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Development Strategy of Integrated Farming System (Beef Cattle, Rice, Corn) on Suboptimal Land: Minahasa Regency

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ABSTRACT

Suboptimal land in Minahasa Regency has strong potential for integrated cattle–rice–corn farming, but production inefficiency and limited managerial capacity still hinder its performance. This study aims to evaluate technical efficiency, competitiveness, and strategic development priorities for the integrated system on suboptimal land in Minahasa. SFA and DEA are used to measure technical efficiency, while the PAM assesses comparative and competitive advantages. SWOT analysis, the IE Matrix, and the QSPM are applied to formulate strategic directions. Primary data were collected from 90 farmer–breeders representing traditional, semi-commercial, and commercial business types. The findings show an average technical efficiency of 0.72, indicating a 28% improvement potential. The cattle–corn system has a stronger comparative advantage (DRCR 0.79) than cattle–rice (DRCR 0.82), although both face private competitiveness constraints (PCR > 1). SWOT–IE results place the system in Quadrant V ("Hold and Maintain"), with QSPM prioritizing efficiency enhancement, institutional strengthening, waste-based downstream product development, and risk adaptation. The integrated system can become an efficient and competitive sustainable agriculture model with adequate institutional support and technological innovation.

Keywords: Comparative Advantage; Competitive Advantage; Integrated Farming; Strategic Priorities; Technical Efficiency

INTRODUCTION

Agricultural and livestock development primarily focuses on increasing production, productivity, and competitiveness (Amelia et al., 2022; Setiawan et al., 2021). Research by Moeis et al. (2020) and Rao (2018) shows the low land ownership by agricultural households (RTP) in Indonesia, which impacts the limitations in production and farming efficiency. One strategic solution to optimize the potential of limited land, especially suboptimal land such as marginal and critical land, is through the application of an integrated farming system. This model integrates the agricultural, livestock, and environmental management sectors, where plant waste such as rice straw, corn stalks, and other by-products can be utilized as feed for beef cattle, while livestock waste is processed into organic fertilizer to improve soil fertility and land productivity sustainably.

Minahasa Regency, with a land area of 1,141.64 km² and a water area of about 46.54 km², consists of 25 districts, 227 villages, and 43 urban villages, and has a population of 350,317 people. Research by Lainawa, Lumy et al. (2024) shows that an integrated farming system of crops and beef cattle can be developed in various regions of Minahasa. However, the utilization of suboptimal land still faces various obstacles, such as limited technology, low farmer skills, and weak farm management. Therefore, further studies are needed to formulate appropriate management strategies in developing an integrated system of beef cattle with rice and corn crops on dry or marginal land.

Suboptimal land in Minahasa Regency presents significant challenges but also holds extraordinary potential to support food security, economic sustainability, and environmental preservation. Through a strategy management approach based on efficiency and competitiveness, as well as support from technological innovation and collaboration among stakeholders, an integrated agricultural system is expected to become an effective and adaptive development model in response to changing resource conditions (Lainawa et al., 2019).

This research, based on the UNSRAT Superior Basic Research Scheme Cluster 1 (RDUU_K1), aims to develop an integrated cattle–rice–corn farming system on suboptimal land in Minahasa Regency. The objectives include: (1) describing land potential, production factors, cattle maintenance systems, as well as rice and corn cultivation; (2) analyzing the relationship between production factors and yield, income, efficiency, and competitiveness; (3) formulating optimal development strategies for the system; and (4) designing an innovative strategic management model based on suboptimal land. The phenomenon of limited land ownership threatens productivity and farmers' welfare, while food demand continues to increase. The integration system is expected to improve productivity, efficiency, nutritional fulfillment, and farmers' welfare, as well as be adaptive to economic, social, and ecological challenges.

The benefits of the research encompass three dimensions: academic (enriching the literature on integrated agriculture, efficiency, competitiveness, and development strategies for beef cattle), practical (implementation guidelines for farmers to utilize agricultural-livestock waste for business efficiency and sustainability), and policy (basis for formulating agricultural-livestock policies on suboptimal land supporting food security, Sustainable Development Goals [SDGs], and farmer welfare). The novelty of this research lies in the development of an integrative strategic management model that combines technical efficiency, waste utilization, and socio-economic adaptation of farmers, which has not been extensively explored in the context of suboptimal land.

The research questions focus on: land potential and production factors; characteristics of cattle maintenance systems as well as rice–corn cultivation; factors influencing production, income, efficiency, and competitiveness; optimal strategies for system development; and the design of strategic management models that enhance productivity, efficiency, competitiveness, and farmer welfare in Minahasa Regency.

LITERATURE REVIEW

Previous Research Results

Research results by Lainawa, Lumy et al. (2024), in Minahasa Regency, North Sulawesi Province, show that the number of farming families engaged in cattle farming on productive land averages less than 0.5 to 1 hectare. However, there is still a lot of marginal and critical land (suboptimal land) available. Furthermore, the development of beef cattle integrated with food crops on various sizes of productive land is economically and socially feasible, but not ecologically feasible, due to the production of organic fertilizer from cattle waste (feces and urine) not yet meeting the fertilizer needs of the plants.

