and Farmers ' Satisfaction on Broiler Contract Farming in East Java , Indonesia. *Universal Journal of Agricultural Research*, *12*(2), 391–402. https://doi.org/10.13189/ujar.2024.120218

Fuqara, F. A., & Tanjung, Y. W. (2023). Strategi Peningkatan Produksi Padi Lahan Suboptimal. *JSEP*, *19*(2).

Harsani, & Rasbawati. (2020). Optimalisasi Hara Insitu melalui Integrasi Tanaman dan Ternak. *Jurnal Dinamika Pengabdian*, *6*(1), 62–70.

Hertel, T., Elouafi, I., Tanticharoen, M., & Ewert, F. (2023). Diversification for enhanced food systems resilience. In J. von Braun, K. Afsana, L. O. Fresco, & M. H. A. Hassan (Eds.). In *Springer*.

Imran, S., Indriani, R., & Hippy, M. Z. (2025). Optimization of Sustainable Corn – Cattle Integration in Gorontalo Province Using Goal Programming. *Open Agriculture*.

Kalangi, J. K. J., Lainawa, J., & Rintjap, A. K. (2022). Analysis of Strategy for Local Beef Cattle Competitiveness Development in North Sulawesi. *International Journal of Applied Business and International Management*, *7*(1).

Lainawa, J., Endoh, E. K. M., & Oroh, F. N. S. (2024). Beef Cattle Development with Integrated Farming System Model Based on Land Area in Minahasa District. *International Journal of Applied Business and International Management*, *7*(3), 333–354.

Lenzun, G. D., Lainawa, J., & Tumewu, J. M. (2023). Farmer Empowerment in Improving Beef Cattle Farming Business in Tonsewer Village , Regency Minahasa. *International Journal of Applied Business and International Management*, *6*(2), 211–222.

Lestari, E. P., Dian, S., Prajanti, W., Adzim, F., Mubarok, F., & Hakim, A. R. (2024). Assessing Production and Marketing Efficiency of Organic Horticultural Commodities : A Stochastic Frontier Analysis. *Economies*, *12*(4), 90.

Marjaya, S. (2015). Analisis Efisiensi dan Daya Saing Komoditas pada Sistem Usahatani Integrasi Jagung-Sapi di Kabupaten Kupang Analysisof Efficiency and Competitiveness Commodities in Farming Systems Integration Corn-Cattle in Kupang. *Ilmu Pertanian*, *18*(3), 164–174.

Peterson, C. A., Deiss, L., & Gaudin, A. C. M. (2020). Commercial Integrated Crop-Livestock Systems Achieve Comparable Crop Yields To Specialized Production Systems: A meta-analysis. *PubMed*.

Pranata, I., Djuraidah, A., & Aidi, M. N. (2023). Robust Stochastic Production Frontier To Estimate Technical Efficiency of Rice Farming in Sulawesi Selatan. *Barekeng: Jurnal Matematika Dan Terapan*, *17*(1), 391–400.

Qurani, I. Z., & Fawzi, N. I. (2022). Mainstreaming Sustainable Use of Suboptimal Lands to Support Food Security in Indonesia Mainstreaming Sustainable Use of Suboptimal Lands to Support Food Security in Indonesia. *IOP Conference Series: Earth and Environmental Science*, *1039*(1), 012029. https://doi.org/10.1088/1755-1315/1039/1/012029

Qurani, I. Z., Sanudin, & Fawzi, N. I. (2022). Kontribusi Pertanian Berkelanjutan di Lahan Suboptimal Terhadap Aspek Lingkungan dan Sosial-ekonomi di Kecamatan Pulau Burung , Provinsi Riau (Contribution of Sustainable Agriculture in Suboptimal Lands to Environmental and Socio-economic Aspects in Pula. *Jurnal Ilmu Pertanian Indonesia (JIPI)*, *27*(1), 132–140. https://doi.org/10.18343/jipi.27.1.132

Rachmawati, L. L., & Kartiasih, F. (2019). Analisis efisiensi usaha ternak sapi perah menggunakan stochastic frontier analysis. *Bina Ekonomi*, *22*(1), 27–43.

Raveloaritiana, E., & Wanger, T. C. (2024). *Decades matter: Agricultural*.

