



Development Model of Food Crop-Beef Cattle Livestock Integration Based on Technology and Ecosystem Downstreamization for Improving Social Structure Communities in Gorontalo Province

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Abstract | This study aimed to assess the effectiveness of integrating food crops and beef cattle through technology and downstream ecosystems to enhance the social structure of communities in Gorontalo Province. It also sought to develop a model for technology-based integration within the downstream ecosystem. A mixed-method approach was used, with a focus on quantitative analysis supported by qualitative data. Importance–performance analysis (IPA), revenue analysis, the R/C ratio, independent samples t test, SWOT analysis, and the analytical hierarchy process (AHP) were applied. The results indicated that the integration of food crops with cattle using technology and downstream ecosystems was moderately effective in improving the community's social structure. The social and partnership pillars surpassed expectations, whereas the environmental pillar was of lower priority. However, the economic pillar remains a key challenge, as it ranks as a top priority. Farmers practicing integration achieved an R/C ratio of 2.75, whereas those not engaged in integration achieved an R/C ratio of 2.09. A significance value of 0.058 ($p > 0.05$) suggested that income differences between the two groups in Gorontalo were not statistically significant. The integration development model, which is based on the LAMAHU “Livestock and Agriculture Management for Holistic Utilization” Octahelix model, focuses on enhancing production, productivity, and community welfare by establishing a downstream ecosystem. Village-owned enterprises, capitalizing on agricultural and livestock potential, play a central role. The model's success was driven by partnerships, agricultural technology, and natural resources. The key strategies included accelerating organic farming and livestock groups through partnerships, integrated marketing, and infrastructure development.

Keywords | Beef cattle, Ecosystem, Food crops, Integration, Technology

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The Gorontalo Provincial Government consistently ranks as the province with the best financial management or regional budget (APBD), demonstrating the true accountability of its various programs, both administratively and technically. Nevertheless, Gorontalo Province continues to face various challenges related to sustainability in these programs, including social (the increasing poverty of farmers), economic (the cost efficiency of farming and the effectiveness of farming income), technological (farmers' scepticism towards technology adoption), and institutional aspects (accessibility of capital for farming), particularly when they are linked to the agricultural sector. The development of the agricultural sector is closely related to fiscal policy in agriculture because appropriate fiscal policies, including adequate budget allocation for infrastructure development, agricultural technology innovation, and institutional support, are key to ensuring sustainability and increasing productivity in the agricultural sector. Gorontalo Province must continue to optimize the agricultural sector, given its significant contribution to the gross regional domestic product (GRDP). However, the majority of poverty in the province still affects farming communities, underscoring the need to further enhance farmers' social structures.

Poverty among farmers is a persistent issue that challenges economic development and social welfare in Gorontalo Province, where the extreme poverty rate is 8.17%. Three areas are prioritized for addressing extreme poverty in Gorontalo Province, namely, Gorontalo Regency (6.92%), Pohuwato Regency (4.91%), and Bone Bolango Regency (3.23%). The Human Development Index (HDI) from 2012–2022 places the country in the moderate category, with an average life expectancy of 67.47 years and an average expected years of schooling of 13.07 years. The analysis of social development in 2022 revealed an inequality rate of 0.411 and an unemployment rate of 3.60%. At the elementary school level, the APM figure in Gorontalo Province reached 97.30%; at the junior high school level, it was 68.53%; at the senior high school level, it was 55.80%; and at the higher education level, it was 12.04%. As educational levels rise, disparities continue to widen. In fact, at the college level, the disparity between urban and rural areas reaches 10.61%.

The aforementioned conditions clearly demonstrate the need to enhance the social aspects of the community through diverse social development initiatives, which consistently aid in the government's achievement of social and economic macro metrics. One solution that is particularly important in this situation, especially in improving the social structure of farming communities in rural areas, is the development model of sustainable agricultural systems

focused on the integration of food crops and beef cattle livestock. The design of this model encompasses the entire agribusiness system and its subsystems, linking them to various technological advancements and integrated ecosystem designs.

The selection of integrating food crops with beef cattle is based on the results of the location quotient (LQ_{Share} and LQ_{Shift} analyses (in Appendix Figure 1), which revealed that the food crop subsector falls into the category of a leading sector but tends to be slow. This means that the specialization/concentration of this subsector is high, but its rate of change/competitiveness is low. Moreover, the livestock subsector is categorized backwards, indicating that it has a low level of specialization or concentration, as well as a relatively low rate of change. Therefore, this subsector has poor prospects for contributing to agricultural development in Gorontalo Province. Thus, the integration of both will have great potential in optimizing the food crop and beef cattle livestock sectors in Gorontalo Province, especially when enhanced by technology and a downstream ecosystem. However, the use of this technology also presents new challenges, including unequal access, market uncertainty, and adaptation to rapid changes (Méndez-Zambrano *et al.*, 2023). The agricultural sector remains one of the main pillars of the economy, with the challenges and opportunities arising from the era of technological disruption becoming highly relevant. Along with the rapid development of technology, the role of good policy in managing this transformation has become increasingly important (Sadjadi and Fernández, 2023; Rasyid and Ningsih, 2024).

No	GRDP - Agriculture Sector	LQ Share Value	LQ Shift Value	Description	Criteria
1	Food Crops	2.468	0.020	$LQ_{Share} \geq 1$ dan $LQ_{Shift} < 1$	Sluggish Sector
2	Horticultural Crops	0.611	0.779	$LQ_{Share} < 1$ dan $LQ_{Shift} < 1$	Backward Sector
3	Plantation Crops	0.282	0.696	$LQ_{Share} < 1$ dan $LQ_{Shift} < 1$	Backward Sector
4	Livestock	0.589	0.761	$LQ_{Share} < 1$ dan $LQ_{Shift} < 1$	Backward Sector
5	Agriculture Services and Hunting	0.717	1.195	$LQ_{Share} < 1$ dan $LQ_{Shift} \geq 1$	Developing Sector
6	Forestry and Logging	0.338	0.589	$LQ_{Share} < 1$ dan $LQ_{Shift} < 1$	Backward Sector
7	Fishing	1.221	1.352	$LQ_{Share} \geq 1$ dan $LQ_{Shift} \geq 1$	Progressive Sector

Figure 1: LQ Share and LQ shift analysis results; **Source:** Processed data, 2024.