Minahasa Regency is one of the regions in North Sulawesi province, which has agricultural land potential for the development of beef cattle agribusiness both intensively and extensively. However, the existing land potential has not been utilized optimally due to limitations in management technology (Kalangi et al., 2022; Lainawa, Endoh et al., 2024; Lenzun et al., 2023).

State-of-the-art approaches: (1) a landscape approach that manages land by considering the relationship between ecological, social, and economic aspects; (2) diversification of land use, which combines agriculture and livestock to increase land productivity; and (3) minimizing the use of synthetic chemicals and utilizing organic materials to maintain soil fertility.

Suboptimal Land

Suboptimal land is a type of land that has natural limitations, such as low fertility levels, high soil acidity, or drainage problems, thus requiring special interventions to be utilized optimally. Research by Wahid et al. (2020) shows that suboptimal land has the potential to be developed for beef cattle farming and agricultural crops, where the utilization of suboptimal land has not been optimally managed as agricultural farming. Land categorized as suboptimal usually has biophysical limitations (low pH, low organic matter, poor drainage) and small farmer land ownership, conditions that affect agrarian productivity and technology choices. General literature regarding the definition and characteristics of suboptimal land emphasizes that soil management interventions (organic fertilizers, conservation) and integrated farming can increase productivity on such land. Based on their dominant characteristics, suboptimal lands are divided into two types: dry land and wet land. There are five types of suboptimal land in Indonesia, namely (1) acidic dry land, (2) dry land with a dry climate, (3) tidal land, (4) swampy lowland, and (5) peatland (Rahmasary et al., 2020).

Concept and Empirical Evidence of Integrated Farming Systems

The integrated crop-livestock-fish farming system is popularly applied in many countries (Garrett et al., 2017; Harahap et al., 2019; Wiesner et al., 2020). This system optimizes plant waste into livestock feed and livestock manure as fertilizer to improve fertility, nutrient cycling, and land productivity (Reddy, 2016). The implementation of the system on a large scale can even accelerate the reduction of poverty and malnutrition, strengthen environmental sustainability, and reduce global warming (Reddy, 2016; Wiesner et al., 2020). The integrated farming system of cattle, rice, and corn, according to Elly et al. (2020), Haryanta et al. (2018), Mukhlis et al. (2016), and Ruhiyat et al. (2020), will produce the 4Fs: food, feed, fuel, and fertilizer.

Integrated Crop-Livestock Systems (ICLS) refer to practices in which food crops and livestock are managed together to create circularity of inputs and outputs (litter/straw becomes feed; livestock manure becomes fertilizer/organic matter; crop residues become bedding/forage), potentially increasing productivity, resource efficiency, and farmers' income resilience on marginal/suboptimal land. Review studies document environmental benefits (increased soil carbon, waste reduction), economic benefits (increased income, risk diversification), and social benefits (household food security). (Shanmugam et al., 2024).

Factors Affecting Production, Income, Efficiency, and Competitiveness in The Integrated Cattle-Rice-Corn System

Empirical evidence from Indonesia and ICLS studies shows several key factors: (1) Biophysical: soil fertility, water/irrigation availability, microclimate conditions (Rahmasary et al., 2020); (2) Technical: rice/corn varieties, conservation practices, feed and livestock health management, feed technology (silage, haylage) (Shanmugam et al., 2024); (3) Socio-economic: market access, output prices/input costs, business scale, land ownership, access to capital, and information; and (4) Institutional/organizational: presence of farmer groups, extension services, government subsidy/support programs (Aryawiguna et al., 2024).

For technical efficiency and competitiveness, comparative studies show that integration systems are often more resource-efficient (reducing feed/urea purchases, increasing manure utilization) and can enhance profitability per unit area if well managed. However, results vary according to scale and level of technology adoption; therefore, local empirical analysis using Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) is needed to assess relative efficiency among business units (Afi & Parsons, 2023).

The Concept of Low External Input Sustainable Agriculture (LEISA)

The Low External Input Sustainable Agriculture (LEISA) concept, implemented according to Bahasoan & Buamona (2023), Harly & Mulyani (2024), and Mukhlis et al. (2016), will produce benefits and advantages, namely the optimization of local resource utilization, maximization of recycling (Zero Waste), minimization of environmental damage (environmentally friendly), product diversification, sustainable business, as well as creating independence. The LEISA research conducted by Kesseler and Moolhuijzen in Firman et al. (2019), in the Philippines and Ghana, shows that in regions with high agricultural production potential, LEISA simultaneously improves socio-economic aspects by reducing the use of inputs from outside the area and is able to sustainably improve the ecological environment.

Processing of Crop Waste and Cattle Manure

Rice straw is an agricultural waste that has great potential to be used as animal feed. (Muhakka et al., 2017). In addition to rice plant waste, corn plant waste is also used for animal feed (Hetharia et al., 2021). The utilization of plant waste as animal feed through silage (fermentation of forage) contains a high moisture content (Marlina et al., 2019). Compost fertilizer is the best and most natural soil conditioner compared to artificial/synthetic conditioners. Generally, organic fertilizers contain low macro nutrients N, P, and K, but contain sufficient micro nutrients that are very necessary for plant growth. (Wadi et al., 2021). Cattle manure can become an environmentally friendly alternative energy source, as well as increase energy efficiency and community welfare (Sari & Emawati, 2020).