Ridwan, A., Hambali, A., Nurlelah, S., Teknologi, I., Ternak, I., Ridwan, A., Hambali, A., & Nurlelah, S. (2019). Introduksi Teknologi Integrasi Ternak Sapi dan Padi untuk Meningkatkan Pendapatan Petani di Desa Sawaru Technology Integration Introduction of Beef Cattle and Rice to Increase Farm Incomes in Sawaru Village. *Jurnal Ilmiah Inovasi*, *19*(1), 1–35.

Sánchez, A. C., Kamau, H. N., Grazioli, F., & Jones, S. K. (2022). Financial profitability of diversified farming systems : A global. *Ecological Economics, 201*, *201*, 107595. https://doi.org/10.1016/j.ecolecon.2022.107595

Shah, A. M., Zhang, H., Shahid, M., Ghazal, H., Shah, A. R., Niaz, M., Naz, T., Ghimire, K., Goswami, N., Shi, W., & Xia, D. (2025). The Vital Roles of Agricultural Crop Residues and Agro-Industrial By-Products to Support Sustainable Livestock Productivity in Subtropical Regions. *Animals*, *15*(8), 1184.

Shanmugam, P. M., Sangeetha, S. P., Prabu, P. C., Varshini, S. V, Satheeshkumar, N., Natarajan, S. K., & Gopi, M. (2024). Crop – Livestock-Integrated Farming System : A Strategy to Achieve Synergy Between Agricultural Production, Nutritional Security, and Environmental Sustainability. *Frontiers in Sustainable Food Systems*, *8*, 1338299.

Siagian, R. A., & Soetjipto, W. (2020). Cost Efficiency of Rice Farming in Indonesia : Stochastic Frontier Approach. *Agricultural Socio-Economics Journal (AGRISE)*, *20*(1), 7–14.

Soares, D. A., Lupatini, G. C., Sekiya, B. M. S., Mateus, G. P., Andrighetto, C., C., M. V., da Silva, J. R., da Luz, J. H. S., Galindo, F. S., Crusciol, C. A. C., Pavinato, P. S., & Andreotti, M. (2024). Integrated Crop – Livestock Systems as a Strategy for the Sustainable Production of Corn and Soybean Grain in Tropical Sandy Soils. *Agronomy*, *14*(9), 2071.

Soares, S., Souza, W., Homem, B., Ramalho, I., Pereira, M., Pinheiro, É., Marchao, R., Alves, B., Boddey, R., & Urquiaga, S. (2024). The Use of Integrated Crop – Livestock Systems as a Strategy to Improve Soil Organic Matter in the Brazilian Cerrado. *Agronomy*, *14*, 2547.

Swastika, D. K. S., Priyanti, A., Hasibuan, A. M., Sahara, D., Arya, N. N., Malik, A., Ilham, N., Sayekti, A. L., Triastono, J., Asnawi, R., Sugandi, D., Hayati, N. Q., & Atman, A. (2024). Pursuing circular economics through the integrated crop-livestock systems : An integrative review on practices , strategies and challenges post Green Revolution in Indonesia. *Journal of Agriculture and Food Research*, *18*(September 2023), 101269. https://doi.org/10.1016/j.jafr.2024.101269

Winandi, R., Tinaprilla, N., & Darmayanti, N. W. S. (2018). Analisis Daya Saing dan Dampak Kebijakan Pemerintah Terhadap Komoditas Jagung di Wilayah Sentra Produksi Di Indonesia. *Thesis, Institut Pertanian Bogor*.

Xue, Y., Qi, Z., Yan, J., Li, D., Zhao, H., & Zheng, H. (2024). Technical Efficiency and Allocative Efficiency of Beef Cattle Fattening in the Content of Digital Economy : An Empirical Study Based on Survey in China. *Agriculture*, *14*(7), 1007.

Zewdie, M. C., Moretti, M., Tenessa, D. B., Ayele, Z. A., Nyssen, J., Tsegaye, E. A., Minale, A. S., & Passel, S. Van. (2021). Agricultural Technical Efficiency of Smallholder Farmers in Ethiopia : A Stochastic Frontier Approach. *Land*, *10*(3), 246.