The importance of sustainable agriculture lies in its ability to ensure that the agricultural commodities produced can provide consistent benefits for farmers. Indrawanto and Atman (2017), state that the integration of food crops and beef cattle livestock is a technology that combines and links agricultural activities with livestock farming. This technology also applies the concept of cleaner production aimed at waste reduction, as livestock waste is used as a source of fertilizer for agricultural enterprises, and agricultural waste is used for animal feed. Tiro *et al.* (2023) reported that the technology used in sustainable agricultural systems, particularly the integration of food crops and beef cattle livestock, includes production process technologies for crops, livestock breeding, and the management of straw for feed

and manure for organic fertilizer. During the production process, both businesses can provide each other with internal input by utilizing leftover products or byproducts while also minimizing external input (low external input). Fermentation plays a role in stopping enzymatic reactions and minimizing the loss of energy, protein, and nutrients present in forage so that they remain in a form that can be efficiently utilized by livestock (Mukhtar *et al.*, 2023).

The urgency of designing an integrated model for food crops and beef cattle on the basis of technology and downstream ecosystems becomes very important in making comprehensive, holistic decisions grounded in the principles of collaboration. This model not only focuses on optimizing the upstream sector but also includes strengthening the downstream sector, thereby supporting a broader improvement in the socioeconomic structure of the community. This approach can strengthen the sustainability of farming businesses in the future by enhancing efficiency, productivity, and the added value derived from agricultural activities.

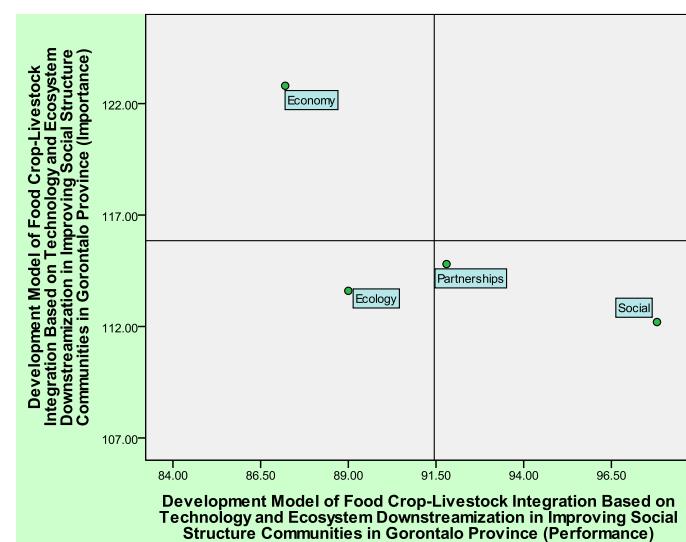


Figure 2: Importance performance analysis (IPA) results; **Source:** Processed data, 2024.

MATERIALS AND METHODS

The research approach is a mixed method with an explanatory method that prioritizes quantitative aspects, which are then supported by qualitative results. The subjects in this research consisted of farmers and livestock breeders, local governments (Agricultural Office), agricultural and livestock extension workers, MSME actors, village governments, village-owned enterprises (BUMDes) actors, and private sector representatives. Data were collected via questionnaires, observations, interviews, and documentation. The subjects in this study consisted of 60 individuals spread across districts/cities in the province of Gorontalo. Data analysis was performed via five methods, namely, importance performance analysis (IPA), followed by revenue

analysis and R/C ratio, independent samples t test, SWOT analysis, and analytical hierarchy process analysis. (AHP).

Importance performance analysis is a method that employs a graph to illustrate the significance of various attributes in relation to the performance of a company or product via a matrix (Ng, 2013). The importance scores and performance scores are plotted on a matrix consisting of four different quadrants: major priorities, low priorities, maintain performance, and overperformance (Agustina *et al.*, 2022; Fan *et al.*, 2024).

Group Statistics				
Food Crop-Beef Cattle Integration		N	Mean	Std. Deviation
R/C Ratio	Integration	12	2.7483	1.03429
	Non Integration	24	2.0898	.90667

Independent Samples Test				
		R/C Ratio		
		Equal variances assumed	Equal variances not assumed	
Levene's Test for Equality of Variances	F	.182		
	Sig.	.672		
t-test for Equality of Means	t	1.961	1.874	
	df	34	19.687	
	Sig. (2-tailed)	.058	.076	
	Mean Difference	.65840	.65840	
	Std. Error Difference	.33582	.35128	
	95% Confidence Interval of the Difference	Lower Upper	-.02406 1.34086	-.07510 1.39191

Figure 3: Independent samples t test analysis results; **Source:** Processed Data, 2024.

The next step is the analysis of the R/C ratio from the perspective of crop farming and livestock farming. Income from the farming/livestock business:

$$I = TR - TC$$

Description;

I: Income (IDR)

TR: Total revenue (IDR)

TC: Total cost (IDR)

R/C ratio analysis is a feasibility test that compares total revenue with total costs. The larger the R/C ratio is, the greater the profit obtained.

$$R/C \text{ Ratio} = \frac{\text{Total Revenue}}{\text{Total Cost}}$$

The criteria for decision-making on the basis of the R/C ratio are as follows:

- If the R/C ratio is > 1, then cattle farming for beef production is profitable and should be considered an agricultural activity.
- If the R/C ratio is < 1, then cattle farming for beef production is not profitable (a loss) to be considered a farming activity.
- If the R/C ratio = 1, then cattle farming for beef is neither profitable nor unprofitable. (impas).