The Concept of Strategic Management and Strategy Formulation
The concept of strategic management analysis is carried out through three main stages, namely formulation, implementation, and evaluation of strategies. Each stage uses specific analytical tools to ensure the accuracy of direction, effectiveness of execution, and sustainability of the integrated agricultural system model (David & David, 2017; Whittington et al., 2023).

The formulation results: Internal Factor Evaluation (IFE), External Factor Evaluation (EFE), Strengths, Weaknesses, Opportunities, Threats (SWOT), and Quantitative Strategic Planning Matrix (QSPM) are used to determine the strategic position of the integrated farming system of beef cattle–rice–corn in Minahasa. Internal and external environment scanning: conducting a detailed SWOT analysis based on survey and Focus Group Discussion (FGD) results (strengths: availability of crop residues, farmer experience; weaknesses: limited capital/technology; opportunities: regional policy support, local market; threats: climate change, price fluctuations). The external environment analysis is complemented by a brief Political, Economic, Social, Technological, Environmental, and Legal (PESTEL) analysis to map relevant climate, economic, regulatory, and market factors (Alharbi, 2024).

Determination of strategic goals: formulating short-term goals (increasing productivity and income of RTP within 1–2 years) and medium/long-term goals (achieving feed self-sufficiency, increasing added value, and environmental sustainability). Formulation of strategic alternatives: developing strategy packages (e.g., operational strategy: feed optimization from straw/waste; financial strategy: group mechanisms/microcredit access; marketing strategy: development of local value chains; technology strategy: adoption of composting/feed fermentation). These alternatives are prioritized using the IE Matrix and scenario analysis based on the results of SFA/DEA/PAM to ensure consistency between economic efficiency and social competitiveness.

RESEARCH METHOD

The research was conducted in Minahasa Regency from March to August 2025, with locations selected based on the potential of suboptimal land and the presence of beef cattle that can be integrated with rice and corn, creating an efficient and sustainable farming system. The research population consisted of farming households (RTP) with a minimum of two years of experience in cattle–crop integration. A sample of 50 RTPs was determined through Stratified Random and Purposive Sampling based on cattle ownership (2–10 heads/hectare) in five districts (Aryawiguna et al., 2024). The research sites were selected purposively in key integration areas, after which respondents were chosen using stratified random sampling to capture variations in technology and scale of operation while meeting the requirements of the efficiency analysis.

Primary data were obtained through interviews and FGDs, while secondary data came from agency reports, literature, and online sources. The survey instrument used a structured questionnaire that recorded the main inputs, feed, labor, production costs, land area, and number of cattle, as well as the outputs in the form of cattle selling weight, rice grain yield, and corn yield. The analysis includes: (1) descriptive analysis of land potential and integration systems; (2) SFA using the Cobb–Douglas model for technical, allocative, and economic efficiency; (3) DEA for relative efficiency; (4) Policy Analysis Matrix (PAM) for competitiveness; and (5) business feasibility analysis through Gross Margin, R/C Ratio, and Break Even Point (BEP). Statistical assumptions include normally and half-normally distributed error components, independent explanatory variables free from multicollinearity, and homogeneous variance. Diagnostic checks were conducted using the Variance Inflation Factor (VIF) tests, the Breusch–Pagan test for heteroskedasticity, and returns-to-scale analysis (CRS–VRS) in the DEA framework to ensure the consistency of the production structure. The strategic management framework follows the classic stages: formulation, implementation, and evaluation, with a focus on strategy formulation based on internal and external conditions (David & David, 2017; Whittington et al., 2023). The weights and scores of the IFE/EFE matrices were determined by a panel of experts, extension officers, academics, and key farmers, through an FGD that validated the strategic factors. Each expert assigned weights and ratings independently, and the results were averaged. The same panel then provided the QSPM attractiveness scores to objectively prioritize the strategies.

The study obtained ethical approval prior to implementation, and data collection was carried out in stages in accordance with the cropping calendar and cattle management cycle, ensuring that interviews and data recording were consistent, replicable, and maintained the integrity of the research.

Table 1. Tools for Analyzing Strategy Formulation Used

Stage of Analysis	Analytical Tool	Purpose of Use	Resulting Output
Internal Environment Analysis	IFE (Internal Factor Evaluation Matrix)	To identify the main strengths and weaknesses of the cattle–rice–maize integration system.	Total strength–weakness score (determines internal position).
External Environment Analysis	EFE (External Factor Evaluation Matrix)	To analyze opportunities and threats from external factors (policy, climate, market, technology).	Total opportunity–threat score (determines external position).
Strategic Position Mapping	SWOT Matrix & IE (Internal–External) Matrix	To integrate IFE and EFE results to determine the strategic position (Quadrants I–IX).	Main strategic alternatives: growth, hold and maintain, harvest, or divest.
Strategy Prioritization	QSPM (Quantitative Strategic Planning Matrix)	To assess the relative attractiveness among strategies generated from SWOT/IE analysis.	Total Attractiveness Score (TAS), selected priority strategy.