No.	Description	Actual Points	Points Weight	Rating	Score
1	Technology-based crop-livestock integration systems provide significant economic benefits to the community.	66.67%	0.091	2.000	0.181
2	Abundant natural resources in Gorontalo Province support the successful implementation of crop-livestock integration.	74.67%	0.101	3.000	0.304
3	A well-integrated downstream ecosystem (potential collaboration) supports the improvement of the quality of agricultural and livestock production.	73.33%	0.100	3.000	0.299
4	Farmers and ranchers adopt local wisdom values in beef cattle farming-livestock integration as part of cooperation development (strengthening social capital).	62.67%	0.085	1.000	0.085
5	Community involvement in the development of this system increases solidarity and co-operation among residents	76.00%	0.103	4.000	0.413
Total Strengths			0.480		1.283
1	Limited knowledge of the technology used in crop-livestock integration.	69.33%	0.094	1.000	0.094
2	Lack of training and mentoring for farmers and ranchers related to the application of new technologies, resulting in difficulties (lack of skills of farmers) in adopting new technologies and understanding integrated farming and livestock management.	77.33%	0.105	3.000	0.315
3	The distribution system of agricultural and livestock products is not optimal, hampering the marketing of products and derivative products.	70.00%	0.095	2.000	0.190
4	Most farmers have not been able to fulfil more than two roles in a household.	91.33%	0.124	4.000	0.496
5	Farmers-farmers do not have a strong commitment in implementing crop-livestock integration.	74.67%	0.101	3.000	0.304
Total Weaknesses			0.520		1.400
Total IFAS		7.36	1.000		
Score IFAS					-0.118

Figure 4: Internal strategic factor analysis summary (IFAS); Source: Processed data, 2024.

The findings from the R/C ratio analysis were then compared via the independent samples t test, which compares the R/C ratio of farmers who implement integration with those who do not integrate food crops and beef cattle livestock. SWOT-AHP analysis combines strengths, weaknesses, opportunities, and threats (SWOT) analysis with the analytical hierarchy process (AHP). Through this analysis, the research process is carried out in two stages: first, the identification and mapping of strategies through SWOT analysis are performed, followed by AHP, which is based on the hierarchy established from the previous SWOT findings. This decision support model breaks down complex multifactor or multicriteria problems into a hierarchy. With AHP analysis, it is possible to determine the actors, factors, and priority strategies involved in the integration of food crops with beef cattle. The hierarchy of actors consists of local governments, farmers and livestock breeders, MSME players and MSME institutions, universities and research groups, village governments (village-owned enterprises and community self-help groups or NGOs), the private sector (companies and banks), agricultural and livestock extension workers, and consumer communities. The hierarchy of factors consists of partnerships and collaboration, infrastructure, regulations and government programs, natural resources, market access and distribution, the quality of human resources in implementation, and agricultural technology (Good Agricultural Practice and Good Breeding Practice). Moreover, the strategy hierarchy includes training and empowerment as well as human resource capacity in agricultural technology, development of infrastructure and agricultural and livestock technology, acceleration of organic farmer and livestock groups on the basis of partnerships and social capital, development of financial support for sustainable agriculture, integrated marketing of production inputs and organic production outputs, and strengthening of the production system and productivity of

agribusiness commodities. Therefore, the AHP hierarchy in this research is level 1 for goals, level 2 for actors, level 3 for factors and level 4 for strategies. The stages and formulas of the AHP, according to the opinions of (Taherdoost, 2017; Stofkova *et al.*, 2022; Derrick *et al.*, 2023).

No.	Description	Actual Points	Points Weight	Rating	Score
1	Government support for downstream programmes and agricultural technology in Gorontalo Province opens up opportunities for increased community income.	78.00%	0.093	1.000	0.093
2	There is a wide market for products resulting from food crop-livestock integration, especially products with the use of organic materials such as fertilisers and feed, so that public preference for organic products is increasing.	93.33%	0.112	4.000	0.447
3	The potential for cross-stakeholder cooperation can improve the quality and quantity of production.	88.67%	0.106	3.000	0.318
4	Opportunities for diversification of products and services from the results of integration can become Edu-tourism Farming-cow slaughter integration	91.33%	0.109	4.000	0.437
5	Technological innovations continue to develop and are simplified to be adopted by the community to increase productivity.	82.67%	0.099	2.000	0.198
Total Opportunities			0.519		1.493
1	Erratic climate change can disrupt crop and livestock production.	81.33%	0.097	3.000	0.292
2	Farmers' scepticism over the nutritional content of silage derived from agricultural waste for animal feed and scepticism that crop nutrients can be met with organic fertiliser	83.33%	0.100	4.000	0.399
3	Lack of support from the younger generation to get involved in the agriculture and livestock sector.	76.67%	0.092	1.000	0.092
4	Potential for Green inflation, which is an increase in the price of goods and services related to environmentally friendly production and distribution processes as a result of the additional high costs of transitioning to a green economy.	83.33%	0.100	4.000	0.399
5	Competition with other regions that also develop similar programmes can reduce the competitiveness of integrated products	77.33%	0.093	2.000	0.185
Total Threats			0.481		1.366
Total EFAS		8.36	1.000		
Score EFAS					0.127

Figure 5: Economic strategic factor analysis summary (EFAS); Source: Processed data, 2024.

The following steps are included in the data analysis technique. Initially, the data gathered from the interviews are used to extract the pairwise comparison matrix, or matrix A. Matrix A's principal right eigenvector is calculated as 'w'. The pair comparison matrix cannot be employed by normalizing the column to obtain Wi if the matrix is incompatible or if there is incomplete consistency.

If "aik·akj=aij" is not confirmed for all k, j, and i, the eigenvector method is selected (Jalaliyoon, *et al.*, 2012). The following situations can employ the eigenvector approach for a positive and reversed matrix:

$$e^{2T} = (1, 1, \dots, 1)$$

$$W = \lim_{k \rightarrow \infty} \frac{A^k \cdot e}{e^T \cdot A^k \cdot e}$$

When faced with an incompatible matrix, the computation should be performed multiple times to reach convergence among the set of responses in the subsequent iteration of this process. The raw data are subsequently converted into understandable absolute values, and the normalized weights $w = (w_1, w_2, w_3, \dots, w_n)$ are calculated via the following formula:

$$Aw = \lambda_{\max} w, \lambda_{\max} \geq n$$

$$\lambda_{\max} = \frac{\sum_{j=1}^n a_{ij} w_j}{w_i} - n$$

A: Pairwise comparison

w: normalized weight vector

λ_{max} : maximum eigenvalue of matrix A

a_{ij} : numerical comparison between the values i and j

The consistency ratio (CR) is then computed via the formula $CR = RI/CI$ to confirm the AHP results. The consistency index (CI) is then determined via the following formula:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Notably, an acceptable comparison is confirmed by a consistency ratio of less than 0.10.

RESULTS AND DISCUSSION

THE EFFECTIVENESS OF INTEGRATING FOOD CROPS AND BEEF CATTLE LIVESTOCK

The effectiveness of integrating food crops and beef cattle livestock is analysed via importance performance analysis (IPA). As shown in appendix [Figure 2](#), the following conclusions were drawn:

ECONOMIC ASPECTS: The results of importance performance analysis (IPA) for the economic aspect of the integration of food crops and beef cattle livestock based on technology and downstream ecosystems for improving the social structure of the community in Gorontalo Province fall into the main priority criteria, namely, a high level of importance but still low performance. This suggests that the primary focus should be on the integration of food crops and beef cattle livestock, with the main expectation and target for farmers and ranchers being the improvement of economic aspects or adequate income. However, the income of these farmers and ranchers remains below optimal levels. The findings from the independent samples t test analysis in attachment [Figure 3](#) indicate that the results are not yet optimal. Specifically, the R/C ratio for farmers implementing an integration system is 2.75 units, whereas for those not implementing integration, it is 2.09 units. The significance value is greater than the alpha value of 5% ($0.058 > 0.05$). It can be concluded that there is no significant (real) difference in the income of farmers and livestock breeders who implement the integration system of food crops and beef cattle livestock with those who do not implement this integration system in Gorontalo Province.

SOCIAL ASPECTS: The results of the importance performance analysis (IPA) for the social aspect of integrating food crops and beef cattle livestock based on technology and downstream ecosystems to enhance the social structure in the community of Gorontalo Province fall into the excessive criteria, where the level of importance is low but the performance is high. This finding indicates that there

is strong social support when integration is implemented on the basis of technology and the establishment of an ecosystem as a main foundation, as well as the presence of trust and positive cooperation among the community, which are essential foundations for the success of the integration program of food crops and beef cattle livestock.

ENVIRONMENTAL ASPECTS: The results of the importance performance analysis (IPA) for the environmental (ecological) aspect of the integration of food crops and beef cattle livestock based on technology and downstream ecosystems in improving the social structure of the community in Gorontalo Province are categorized as low priority, indicating both low importance and low performance. This indicates a lack of awareness or priority from the relevant parties regarding issues such as waste management, the conservation of natural resources, and the implementation of environmentally friendly agricultural practices.

PARTNERSHIP ASPECTS: The partnership part of integrating food crops and beef cattle based on technology and downstream ecosystems to improve the social structure in the community of Gorontalo Province scored too low on the importance performance analysis (IPA) scale, meaning that the level of importance is low but the performance is high. This shows that although partnerships are not considered the most urgent element in integration, achievements in building and managing partnerships have been carried out effectively.

The integration of food crops and beef cattle is an agricultural system that combines the cultivation of food crops with the raising of beef cattle as a single unit. In this system, waste from food crops can be used as animal feed, whereas cow manure can be used as organic fertilizer to increase soil fertility. This approach aims to increase production efficiency, reduce costs, and support environmental and economic sustainability. The economic pillar of integrating food crops and beef cattle livestock through technology and downstream ecosystems, aimed at enhancing the social structure of the community in Gorontalo Province, aligns with the main priority criteria of high importance but low performance. This is certainly influenced by various factors, such as better technology for cost efficiency in the farming and livestock businesses, issues with capital, the farmers' limited ability to perform multiple roles, and the lack of socialization regarding the marketing of organic products, both in terms of production results and fertilizers or feed from those integrations. The R/C ratio of farmers implementing an integration system is 2.75 units, whereas those not implementing integration have a ratio of 2.09 units. A higher R/C ratio indicates that farmers using the integration system earn greater income. This means that farmers can improve the welfare of themselves and their families more effectively.

The social pillar is classified as an excessive criterion, meaning that its level of importance is low, but its performance is high. This finding indicates that there is strong social support when integration is implemented on the basis of technology and the establishment of ecosystems as a main foundation, as well as the presence of trust and good cooperation among the community, which are crucial foundations for the success of the integration program of food crops and beef cattle livestock. Therefore, efforts to maintain and strengthen social performance remain important, as this aspect supports the long-term sustainability of the integration program and enhances the sense of togetherness and solidarity among the community. The environmental pillar (ecology) is categorized as low priority, indicating its low importance and low performance. This indicates a lack of awareness or prioritization from the relevant parties regarding issues such as waste management, the conservation of natural resources, and the implementation of environmentally friendly agricultural practices. This is because farmers and livestock breeders still believe that this integration is aimed solely at achieving cost efficiency and income effectiveness in farming and livestock businesses. Therefore, moving forward, there is a need for increased focus on environmental education and awareness, as well as the development of more sustainable and ecosystem-based agricultural technologies and practices both upstream and downstream (Abiri *et al.*, 2023; Thompson *et al.*, 2023). Thus, even though environmental aspects are not currently a priority, improving performance is important for maintaining ecosystem balance and ensuring that this integration program can operate in the long term without harming the environment, as eco-friendly and organic farming labels become a selling point for communities with a preference for a healthy lifestyle, or in this case, the community's willingness to pay remains high even though the prices offered are also quite high.

Then, the partnership pillar falls into the excessive criteria, where the level of importance is low but the performance is high. This shows that although partnerships are not considered the most urgent element in integration, the achievements in building and managing partnerships have been carried out very well. Various actors believe that success in building solid collaboration among different parties, such as farmers, ranchers, the government, research institutions, and the private sector, will support various productive cooperation agreements, technology transfers, and strong financial backing from strategic partners. The integration program must continue to run in a balanced and sustainable manner, providing maximum benefits for all parties involved.

The integration system of food crops and beef cattle livestock can affect farmers' income by optimizing resource use, reducing production costs, and obtaining byproducts

(Parulian *et al.*, 2019). According to Mukhlis *et al.* (2018), an integrated farming system is a type of farming that combines two or more agricultural sectors. It is based on the idea of biological recycling and is linked to the input-output interactions between goods that help each other and use little external input. An integrated farming system (IFS) can help farmers achieve higher incomes and reduce production costs. This system can also improve the welfare of farmers, obtain byproducts, and strengthen the rural economy.

Thus, the integration of crop farming and beef cattle farming not only impacts production efficiency and resource management but also serves as a strategic step toward achieving a sustainable agricultural system (Karwacka *et al.*, 2020). Farmers and livestock breeders can increase their income while maintaining environmental sustainability and local economic stability by considering the land ecosystem, cultivation aspects, and regional potential (Karwacka *et al.*, 2020). The benefits of integrating food crops with beef cattle are highly significant for the income of farmer-raisers. Waste from beef cattle farms, such as manure and organic waste, can be utilized as organic fertilizer for agriculture, thereby reducing fertilization costs and simultaneously increasing crop productivity. Cow urine can be utilized as a liquid organic fertilizer, making it a more beneficial agricultural product commonly referred to as cow urine POC.