The strategic analysis was carried out through four main stages, as presented in Table 1. First, the IFE matrix identified the key internal strengths and weaknesses of the cattle–rice–maize integration system, producing the internal position score. Second, the EFE matrix assessed external opportunities and threats related to policies, climate, markets, and technology, generating the external position score. Third, the results of the IFE and EFE were combined using the SWOT and IE matrices to determine the strategic position across nine quadrants and formulate suitable strategic alternatives such as growth, hold and maintain, or harvest. Finally, the QSPM was applied to evaluate the relative attractiveness of each strategy, resulting in Total Attractiveness Score (TAS) values that determine the most appropriate priority strategy for implementation.

RESULTS

Respondent Characteristics

Table 2. Characteristics of 50 Integrated Crop–Livestock Farmers in Minahasa Regency

Characteristic Variable	Category	Number of Respondents	Percentage (%)
Age	Productive age (18–50 years)	33	66
	> 50 years	17	34
Experience in Integrated Farming	< 2 years	15	30
	≥ 2 years	35	70
Cattle Ownership Scale (head/ha)	Low (1–3 head)	12	24
	Medium (4–6 head)	33	66
	High (≥ 7 head)	5	10
Formal Education Level	Primary school	12	25
	Junior–Senior High School	38	75
Source of Labor	Family labor	40	80
	Hired labor	10	20
Land Condition	Suboptimal land	35	70
	Relatively optimal land	15	30
Use of Crop Residues as Feed	Yes	40	80
	No	10	20
Use of Manure as Organic Fertilizer	Yes	40	80
	No	10	20

Source: Primary Data Processing Results (2025), (n = 50 farming households)

Based on the data summarized in Table 2 above, the 50 respondents exhibit relatively homogeneous characteristics as practitioners of integrated crop–livestock farming systems. The majority of farmers (66%) are within the productive age group (18–50 years), which indicates sufficient availability of household labor to support daily farming operations. Furthermore, most respondents (70%) have more than two years of experience in integrated farming, reflecting adequate practical knowledge and familiarity with crop–livestock integration principles.

In terms of cattle ownership, the dominant production scale is classified as medium (4–6 head per hectare), representing 66% of the respondents. Small- and large-scale cattle ownership categories account for 24% and 10% of respondents, respectively. This distribution suggests that most farmers operate at a moderate production scale consistent with available land resources and family labor capacity.

With regard to education, 75% of farmers have completed junior or senior high school, while 25% possess only primary education. This educational profile implies a relatively adequate capacity for technology adoption, particularly for simple integrated farming innovations, although continuous technical assistance remains necessary to enhance management skills.

Family labor constitutes the primary workforce for farm operations, utilized by 80% of the respondents, which underscores the smallholder and household-based nature of the integrated production systems. From an agroecological perspective, the majority of respondents (70%) manage their farms on suboptimal land, aligning with the focus of this study on production systems under marginal land conditions.

Concerning resource integration, approximately 80% of respondents utilize crop residues as livestock feed and apply cattle manure as organic fertilizer, demonstrating the circular use of on-farm resources within their production systems. Nevertheless, the intensity and consistency of these practices vary among farmers, largely influenced by livestock scale and individual management capacities.

Minahasa Agricultural Production

Table 3. Production of Main Cereals and Tubers 2018-2022 (Tons)

Commodity	2018	2019	2020	2021	2022	Total (5 Years)
Lowland Rice	91.468	82.406	78.911	81.684	70.161	404.630
Upland Rice	11.058	14.030	259	855	-	26.202
Maize	251.122	169.476	184.506	139.921	158.424	903.449
Cassava	931	1.361	1.760	1.806	1.064	6.922
Sweet Potato	1.587	1.830	2.034	2.403	5.928	13.782

Source: Secondary Data Processing Results (2025)

Rice and corn are staple foods in Minahasa Regency, contributing almost 20.251% of the total cereal production in the regency. Based on Table 3, paddy rice production tends to decline over 5 years, from a production achievement of 91,468.3 tons in 2018 to 70,161 tons in 2022.

Suboptimal Land Potential and Availability of Production Factors

Studies in Indonesia show that cow–crop (rice–corn) integration increases income and input efficiency through the utilization of agricultural waste as feed and fertilizer, depending on farmers ' access to capital, technology, and institutions (Elly et al., 2020; Lainawa, Endoh et al., 2024). The suboptimal land of Minahasa (±37 thousand ha, pH 4.8-5.5) has the potential to be developed in an integrated manner.

Table 4. Availability of Production Factors in the Minahasa Suboptimal Land

Production Factor	Average Availability/Ha	Description
Family labor	2–3 workdays/day	Most farmers rely on family labor
Rice seeds	25–30 kg/ha	Local varieties and some improved varieties
Maize seeds	12–15 kg/ha	Hybrid and composite varieties
Beef cattle	1–2 heads/ha	Ongole Crossbreed (PO) and Bali crossbreeds
Inorganic fertilizer	150–200 kg/ha	Urea, NPK, SP-36
Organic fertilizer	± 1 ton/ha	Only a portion of farmers apply it

Source: Primary Data Processing Results (2025)

Table 4 shows that the integrated farming system in Minahasa utilizes family labor (2-3 HOK/day), rice seeds 25-30 kg/ha, and corn 12-15 kg/ha, and 1-2 cows PO/ha as a source of organic fertilizer. The use of inorganic fertilizers of 150-200 kg/ha is still dominant, while organic fertilizers are only ±1 ton/ha due to technical and institutional limitations.