The integration system of food crops and beef cattle livestock is highly important for increasing farmers' income; therefore, it must always be optimized. With the integration system in place, farmers can produce processed products or byproducts from their agricultural and livestock yields. For example, milk from beef cattle can be processed into dairy products, or beef can be turned into ready-to-eat processed products. This can enhance the added value of the product and open broader market opportunities.

SWOT AND AHP ANALYSIS

STRATEGY DESIGN BASED ON SWOT ANALYSIS: The analysis of the development strategy for the integration of food crops and beef cattle livestock based on technology and downstream ecosystems to enhance the social structure in the community of Gorontalo Province can be outlined as follows:

INTERNAL FACTOR ANALYSIS SUMMARY (IFAS): The IFAS analysis revealed that for internal factors (Figure 4), the strength score is 1.283, whereas the weakness score is 1.400. Thus, these values indicate a negative difference of -0.118 between the internal and external factors, meaning that the strength score is lower than the weakness score. This implies that the development of technology-based integration of food crops and beef cattle livestock, along with downstream ecosystem management, faces various

challenges due to several weaknesses in enhancing the social structure within the community in Gorontalo Province.

EXTERNAL FACTOR ANALYSIS SUMMARY (EFAS): The EFAS analysis revealed (Figure 5) that the value of the opportunity factor for developing an integrated food crop and beef cattle livestock farming system based on technology and downstream ecosystems to improve the social structure of the community in Gorontalo Province is 1.493, whereas the threat factor is 1.366. Therefore, upon comparison, the opportunity factor outweighs the threat factor. These results show that many important chances must be taken advantage of in the advancement of technology-based integration of food crops and beef cattle livestock, as well as downstream ecosystem processes, to improve the social structure in the Gorontalo Province community.

SWOT ANALYSIS DIAGRAM: The strategic position for the development of integrated food crops and beef cattle livestock farming, which relies on technology and downstream ecosystems to enhance the social structure of the community in Gorontalo Province, lies in quadrant 3, known as the turn-around strategy. This strategy underscores the importance of optimizing the development of integrated food crop and beef cattle livestock farming and leveraging technology and downstream ecosystems to enhance the social structure of the community in Gorontalo Province (Figure 6). This involves leveraging various opportunities and minimizing weaknesses to ensure that the system operates effectively, benefits, and is sustainable. Alternative strategies include training and empowerment as well as human resource capacity building in agricultural technology, infrastructure development, and agricultural and livestock technology; the acceleration of organic farmer and livestock groups on the basis of partnerships and social capital; the development of financial support for sustainable agriculture; the integrated marketing of production inputs and organic production outputs; and the strengthening of production systems and the productivity of agribusiness commodities.

DEVELOPMENT MODEL DESIGN BASED ON AHP ANALYSIS

The AHP model design for the development of an integration of food crops and beef cattle livestock based on technology and downstream ecosystems to enhance the social structure of the community in Gorontalo Province in this study can be divided into 4 hierarchy levels (Figure 7).

THE ROLE LEVEL OF ACTOR ELEMENTS: The level of the role of actor elements concerning focus elements in the model of integrated food crop and beef cattle livestock development on the basis of technology and downstream ecosystems to enhance the social structure of the community in

Gorontalo Province revealed that the most dominant actor is the village government (village-owned enterprises and community self-help groups/nonprofit organizations), with a weight of 0.218 units (Figure 8). The second priority actor is farmers and ranchers, with a weight of 0.215 units. The third and fourth priorities are local governments with a weight of 0.136 units. The fourth priority is agricultural and livestock extension workers, with a weight of 0.136 units. The fifth priority is the private sector (companies and banks), with a weight of 0.085 units. The sixth priority is MSME actors and MSME institutions, with a weight of 0.080 units. The seventh priority is universities and research groups, with a weight of 0.067 units. The eighth priority is consumer society, with a weight of 0.062 units. The dominant role of village government actors (village-owned enterprises and community self-help groups/nonprofit organizations) and farmers and livestock breeders clearly illustrates that these two actors must be able to collaborate more effectively, especially if village-owned enterprises take on the role of reducing the influence of middlemen in agriculture. Furthermore, as mandated by the Minister of Village, Development of Disadvantaged Regions, and Transmigration Regulations number 7 and number 13 of 2023 regarding the priority of village funds that can be used for the development of plant and animal food security. Furthermore, the social structure within the community will be enhanced if local governments, agricultural and livestock extension workers, and other stakeholders support these actors in optimizing the integration of food crops and beef cattle livestock on the basis of technology and downstream ecosystem development.

THE LEVEL OF ROLE OF FACTOR ELEMENTS: There are six interrelated factors involving actors in the model of developing an integration of food crops and beef cattle livestock on the basis of technology and downstream ecosystems to enhance the social structure in the community of Gorontalo Province. Figure 10 shows that the dominant factor is partnership and collaboration, with a weight of 0.254 units. The second priority factor is agricultural technology, namely, good agricultural practice (GAP) and good breeding practice (GBP), with a weight of 0.228. The third priority factor is natural resources, with a weight of 0.145. The fourth priority factor is the quality of human resources, with a weight of 0.143. The fifth priority factor is infrastructure, regulations, and government programs, with a weight of 0.122. The sixth priority factor is market access and distribution, with a weight of 0.108. All these factors interact and support each other to achieve the ultimate goal of this development model, which is to enhance the social structure and welfare of the community in Gorontalo Province. By considering priority factors such as partnerships and collaboration, it is important to establish an ecosystem within an integrated agricultural system from upstream to downstream. Certainly, farming

with organic products will become a trend and preference that will start to be favoured by all parties, as evidenced by consumers' willingness to pay a higher price for the organic agriculture label.

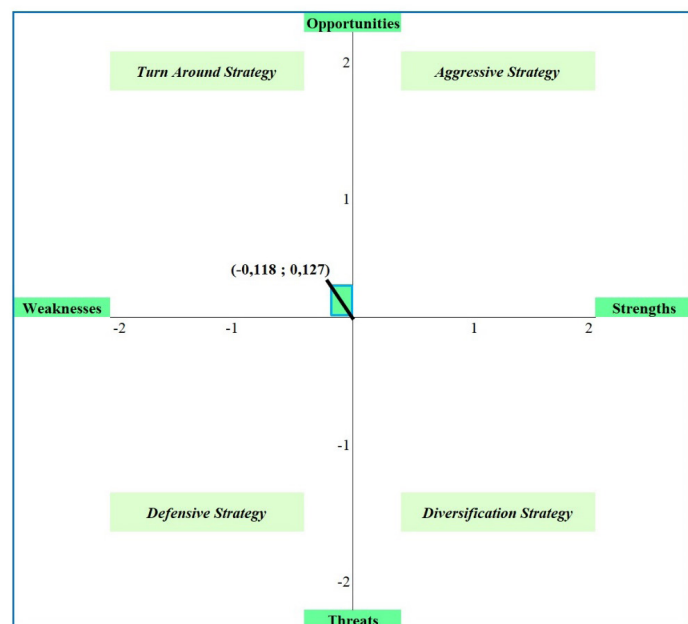


Figure 6: SWOT analysis diagram; **Source:** Processed data, 2024.

THE ROLE OF STRATEGIC ELEMENTS: The first-priority strategy that needs to be implemented as an effort to integrate food crops and beef cattle livestock on the basis of technology and downstream ecosystems to improve the social structure of the community in Gorontalo Province is the acceleration of organic farmer and livestock groups on the basis of partnerships and social capital, with a weight of 0.222 units (Figure 9). The second priority strategy is the integrated marketing of integrated production inputs and organic production results, with a weight of 0.208 units. The third priority strategy is strengthening the production system and productivity of agribusiness commodities with a weight of 0.167 units. The fourth priority strategy is the development of infrastructure and agricultural and livestock technology, with a weight of 0.153 units. The fifth priority strategy is the development of capital support for sustainable agriculture, with a weight of 0.127 units. The sixth priority strategy is training and empowerment as well as human resource capacity for agricultural technology, with a weight of 0.123 units. These strategies complement each other in supporting the main goal of developing the integration of food crops and beef cattle livestock in Gorontalo Province. With a focus on infrastructure, capital, and capacity building of human resources, these strategies aim to create a more efficient, sustainable agricultural and livestock system that can enhance the social structure and well-being of the community.

On the basis of the comprehensive AHP analysis, the de-

velopment of the integration of food crop and beef cattle livestock farming based on technology and downstream ecosystems to improve the social structure of the community in Gorontalo Province is carried out via the LAMA-HU Octahelix Model, which is a development model that considers the integration of food crop and beef cattle livestock farming from upstream to downstream into a unified agribusiness system. LAMAHU has the acronym "Livestock and Agriculture Management for Holistic Utilization," while the term Lamahu itself comes from the Gorontalo language, meaning goodness or to improve or make better/best.

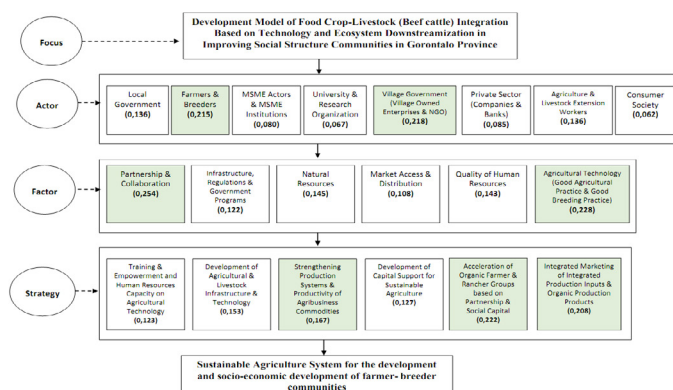


Figure 7: Value of the AHP; **Source:** Processed Data, 2024.

The SWOT strategic position for the development of a technology-based integration of food crops and beef cattle livestock farming, focused on downstream ecosystems to enhance social structure in the province of Gorontalo, is in quadrant 3, which is the turn-around strategy. Moreover, the AHP analysis revealed that in the model for developing the integration of food crops and beef cattle livestock farming on the basis of technology and downstream ecosystems to improve social structure in Gorontalo Province, six main interrelated factors involving the actors involved. These factors play crucial roles in the overall success of the model, with weights indicating the level of influence of each factor. Partnership and collaboration emerge as the most dominant factors, as collaboration among various actors, including the government, farmers, livestock breeders, educational institutions, and the private sector, is a key element determining the success of integration. A strong partnership allows various parties to share resources, knowledge, and skills, which ultimately enhances effectiveness and efficiency in achieving common goals (Siddiqui *et al.*, 2023). The second priority factor is agricultural technology, particularly the implementation of good agricultural practices (GAPs) and good breeding practices (GBPs), as the application of appropriate technology in the agricultural and livestock sectors is crucial for enhancing productivity and product quality, which in turn can improve the income and well-being of the community. The priority strategy includes the acceleration of organic farmer and livestock

groups through partnerships, integration, and the development of infrastructure and technology (Siddiqui *et al.*, 2023).

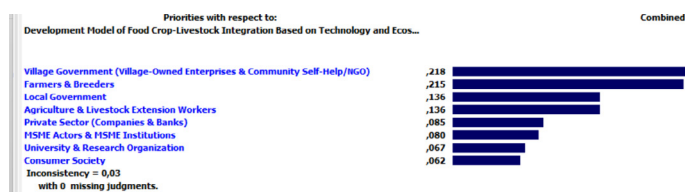


Figure 8: Actor priority hierarchy; Source: Processed data, 2024.



Figure 9: Strategy priority hierarchy; Source: Processed data, 2024.

Natural resources are prioritized third because their availability and proper management constitute the fundamental foundation for the sustainability of the integration model. Rendel *et al.* (2020) stated that resources such as agricultural land, water, and livestock feed must be managed wisely to support long-term success. The quality of human resources is ranked fourth in priority, where the development of the capacity and skills of farmers, ranchers, and other actors is crucial in supporting the implementation of technology and good agricultural practices. Training, education, and outreach play crucial roles in enhancing the quality of human resources. The fifth factor is infrastructure, regulations, and government programs. Adequate infrastructure, supportive regulations, and targeted government programs play essential roles in creating a conducive environment for the development of integrated food crops and beef cattle livestock (Fernando *et al.*, 2023). Finally, market access and distribution rank sixth in priority, as the ability to access a wide market and distribute products efficiently is crucial to ensure that the produced goods can be sold well and profitably, which ultimately enhances the welfare of the community.