Characteristics of the Maintenance and Cultivation System in Integrated Agriculture

Table 5. Characteristics of Livestock Management and Crop Cultivation in Integrated Farming Systems in Minahasa

Component Observed	Category / Parameter	Value / Findings	Percentage / Range	Description
Beef Cattle Management System	Traditional system	32 farmers	64%	Free grazing, limited feed control, minimal housing and technology
	Semi-intensive system	18 farmers	35%	Combined grazing and stall-feeding; simple housing; partial feed management

	Intensive system	0 farmers	0%	No fully intensive farms recorded in the sample
Utilization of Rice Straw as Feed	Not using rice straw	25 farmers	50%	Straw is not collected or processed; often burned or left on fields
	Partial use (≤30%)	15 farmers	30%	Straw supplied as supplemental feed only; not processed
	Optimal use (>30%)	10 farmers	20%	Processed through silage or simple fermentation
	Overall utilization rate	-	25–30%	Consistent with interview and FGD findings
Crop Productivity (Suboptimal Land)	Rice productivity	-	3.5 – 4.0 tons/ha	Below national average (5.1–5.3 tons/ha)
	Maize productivity	-	4.5 – 5.0 tons/ha	Below national average (5.8–6.0 tons/ha)
	Key limiting factors	-	-	Acid soil (pH 4.8–5.5), low organic fertilizer use, limited technology adoption, prevalence of local varieties

Source: Primary Data Processing Results (2025), (n = 50 farming households)

Based on the presented data in Table 5, the beef cattle rearing pattern in Minahasa is still traditional; only 35% of farmers implement a semi-intensive system. The utilization of rice straw as feed is only 25-30%, while the productivity of rice (3.5–4 tons/ha) and corn (4.5–5 tons/ha) is still below the national average. Technological limitations, the use of high-yielding seeds, and organic fertilizers are the main causes. The development strategy is directed at improving the utilization of agricultural waste, adoption of organic feed and fertilizer technology, strengthening farmers ' institutions, and integrated farm management training to support sustainable agricultural systems in Minahasa.

Factors Affecting Production, Revenue, Efficiency, and Competitiveness
Analysis of SFA and DEA showed an average technical efficiency of 72%, indicating the utilization of production potential is quite high, but there is still a chance of improvement of 28% through the optimization of inputs and technology (SFA, DEA).

Table 6. Technical Efficiency of Agro-Livestock Enterprises (SFA)

Commodity	Average Technical Efficiency (TE)	Minimum	Maximum
Rice	0.74	0.55	0.91
Maize	0.70	0.52	0.89
Beef Cattle	0.73	0.56	0.88

Source: Primary Data Processing Results (2025)

According to Table 6, the highest technical efficiency is in rice (0.74), followed by beef cattle (0.73) and corn (0.70). DEA analysis shows 25% efficient farmers, 75% is not optimal. PAM indicates cow–rice and cow–corn integration is economically beneficial (DRCR<1), but competitiveness is still weak (PCR>1) due to low input efficiency (SFA, DEA, PAM).

Table 7. Results of Analysis of Pump System Integration

Integration System	Private Profit (IDR/ha)	Social Profit (IDR/ha)	DRCR	PCR
Cattle–Rice	6,500,000	7,200,000	0.82	1.15

Cattle–Maize	7,100,000	7,900,000	0.79	1.12

Source: Primary Data Processing Results (2025)

The SFA analysis in Table 7 showed an average technical efficiency of 0.72 (rice 0.74; cattle 0.73; corn 0.70), with a potential increase of 28%. The DEA yield is slightly higher (0.75-0.80) because it assesses the relative efficiency between farmers (DMU). The difference between them reflects the influence of external factors on technical performance. The PAM analysis showed that the cow–corn integration system is more profitable (private IDR 7.1 million/ha; social IDR 7.9 million/ha) than cow–rice (IDR 6.5 million/ha and IDR 7.2 million/ha). The value of DRCR<1 indicates comparative efficiency, while PCR>1 indicates that private competitiveness is still weak due to high input costs. The synthesis of SFA–DEA–PAM affirms that improved technical efficiency, input management, and policy interventions are needed for a highly competitive cow–crop integration system in Minahasa (SFA, DEA, PAM).

Optimization Strategies for the Implementation of Integrated Agricultural Systems
SWOT analysis: strength of local resources and government support; weakness of capital–technology; price and climate threats (SWOT).

Table 8. Internal Factor Analysis (IFAS) of the Integrated Agriculture System in the Minahasa Regency

Internal Factors (IFAS)	Weight	Rating	Score
Availability of livestock and crop residues	0.20	4	0.80
Experienced human resources (farmers)	0.15	3	0.45
Limited capital and technology	0.25	2	0.50
Weak farmer institutions	0.15	2	0.30
Total			2.05

Source: Primary Data Processing Results (2025)

Based on Table 8, a total score of 2.05 indicates that the internal position of the Minahasa integrated agriculture system is still below average (2.5), indicating that internal weaknesses are more dominant. The main strength is the availability of livestock and crop waste (score 0.80), which has great potential as organic fertilizer and feed. Experienced farmers ' human resources are also an important strength. However, limited capital and technology (score 0.50) are the main weaknesses, compounded by weak institutions (score 0.30) that reduce the bargaining power of farmers.