The model designed for the development of the integration of food crops and beef cattle livestock based on technology and downstream ecosystems to enhance the social structure in the community of Gorontalo Province is the LAMA-HU Octahelix Model (Figure 11). This model emphasizes holistic management of agriculture and livestock to maximize benefits at every value chain. The main focus of this model is to integrate all the components of the agribusiness process, including technology, human resources, infrastructure, and collaboration among stakeholders. LAMA-HU aims to create a system that is not only productive but also capable of supporting the improvement of community wel-

fare. Every stage of the production and distribution of food crops and beef cattle livestock is interconnected, forming an ecosystem that supports the sustainability and effectiveness of agribusiness. Furthermore, the term Lamahu comes from the Gorontalo language, which means goodness, to improve, or to make something better or the best. This reflects the fundamental philosophy of this model, which is to strive for continuous improvement in every aspect of agriculture and livestock farming to achieve optimal results. Through this approach, it is hoped that a strong synergy will be created among various elements in the agribusiness ecosystem, thereby providing a significant positive impact on the social and economic structure of the community in Gorontalo. This model of integrating food crops and beef cattle livestock also takes into account the importance of collaboration and partnerships between the government, private sector, educational institutions, and community to ensure sustainability and long-term success.

No	Actors	Factors					
		Partnership & Collaboration	Infrastructure, Regulations & Government Programs	Natural Resources	Market Access & Distribution	Quality of Human Resources	Agricultural Technology (GAP & GBP)
1	Local Government	0.132	0.290	0.133	0.115	0.106	0.224
2	Farmers & Breeders	0.322	0.062	0.351	0.157	0.043	0.066
3	MSME Actors & MSME Institutions	0.163	0.087	0.193	0.097	0.188	0.271
4	University & Research Organization	0.153	0.110	0.147	0.156	0.132	0.302
5	Village Government (Village-Owned Enterprises & NGO)	0.244	0.148	0.082	0.077	0.257	0.192
6	Private Sector (Companies & Banks)	0.289	0.115	0.102	0.088	0.132	0.273
7	Agriculture & Livestock Extension Workers	0.423	0.077	0.063	0.077	0.130	0.230
8	Consumer Society	0.307	0.090	0.087	0.096	0.152	0.268
Averages		0.254	0.122	0.145	0.108	0.143	0.228

Figure 10: Factor priority hierarchy; Source: Processed data, 2024.

The level of the role of actor elements concerning focus elements in the model of developing an integration of food crops and beef cattle livestock based on technology and downstream ecosystems to enhance the social structure of the community in Gorontalo Province revealed that the most dominant actor is the village government through village-owned enterprises (BUMDes) and community self-help groups as accelerators. The village government plays a crucial role in driving and optimizing integration in integrated agriculture. Through village-owned enterprises (BUMDes) engaged in agriculture and livestock, the village government can utilize village funds, which are mandated by government regulations for the development of agriculture and livestock. Furthermore, BUMDes are also supported by self-help groups involved in waste management, which can easily leverage their role in processing organic waste from agriculture and livestock into fertilizers or animal feed. Moreover, these self-help groups include farmers and livestock breeders who are willing and motivated to engage in sustainable organic farming. One concrete effort that can be made through collaboration, with the village government playing a key role and supporting

BUMDes and self-help groups, is the feed bank, which is also supported by facilities such as pressing machines, chopping tools for greens, and equipment for fermentation technology.

demand for products. Although its role in this process is smaller than that of other actors, the massive and consistent consumer demand motivates farmers to be enthusiastic and disciplined in integrating food crops and beef cattle livestock.

The importance of village governments in the integration of food crops with beef cattle, according to [Indraningsih et al. \(2021\)](#), is that village funds influence the increase in production and income for farmers. Village funds allocated for infrastructure development, such as training in agricultural, livestock, and fishery skills in accordance with the village's potential, should also be used to support sustainable agricultural development in rural areas. Therefore, the government also needs to allocate village funds for various advancements in agriculture and livestock. These various issues can be addressed if farmers are able to maximize their income through organic farming brands, which are becoming a preference among consumers.

The priority of this first strategy emphasizes the importance of accelerating the formation and strengthening of groups of farmers and livestock breeders who adopt organic practices. Partnerships among farmers, livestock breeders, and various other stakeholders, such as village governments, nongovernmental organizations, and the private sector, are very important. Social modalities, such as networks of trust and cooperation, assist these groups in accessing resources, information, and markets, thereby enabling farmers and ranchers to operate more efficiently and sustainably. The second-priority strategy focuses on developing an integrated marketing system for organic products resulting from the integration of food crops and beef cattle livestock. Effective marketing includes the provision of high-quality production inputs that meet organic standards, as well as efficient distribution channels for production output ([Irawan et al., 2022](#)). Integrated marketing helps create added value for organic products, enhances competitiveness, and ensures that these products can be sold at a profitable price for farmers and breeders.

The third strategic priority aims to enhance the production system and productivity of agribusiness commodities through the integration of food crops and beef cattle livestock. This includes the implementation of efficient agribusiness practices, the use of appropriate agricultural technology, and the sustainable management of natural resources ([Casagrande et al., 2023](#)). By strengthening the production system, farmers and ranchers can increase crop yields and livestock productivity, which in turn will increase their incomes and reinforce the social structure of the community ([Wiesner et al., 2020](#)). The fourth priority strategy emphasizes the importance of developing supporting infrastructure, such as roads, irrigation, storage facilities, and modern agricultural and livestock technolo-



Figure 11: LAMAHU Octahelix models; Source: Processed data, 2024.

The second priority actor is farmers and ranchers as creators, who are the main players implementing this integration practice, creating direct value through agricultural and livestock activities. The contributions of farmers and ranchers emphasize the importance of active participation from field actors for the success of the program. The local government acts as a regulator, while agricultural and livestock extension workers serve as initiators; that is, the local government is responsible for policies and regulations that provide support, whereas extension workers play a crucial role in initiating and guiding farmers and livestock breeders in implementing technology and best practices.