Table 9. External Factor Analysis (EFAS) of Integrated Agricultural Systems in the Minahasa Regency

External Factors (EFAS)	Weight	Rating	Score
Increasing demand for food and meat	0.25	4	1.00
Government program support	0.20	3	0.60
Fluctuation in input–output prices	0.20	2	0.40
Extreme climate change	0.15	2	0.30
Total			2.30

Source: Primary Data Processing Results (2025)

Based on IFAS (2.05) and EFAS (2.30) in Table 9, the integrated cow–rice–corn farming system in Minahasa is in Quadrant V (Hold and Maintain), demanding improvement of internal weaknesses while taking advantage of external opportunities. The main strength is the utilization of livestock and crop waste, while the weaknesses include capital, technological, and institutional limitations. Opportunities stem from rising demand for food and meat and government support, while the main threats are price fluctuations and climate change. The strategy focuses on institutional strengthening, access to financing, technology transfer, business diversification, and development of value-added products such as organic fertilizers and fermented feed, as well as local market penetration through cooperative partnerships and village-owned enterprises (*Badan Usaha Milik Desa* or BUMDes) to improve efficiency and sustainable competitiveness.

Table 10. Visual Matrix IE (Quadrant V Position)

FAS/IFAS	Low (1.0–1.99)	Moderate (2.0–2.99)	Strong (3.0–4.0)
High (3.0–4.0)	I. Grow & Build	II. Grow & Build	III. Hold & Maintain
Moderate (2.0–2.99)	IV. Grow & Build	V. Hold & Maintain	VI. Harvest or Divest
Low (1.0–1.99)	VII. Harvest or Divest	VIII. Harvest or Divest	IX. Liquidate/Exit

Source: Primary Data Processing Results (2025)

The results of the IE matrix analysis in Table 10 showed that the integrated farming system of cow-rice-corn in Minahasa is in Quadrant V (Hold and Maintain) with internal conditions (IFAS = 2.05) and external (EFAS = 2.30) in the medium category. Strategies are geared towards maintaining existing systems while correcting structural weaknesses (David & David, 2017). The integration of cows with rice and corn creates an input–output efficiency synergy, where straw and corn waste become animal feed, while cow dung becomes an organic fertilizer that improves soil fertility. Institutional strengthening, increased access to capital and feed processing technology, as well as mitigation of price and climate risks, are key. The SO strategy leverages internal strengths to capture market opportunities, while the WO, ST, and WT strategies emphasize collaboration, diversification, and insurance to strengthen the competitiveness and sustainability of the system on suboptimal Minahasa land.

QSPM Analysis

QSPM analysis is used to determine the priority of the integrated farming system development strategy, cow–rice–corn in Minahasa, based on the relative attractiveness (Attractiveness Score) of each SWOT strategy. US values (1-4) multiplied by the weight of strategic factors produce a TAS to determine the most effective strategy (David & David, 2017).

Table 11. Detailed Strategic Factors and Attractiveness Scores (AS) of Each Alternative Strategy (QSPM Analysis)

No	Strategic Factors	Weight	Strategy			
			1	2	3	4
Internal Factors						
1	Limited capital and technology	0.25	4	3	3	4
2	Availability of livestock and crop residues	0.20	3	2	3	4
3	Farmers' experience and skills	0.15	3	3	3	2
4	Weakness of farmer institutions	0.15	4	3	3	3
External Factors						
5	Increasing demand for food and beef	0.25	4	4	3	4
6	Government program support	0.20	3	4	3	3
7	Fluctuation of input–output prices	0.15	3	2	4	2
8	Extreme climate variability	0.10	2	1	4	1

Source: Primary Data Processing Results (2025)

Note: Strategy 1: Internal Efficiency Improvement (AS), Strategy 2: Market Opportunities & Policy Support (AS), Strategy 3: Risk Adaptation & Business Diversification (AS), Strategy 4: Product Development & Market Penetration (AS)

Table 11 presents the detailed strategic factors and attractiveness scores used to evaluate alternative development strategies for the integrated farming system. The most influential internal factors are limited capital and Technology (weight 0.25) and the availability of livestock and crop waste (0.20), while the dominant external factors are the increase in food and meat needs (0.25) and government program support (0.20). Overall, priority strategies are focused on institutional strengthening, improving input efficiency, and exploiting market opportunities based on cow-rice-corn integration to increase competitiveness and system resilience in a sustainable manner. This strategy aligns with the position of Quadrant V and is oriented towards the efficiency and sustainability of integrated agricultural systems (David & David, 2017).