The private sector, which includes companies and banking, serves as an enabler by providing the necessary financial support and infrastructure. UMKM actors and UMKM institutions, as affiliates, assist in the processing and marketing of products, although their contribution is not as significant as that of others. Many SMEs believe that middle- to upper-class consumers are willing to purchase organic agricultural products because of their health and sustainability preferences. ([Figurek and Thrassou, 2023](#)). Universities and research groups, as conceptors, are responsible for the innovation and development of the technology underlying the integration model to ensure that its implementation is improved. Finally, the consumer society, which acts as a catalyst, provides feedback and generates

gy. Good infrastructure and the right technology enhance production efficiency, reduce costs, and improve the quality of agricultural and livestock outputs (Gao *et al.*, 2019). This will also support the implementation of more sustainable and environmentally friendly agricultural practices.

The fifth strategic priority focuses on providing better access to financial resources for farmers and ranchers. Strong capital support enables farmers and ranchers to invest in new technologies, expand their businesses, and improve product quality. Sufficient capital will also support the sustainability of agricultural and livestock enterprises, which in turn will strengthen the social and economic structure of the community in Gorontalo. The sixth priority strategy emphasizes the importance of training and empowering human resources in the agriculture and livestock sectors. By enhancing the capacity of farmers and livestock breeders to use modern agricultural technology, they will be better prepared to face the challenges of production and marketing (Hubbart *et al.*, 2023). This capacity enhancement will also improve the effectiveness and efficiency of the management of agricultural and livestock enterprises, which will contribute to the welfare of the community.

An integrated farming system can help reduce soil erosion and increase the soil's capacity to retain water, which is vital for long-term sustainability. Furthermore, the use of organic fertilizers decreases the dependency on chemical fertilizers, which can negatively impact the environment. Despite the many benefits, the process of advancing sustainable agriculture through the integration of beef cattle and food crops faces several challenges that require the involvement and cooperation of all stakeholders (Nababan and Regina, 2021). By strategically combining food crops with beef cattle, farmers can achieve greater profitability while also lowering production costs and reducing risks (Amna *et al.*, 2021). This integrated farming approach is more profitable than solely cultivating food crops or raising beef cattle independently (Coffey and Mumma, 2014; Elly *et al.*, 2019). Implementing this integration is essential, as the agricultural sector and sustainable farming movements increasingly prioritize ecological considerations. The use of cow manure as organic fertilizer improves soil health by increasing its structure and organic matter content (El Bilali *et al.*, 2021).

The priority strategy includes the acceleration of organic farmer and livestock groups based on partnerships, integrated marketing, and the development of infrastructure and technology (Siddiqui *et al.*, 2023). These various results are in line with those of previous relevant studies, such as those of Mukhtar *et al.* (2023), who stated that an integrated agricultural system is an approach that combines various agricultural production components into a

mutually beneficial system, especially in terms of feed, as the development of beef cattle can be maximized with the availability of quality feed. Agroecological and permaculture approaches are also becoming new trends in the sustainable management of natural resources. The integration of these principles into the food security area development strategy can help create a more environmentally friendly and economically efficient agricultural system, which will make a significant contribution to addressing new challenges and seizing current opportunities in the development of the agriculture and livestock sectors (Akintan *et al.*, 2024). The consumption of complete feed based on sweet corn as a food crop can improve the quality and weight of livestock (Bahri, 2012), the productivity of beef cattle based on complete corn feed (Bahri *et al.*, 2018), the production of corn biomass with the application of biofertilizers (Mukhtar *et al.*, 2019), the carrying capacity of corn and the productivity of beef cattle, and the percentage and quality of beef carcasses with complete feed. (Bahri *et al.*, 2019).

CONCLUSIONS AND RECOMMENDATIONS

The integration of food crops and beef cattle livestock based on technology and downstream ecosystems to enhance the social structure of the community tends to be quite effective, with social and partnership pillars exceeding targets, whereas the environmental pillar falls into the low-priority category. The area that needs improvement is the economic pillar, which is classified as a top priority, indicating that it remains a primary complaint among farmers and ranchers in implementing the integration of food crops with beef cattle. The suboptimal state of this economic pillar is reflected in the R/C ratio, which shows that farmers practising the integration system have a ratio of 2.75, whereas those not practising integration have a ratio of 2.09, so that there is no significant (real) difference in income. The SWOT analysis reveals that internal strengths are lower than weaknesses are, indicating the need for improvement in integration development, and external threats can still be mitigated by various opportunities. The AHP analysis places partnerships and collaboration as the most dominant factors, followed by the implementation of agricultural technologies such as good agricultural practices (GAPs) and good breeding practices. (GBP). The integration development model is carried out with the LAMAHU "Livestock and Agriculture Management for Holistic Utilization" Octahelix Model, which is a term in the Gorontalo language that aims to accelerate something to be better or to become the best. This model focuses not only on increasing production and productivity but also on improving the quality of life for the community through the establishment of a downstream ecosystem via

village-owned enterprises, particularly those that leverage the potential of villages in the fields of agriculture, livestock, and both plant and animal food security.

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NOVELTY STATEMENT

The novelty of this research lies in the use of an explanatory mixed-method approach, which involves assessing the extent of performance in the integration of food crops and beef cattle from the perspective of sustainability pillars via importance performance analysis (IPA). This analysis is then followed by evaluating the economic pillar through income analysis and comparison via an independent samples t test. A comprehensive and integrated strategy design is subsequently formulated via SWOT analysis and the analytical hierarchy process (AHP), resulting in a development model named the Livestock and Agriculture Management for Holistic Utilization (LAMAHU) Octahelix model, which serves as a partnership-based collaborative model from upstream to downstream within an agribusiness structure for the development of farming and livestock enterprises aimed at enhancing social structure and community welfare.

AUTHOR'S CONTRIBUTIONS

Mahyudin Humalangi and Mohammad Zubair Hippy: Conceptualization, methodology, data curation, writing of the original draft, writing, review and editing.

Sutrisno Hadi Purnomo, Siti Rahmatia Machieu, Nancy N. Lantepon and Ivana Butolo: Data curation, supervision, writing the original draft, writing, review and editing.

Muhammad Mukhtar: Data curation, investigation, writing original draft, writing – review and editing.

CONFLICT OF INTEREST

No potential conflicts of interest relevant to this article are reported.

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