Table 12. Priority Ranking of Strategies Based on QSPM Analysis

No	Strategic Alternative	Total Attractiveness Score (TAS)	Priority Ranking
1	Strategy 1 – Internal Efficiency Improvement	5.10	1 (Top Priority)
2	Strategy 4 – Product Development and Market Penetration	4.95	2
3	Strategy 3 – Risk Adaptation and Business Diversification	4.75	3
4	Strategy 2 – Market Opportunities and Policy Support	4.60	4

Source: Primary Data Processing Results (2025)

The QSPM results in Table 12 show that of the four alternative strategies, Strategy 1 (internal efficiency improvement) obtained the highest score (TAS = 5.10), followed by Strategy 4 (Product Development & Market Penetration, TAS = 4.95), Strategy 3 (Risk adaptation & business diversification, TAS = 4.75), and Strategy 2 (market opportunity utilization & policy support, TAS = 4.60).

DISCUSSION

Potential and Challenges in Utilizing Suboptimal Land Through Integrated Farming Systems

Findings from this study indicate that suboptimal land in Minahasa Regency holds significant potential as a basis for integrated farming systems, with locally available resources such as rice straw, maize stover, and cattle manure that remain relatively stable throughout the year. However, this abundant biomass has not yet been fully transformed into optimal productive outputs. The average Technical Efficiency (TE) of approximately 0.72, with only about 25% of production units (DMUs) classified as efficient based on DEA analysis, reveals substantial room for improving production performance through more consistent and effective management practices.

These results align with global literature on Integrated Crop–Livestock Systems (ICLS). A meta-analysis of 66 ICLS studies worldwide shows that average grain yields under integrated systems differ only slightly from monoculture systems, ranging between –7% and +2%, indicating that the integration of livestock does not necessarily reduce crop productivity (Peterson et al., 2020). This suggests that land productivity can be maintained while simultaneously optimizing additional production factors such as livestock, feed resources, and organic fertilizer.

Nevertheless, turning biophysical potential into actual productivity, particularly on marginal or suboptimal land, requires more than abundant biomass. Managerial skills, technical capacity, institutional support, and market access play critical roles in determining whether this potential can be realized.

Transforming Biophysical Potential Into Value-Added Outputs
Research on innovative farmers adopting ICLS in the United States, Europe, and Brazil demonstrates that transitioning to an integrated system is not merely technical; it is also cultural and structural. Adoption requires changes in mindset, operational adjustments, and often external interventions such as field demonstrations, training, and institutional support (Moojen et al., 2024).

In the context of Minahasa, such findings imply that interventions must be holistic, covering training on the use of rice straw and maize stover as feed (e.g., through silage or fermentation), the production of organic fertilizer or compost from cattle manure, and the conversion of residual biomass into alternative feed or soil amendments.

Recent experimental studies confirm that system fertilization, nutrient management conducted at the system level (livestock + crops), not solely at the crop level, improves soil quality, enhances fodder and crop productivity, and increases profitability without significantly raising external fertilizer use (Tavares et al., 2024). Accordingly, Minahasa has a strong scientific basis for encouraging integrated management practices such as composting, biourine application, silage production, and the use of local feed resources to convert biophysical potential into real productivity and profitability gains.

Interpreting the "Hold and Maintain" Position (IE Matrix Quadrant V): A Strategy of Consolidation Before Expansion
The placement of Minahasa's integrated farming system in Quadrant V (Hold and Maintain) of the IE Matrix is often misinterpreted as a recommendation to maintain the status quo. However, within the context of integrated farming and suboptimal land, this position should be understood differently: it represents a phase of internal consolidation and optimization of production capacity prior to large-scale expansion.

The TE value of approximately 0.72 and the wide variability in efficiency among farmers indicate that improvements in managerial consistency, adoption of appropriate technologies, and institutional strengthening can significantly reduce performance disparities. Therefore, consolidation strategies, such as demonstration plots, simple technology packages, farmer group facilitation (Gapoktan/cooperatives), and continuous technical assistance, are essential early steps. Dynamic capability theory similarly emphasizes that building internal capacity is a prerequisite for sustainable and adaptive agricultural development before scaling up operations.

This interpretation is reinforced by literature suggesting that ICLS and integrated systems more broadly constitute systemic transformations that require time for adaptation, institutional investment, and managerial changes, rather than merely intensifying land use (Moojen et al., 2024).

Explaining the Gap Between Comparative Advantage (DRCR < 1) and Weak Private Competitiveness (PCR > 1)
The observed condition where DRCR < 1 (indicating that the system uses resources efficiently from a social or economic perspective) but PCR > 1 (indicating weak competitiveness at the private or household level) is widely documented in agricultural economics. Numerous PAM studies show that disparities between social prices and actual market prices, combined with transaction costs, limited capital access, and small-scale operations, often prevent comparative advantage from being translated into private profitability.

In Minahasa, this gap can be attributed to several structural factors. First, distortions in input–output prices remain a central issue. Fertilizer, supplementary feed, veterinary drugs, and logistics costs are often much higher than their social values, raising private production costs significantly and preventing efficient systems from generating competitive financial returns for farmers.

Second, long value chains and high transaction costs add further burdens beyond core production expenses. Collecting biomass such as rice straw and maize residues, storing and processing them into compost or silage, and transporting and marketing final products (feed, fertilizer, or beef) require substantial additional costs. Weak institutional structures exacerbate these costs due to the absence of coordinated input and output aggregation mechanisms.

Third, most farmers in Minahasa operate on relatively small scales. Small-scale production limits economies of scale in input procurement and product marketing, resulting in higher per-unit production costs and thinner profit margins. Consequently, social efficiency does not automatically translate into financial efficiency.

Fourth, low conversion rates of biophysical resources into high-value products further widen the gap. Although Minahasa has abundant biomass, these materials do not automatically become high-quality feed or market-standard organic fertilizer. Converting biomass into valuable products requires adequate technology, management skills, and technical capacity. Without efficient and standardized conversion processes, the market value of organic products remains low, restricting farmers' private gains.

Collectively, these factors indicate that the gap between comparative and competitive advantage stems from private cost structures, market institutions, and technical capacity constraints rather than resource inefficiency. Thus, strategies must focus on reducing transaction costs, strengthening production capacity, and implementing policy interventions that reduce price distortions so that comparative advantage can translate into competitive advantage. National literature also highlights that key barriers to IFS adoption include limited capital, technical capacity, institutional weakness, and constrained market access (Usni, 2025). Therefore, without institutional, technological, and market interventions, comparative advantage in Minahasa is unlikely to convert into private competitiveness.

Regional and International Comparisons of Efficiency

Global meta-analyses and ICLS studies demonstrate that the pattern observed in Minahasa, where crop–livestock integration does not always increase crop yields but offers resource-use efficiency and output diversification, is typical (Peterson et al., 2020). However, successful cases of ICLS consistently emphasize system-level management, integrated fertilization, effective forage management, and strong institutional support. Experiments in Brazil, for instance, show that system fertilization increases soil quality, fodder productivity, and profitability without increasing external fertilizer use (Soares et al., 2024).

Long-term studies further affirm that ICLS enhances not only productivity and income but also climate adaptation and mitigation by increasing Soil Organic Carbon (SOC), improving resource efficiency, and strengthening system resilience (Delandmeter et al., 2024). Therefore, the patterns found in Minahasa are not anomalies; they mirror global trends in marginal-land farming systems and smallholder agriculture. Nevertheless, without strategies that convert biophysical potential into productive practice, private competitiveness will remain stagnant or even decline.

Strategic Implications and Evidence-Based Recommendations
Based on the empirical and comparative synthesis, several strategic recommendations can enhance the performance of integrated farming systems in Minahasa. First, integrated management interventions should be implemented through demonstration plots showcasing ICLS best practices, such as silage production, feed fermentation, system-level fertilization, manure management, and biomass conversion, accompanied by continuous technical support to ensure effective farmer adoption.

Second, institutional strengthening is essential. Establishing or revitalizing farmer groups, cooperatives, or BUMDes can facilitate collective input procurement, joint production, processing, and marketing of products such as feed, fertilizer, and beef. Strong institutions reduce transaction costs and enhance farmers' bargaining power.

Third, local government support and improved access to capital are crucial. Transitional incentives, such as microcredit schemes, equipment grants for composting or fermentation, and storage or processing facilities, can ease the initial financial burden and accelerate system transformation.

To ensure measurable progress, monitoring and evaluation frameworks should use DEA and SFA analyses periodically to identify best practices, track improvements in TE, productivity, and profitability, and assess whether comparative advantage (DRCR < 1) is gradually converting into private competitiveness (PCR < 1).

In the medium term, system scaling must proceed cautiously. Expansion should occur only after internal consolidation and stable institutional structures are in place. The "Hold and Maintain" position in Quadrant V should be interpreted as a transitional phase for capability building, efficiency improvement, and system adaptation, not as stagnation. Once foundational capacities are strengthened, further development and competitiveness enhancements can be pursued sustainably.

Overall, this study highlights that although Minahasa's suboptimal lands possess strong biophysical and comparative potential, several constraints, managerial, technical, institutional, scale-related, and transactional, still hinder their realization. These findings are consistent with international ICLS literature, especially in marginal lands and smallholder contexts. Therefore, strengthening internal capacities, targeted policy support, and structured technical interventions are essential to transforming Minahasa's comparative advantage into sustainable private competitiveness and positioning the region toward a more resilient and competitive integrated farming system.

CONCLUSION

This study demonstrates that the integrated cattle–rice–maize farming system on suboptimal land in Minahasa Regency has strong development potential, although the average level of technical efficiency remains moderate (0.72) and private competitiveness is relatively weak. The IFE–EFE and SWOT–IE analyses place the system in the Hold and Maintain quadrant, with key strengths including the availability of biomass residues, farmers' experience, and policy support, while major weaknesses involve limited access to capital, technology, and institutional capacity. Therefore, priority strategies should focus on strengthening farmer organizations, providing facilities for fermented feed and organic fertilizer processing, facilitating productive financing schemes, and developing marketing partnerships for livestock and organic fertilizer products. In practical terms, farmers should optimize business integration, local governments should prioritize technology extension and market stabilization programs, and agricultural development initiatives should promote downstream value-added processing of local resources. This study is limited to a single study area and relies on perception-based SWOT assessments, which may affect the generalizability of the findings and warrant further validation.

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DECLARATION OF CONFLICTING INTERESTS
The results of the study indicate that the development of an integrated cow-rice-corn farming system in Minahasa should improve internal efficiency, take advantage of external opportunities, and optimize resources on suboptimal land through farmers ' technical capacity, local institutions, waste innovation, and integrated policy support for productivity, income, and sustainable food security.

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